VETERINARY EMERGENCY MEDICINE SECRETS

Second Edition

QUESTIONS YOU WILL BE ASKED

- in emergencies
- in critical care settings
- on oral exams
- on rounds

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DEDICATION

To my residents in emergency and critical care medicine I offer this contribution to your education. Let your questions never end. Let your curiosity to find new answers propel you to eliminate anecdotal "facts" from the practice of medicine. Seek the truth and you will find it—and don't forget to publish your results! To the nurses I have had the pleasure of working with—Maura, Leslie, Patti, Sandy, Cheryl, Suzanne, Scott, Rene, Coy, Christine, Martin, Stephanie, Ellen, Brenda, Beth, Jeaninine, Heather B., Kimberly P., June, Sue, Terri, Melba, Vicki, Lee Ann, and Sooz—thank you for your knowledge and wonderful patient skills.

To my wife, Sooz, thanks for being here and for teaching me patience. To our dogs, Sage (a medical nightmare) and Loretta (a happy Sheltie) thanks for your companionship. In the mountains of Colorado there will always be wonderful memories of days past and years to come.

WEW

PREFACE TO THE SECOND EDITION

In this second edition of *Veterinary Emergency Medicine Secrets* we have updated the chapters from the first edition and added some new chapters based on new interests and involvement of emergency veterinarians. This question-and-answer format continues to be a useful means of offering information about veterinary emergency medicine. The stimuli for new questions and answers have come from readers of the first edition, students in the arena of emergency and critical care medicine, veterinary nurses and technicians, and chapter authors. We all encounter new and exciting experiences each and every day of our professional lives. Too often we need that quick answer to one of these new experiences. Undoubtedly this process will continue as our specialty matures and expands. We are in the most exciting specialty of veterinary medicine. Where else could we be afforded the opportunity to practice emergency medicine, internal medicine, surgery, anesthesia, neurology, cardiology, and other specialties? The beauty of our specialty is the advantage of seeing a response to treatment in a short time. These are exciting times—live them, learn from them, and publish your results!

Special thanks are extended to Mr. Bill Lamsback of Hanley and Belfus. He continues to produce exciting products for the veterinary and human medical professions. Without our dedicated, experienced, and productive authors, *Veterinary Emergency Medicine Secrets* would not be available. Thank you to all authors for the time and expertise dedicated to this endeavor.

I. Life-threatening Emergencies

Section Editor: Wayne E. Wingfield, M.S., D.V.M.

1. DECISION MAKING IN VETERINARY EMERGENCY MEDICINE

Wayne E. Wingfield, M.S., D.V.M.

1. Why is emergency medicine so important in veterinary medicine?

Emergencies constitute up to 60% of hospital admissions in veterinary medicine.

2. How does the approach to an emergency patient differ from conventional hospital admission?

A comprehensive medical history and physical examination, routine laboratory diagnostic studies, specialized diagnostic techniques, and formulation of lists of written rule-outs often take too long. Typically, the veterinarian is faced with minimal history and a cursory physical examination that hones in on obvious injuries or illnesses and institutes therapy as the animal is examined.

3. What is an emergency?

An emergency is any illness or injury perceived by the person presenting the animal to the veterinarian as requiring immediate attention. Not every "emergency" is life-threatening; thus, the most important question is, "What is the threat to the animal's life?" In an emergency, conventional approaches to diagnosis and treatment do not ensure an expeditious answer to this question. Significant time constraints may impede the use of conventional methods.

4. How is the life-threatened animal identified?

Three components are necessary to recognize quickly the life-threatened animal:

1. Primary complaint
2. Complete and accurate set of vital signs
3. Opportunity to visualize, auscultate, and touch the animal.

5. Why is the primary complaint so important?

The primary complaint helps the veterinarian to categorize the general type of problem (e.g., respiratory, cardiovascular, traumatic, urinary).

6. Why are vital signs so important in the initial management of an emergency?

Vital signs represent the first objective data available to the veterinarian. Along with the primary complaint, they are used to triage the vast majority of life-threatened patients.

7. What vital signs are most important in the emergency patient?

- Respiratory rate and character
- Heart rate and rhythm
- Pulse rate, rhythm, and character
- Accurate core body temperature
- Color of mucous membranes and capillary refill time

8. What are the determinants of normal vital signs?

- Age
- Animal's behavior
- Underlying physical condition
- Medical problems (e.g., hypertension, increased cerebrospinal fluid pressure)
- Current medications

For example, a well-conditioned, athletic, hunting breed dog brought to the hospital after sustaining a major trauma may arrive with a pulse rate of 100 beats/min. The dog probably is in shock and may have significant blood loss because the normal pulse is likely 40–50 beats/minute.

9. Why do I need to visualize, auscultate, and touch the animal?

In many instances, these measures help to identify the threat to life (e.g., is it the upper airway, lower airway, or circulation?). Touching the animal helps to identify areas of tenderness. Touching the skin is important to determine whether shock is associated with vasoconstriction (traumatic, hypovolemic, or cardiogenic) or vasodilatation (septic, neurogenic, or anaphylactic). Auscultation identifies life threats associated with the lower airway (e.g., bronchoconstriction, tension pneumothorax) or circulation (mitral valvular insufficiency, aortic stenosis).

10. Once I have identified the life threat, what do I do?

Stop! Intervene to reverse the life threat. If the problem is respiratory distress due to tension pneumothorax, immediate thoracocentesis is required. If the problem is blood loss, volume restoration and control of hemorrhage (when possible) are indicated.

11. Now that I have identified and reversed the life threat, what next?

The veterinarian must develop a list of rule-outs, beginning with the most serious condition and working downward. An example is a young dog with a seriously swollen head and respiratory distress. Instead of assuming that the condition is due to trauma, the veterinarian also must consider cellulitis, anaphylaxis, or rattlesnake envenomation. If respiratory distress has been alleviated, you have time to consider the other possibilities and take appropriate action.

12. Why do rule-outs sometimes lead to problems?

The tendency is to think of the most common or statistically most probable explanation of the animal's condition. This approach provides the correct solution in most cases, but you may overlook the most serious, albeit usually least common, problem. The practice of veterinary emergency medicine often requires you to react rather than contemplate the answer. Consider the most serious condition possible and, through a logical process of elimination, rule it out. Thus you will arrive at the correct and generally more common diagnosis.

13. Is diagnosis a requirement during an emergency?

Of course not. Sometimes it takes hours, days, weeks, or even months to make the final diagnosis. It is unreasonable to expect that every emergency patient should have a diagnosis. The veterinarian's role in an emergency is to rule out serious or life-threatening causes for the animal's immediate condition. If you are an obsessive-compulsive personality with a need for absolute certainty before you act to stabilize an animal, you will find emergencies an unhealthy area of work.

14. Describe the traditional approach vs. the algorithmic approach to emergency patients.

The traditional approach to an emergency is first to determine the diagnosis, then to provide treatment, and then to monitor the patient (Fig. 1). This highly inefficient system often overlooks life-threatening emergencies. A more efficient system is to use defined algorithms in which the veterinarian takes a triage approach, initiates treatment, and monitors the patient as problems are identified (Fig. 2).

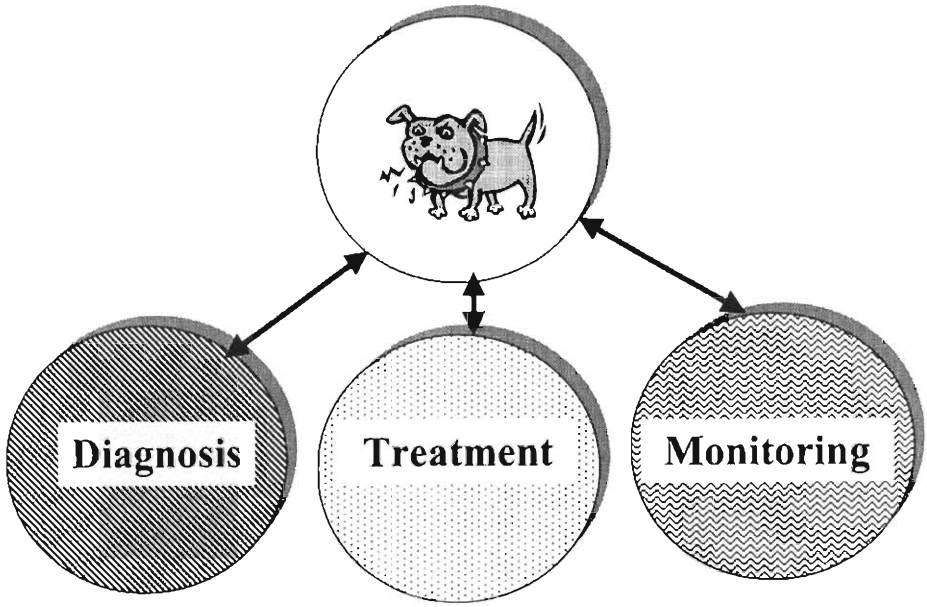

Figure 1. The traditional approach to an emergency involves diagnosis, followed by treatment and monitoring. This inefficient system is likely to result in delayed treatment of life-threatening emergencies

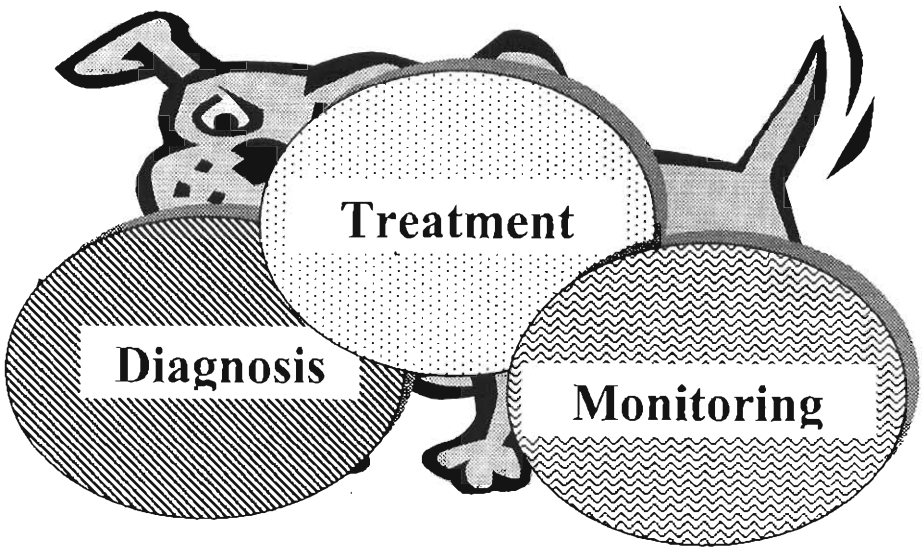

Figure 2. The algorithmic approach to an emergency involves a systems triage for diagnosis, treatment, and monitoring. As a problem is identified, it is treated, and monitoring is begun.

15. How do I decide whether to hospitalize the animal?

Tough question. Obviously several factors are important in making this decision:

- The medical/surgical condition is the first factor to consider. One crucial question must be answered: "Is there a need that can be fulfilled only by hospitalization?" For example, is oxygen, special monitoring, intensive fluid therapy, or intravenous medication required?

- Will the animal receive proper observation and treatment if discharged to the owner? Does the animal even have an owner?
- Unfortunately, economics must be factored into the decision. If the animal's owner cannot afford hospitalization, the veterinarian is faced with two important decisions: (1) Is there any way the animal can be treated at home without endangering survival? (2) Is the condition so severe that euthanasia is a viable option?

16. What criteria may be used for treatment of animals admitted without the owner?

- Is there any way to identify the animal's owner? Check for microchips by scanning, look for a tattoo inside the groin or pinna, check for tags on the animal's collar, ask the person admitting the animal if he or she has seen the animal before, and ask the hospital staff if they recognize the animal.
- Can the animal be made comfortable enough to be held for at least a part of the holding period required by local ordinances?
- Is the animal adoptable? Have you met a veterinarian, veterinary technician, or student who has not adopted an ill or injured animal? I doubt it.

Remember, if the animal enters your front door, you are committed to provide at least first aid care, no matter what the resources of the person admitting the animal.

17. When is euthanasia for humane reasons indicated?

First, you need to know local ordinances. If the animal cannot be made comfortable, it probably should be euthanized. Make complete notes in the medical record, and focus on terms such as pain, suffering, imminent demise, coma, severe respiratory distress, irreversible shock, uncontrollable hemorrhage, irreversible neurologic injuries, and unlikelihood of returning the animal to a "useful purpose."

18. Any last thoughts about decision-making in emergencies?

Often the good samaritan who brings the animal to you in an emergency will go to great lengths to sway your judgment. He or she may even offer to pay (but rarely does so!). Consult with colleagues and professional staff, and, ultimately, do what you think is best for the animal. By all means, keep good records.

2. CARDIOPULMONARY ARREST AND RESUSCITATION IN SMALL ANIMALS

Wayne E. *Wingfield*, M.S., D.V.M.

1. Define cardiopulmonary arrest and list the three phases of resuscitation.

Cardiopulmonary arrest is defined as the abrupt, unexpected cessation of spontaneous and effective ventilation and systemic perfusion (circulation). Cardiopulmonary resuscitation (CPR) provides artificial ventilation and circulation until advanced life support can be provided and spontaneous circulation and ventilation can be restored. CPR is divided into three support stages:

- Basic life support
- Advanced life support
- Prolonged life support

2. Which animals are at risk for cardiopulmonary arrest? What are the predisposing factors?

Cardiopulmonary arrest usually results from cardiac dysrhythmia. It may be due to primary cardiac disease or diseases that affect other organs. In most animals, arrest is associated with diseases of the respiratory system (pneumonia, laryngeal paralysis, neoplasia, thoracic effusions, and aspira-

- Will the animal receive proper observation and treatment if discharged to the owner? Does the animal even have an owner?
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tion pneumonitis) as a result of severe multisystem disease, trauma, and cardiac dysrhythmias. In our hospital, pulmonary diseases result in the highest number of arrests in dogs. In cats, trauma is the most common reason for arrest.

Predisposing factors include the following: (1) cellular hypoxia, (2) vagal stimulation, (3) acid-base and electrolyte abnormalities, (4) anesthetic agents, (5) trauma, and (6) systemic and metabolic diseases.

3. What are the warning signs of cardiopulmonary arrest?

- Changes in respiratory rate, depth, or pattern
- Weak or irregular pulse
- Bradycardia
- Hypotension
- Unexplained changes in the depth of anesthesia
- Cyanosis
- Hypothermia (over 80% of cats and 34% of dogs are hypothermic at the time of arrest)

4. How is cardiopulmonary arrest diagnosed?

The classical description of arrest includes the following: (1) absence of ventilation and cyanosis (respiratory arrest); (2) absence of a palpable pulse (pulse disappears with systolic pressure < 60 mmHg); (3) absence of heart sounds (heart sounds disappear with systolic pressure < 50 mmHg); and (4) dilatation of the pupils.

5. What is involved with each of the phases of cardiopulmonary resuscitation?

Basic life support

A = Establishment of an **A**irway
B = **B**reathing support
C = **C**irculation support

Advanced life support

D = **D**iagnosis and drugs
E = **E**lectrocardiography
F = **F**ibrillation control

Prolonged life support

G = **G**auging the patient's response
H = **H**opeful measures for the brain
I = **I**ntensive care

To optimize CPR, one should *assess* before initiating basic, advanced, and prolonged life support. For example, assessment → airway support, assessment → breathing support, assessment → circulation support, assessment, and so on through each phase.

6. Should I keep accurate records for each animal with cardiopulmonary arrest?

Yes. Although you are not likely to record every action during the arrest, it is important to record basic information.

BASIC LIFE SUPPORT

7. How important is basic life support?

Basic life support is the most important phase of cardiopulmonary resuscitation. It requires practice by the entire staff. It is easy to develop simulated arrests using stuffed toy animals on which you can practice the ABCs of CPR. Through such practice sessions the staff can be trained to respond rapidly to this serious emergency.

8. How do we establish an airway?

The first step is to assess and establish the unresponsiveness of the airway. Quickly check the airway for foreign materials (bones, blood clots, fractured mandible, vomitus). Position the

animal in ventral recumbency in preparation for intubation with an endotracheal tube. Place the endotracheal tube accurately by utilizing a laryngoscope.

9. How do we breathe for the animal?

First, ensure that the animal is apneic and requires assisted ventilation. Once you have seen that there is no movement to the chest wall, begin to ventilate the animal with two *long* breaths (1.5–2.0 seconds each). If the animal does not begin to breathe within 5–7 seconds, begin to ventilate at a rate of 12–20 times/minute.

Use of acupuncture to stimulate respirations has been reported. Placing a needle in acupuncture point Jen Chung (GV26) may reverse respiratory arrest under clinical conditions. The technique involves using a small (22–28 gauge, 1–1.5 inch) needle in the nasal philtrum at the ventral limit of the nares. The needle is twirled strongly and moved up and down while improvement in respiration is monitored. This simple technique can be used quickly. This technique will not work in every case, nor will it work if a narcotic antagonist, such as naloxone, has been given before insertion of the acupuncture needle.

10. How is circulation supported during CPR?

Assessment is necessary to determine the pulselessness of the animal before initiating external cardiac compression. Currently there are two theories to explain the mechanism of forward blood flow during CPR: (1) cardiac pump theory and (2) thoracic pump theory. The cardiac pump theory is probably more important in smaller animals (< 7 kg) and the thoracic pump in larger animals (> 7 kg). It is believed that the cardiac and thoracic pumps are interactive; each contributes to the pressure gradients responsible for blood flow during CPR.

11. What is the cardiac pump theory?

The original hypothesis suggests that blood flow to the periphery during external cardiac compression of the heart results from direct compression of the heart between the sternum and vertebrae (dorsal recumbency) or between the right and left thoracic wall (lateral recumbency) of the dog and cat. According to this concept, thoracic compression (artificial systole) is similar to internal cardiac massage and results in squeezing of blood from both ventricles into the pulmonary arteries and aorta as the pulmonary and aortic valves open. Retrograde flow of blood is prevented by closure of the left and right atrioventricular valves. During the relaxation phase of thoracic compression (artificial diastole), the ventricles recoil to their original shape and fill by a suction effect, while elevated arterial pressure closes the aortic and pulmonic valves.

12. What is the thoracic pump theory?

As pressure is applied to the animal's thorax, there is a correlation between the rise in intrathoracic pressure during compression and the apparent magnitude of carotid artery blood flow and pressure. For brain blood flow to occur during resuscitation, a carotid arterial-to-jugular pressure gradient must be present during chest compression. Experimental studies in large dogs have shown that thoracic compression during CPR results in an essentially equal rise in central venous, right atrial, pulmonary artery, aortic, esophageal, and lateral pleural space pressures with no transcardiac gradient. Aortic pressure is efficiently transmitted to the carotid arteries, but retrograde transmission of intrathoracic venous pressure into the jugular veins is prevented by valves at the thoracic inlet and possibly by venous collapse. Thus, during artificial systole a peripheral arterial venous pressure gradient appears, and blood flow results from this gradient. In such a system, there is no pressure gradient across the heart; thus, the heart acts merely as a passive conduit. Cineangiographic studies in large dogs confirm these observations by demonstrating partial right atrioventricular valve closure, collapse of the venae cavae, and opening of the pulmonary, left atrioventricular, and aortic valves during thoracic compression. When thoracic compression is released (artificial diastole), intrathoracic pressures fall toward zero, and venous flow to the right heart and lungs occurs. During artificial diastole, a modest gradient also develops between the intrathoracic aorta and the right atrium, providing coronary (myocardial) perfusion.

In small dogs receiving vigorous chest compressions, intrathoracic vascular pressures are much higher than recorded pleural pressures. The rise in vascular pressures probably results from compression of the heart during chest compression and not from rising intrathoracic pressure.

13. What are the determinants of vital organ perfusion during CPR?

Cerebral blood flow depends on the gradient between the carotid artery and intracranial pressure during systole (thoracic compression). Myocardial blood flow depends on the gradient between the aorta and right atrium during diastole (release phase of thoracic compression). During conventional CPR, cerebral and myocardial blood flow is less than 5% of prearrest values. Below the diaphragm, renal and hepatic blood flow during CPR is 1–5% of prearrest values.

14. What are the determinants of improved vital organ perfusion during CPR?

Force, rate, and duration of chest compression during CPR determine the effectiveness of organ perfusion. Regardless of the mechanism of forward blood flow during CPR, increasing the force of chest compressions increases arterial pressures. At pressures > 400 newtons (about 40 kg), bone and tissue trauma are more likely. Increasing the rate of chest compressions significantly increases the arterial pressure.

GENERAL GUIDELINES FOR CPR IN ANIMALS

15. What is the optimal position for maximizing blood flow?

Lateral recumbency (the sternum must be kept parallel to the table top by either placing a fist under the chest wall or using a sand bag to hold the sternum off the table top) is used for animals < 7 kg and, ideally, dorsal recumbency for animals > 7 kg. It is extremely difficult to maintain a dog in dorsal recumbency without special V-shaped troughs or other techniques. However, dorsal recumbency provides maximal changes in intrathoracic pressure and thus forward blood flow. When no peripheral pulse is felt during CPR, consider changing the animal's position and CPR technique.

16. What is the optimal compression/relaxation ratio for administering external cardiac compression?

Studies have shown the best ratio of cardiac compression to ventilation is 1:1 (simultaneous compression-ventilation) in animals. You breathe for the animal each time you compress the thoracic wall.

17. At what rate should you compress and ventilate when two persons are available to do CPR?

In animals weighing < 7 kg, the recommended rate of ventilation and compression is 120 times/minute. In animals weighing > 7 kg, the rate of compression and ventilation is 80–100 times/minute.

18. What is interposed abdominal compression?

To improve venous return and to decrease arterial run-off during external thoracic compression, have one person press on the cranial abdomen between each compression of the chest. In humans, this technique improves hospital discharge rates as much as 33%. No comparable studies are yet available in animals.

19. What if only one person is available to do CPR?

One-person CPR in animals is highly ineffective. The ratio of ventilation to chest compression is 15:2. Give 15 chest compressions and then 2 long ventilations. Use a rate of 120 chest compressions/minute when the animal weighs < 7 kg and 80–100 times/minute when the animal weighs > 7 kg.

A recent report in experimentally induced CPR in swine has shown an excellent resuscitation rate through providing only cardiac compression. In fact, the researchers were unable to detect a difference in hemodynamics, 48-hour survival, or neurologic outcome when CPR was applied with or without ventilatory support. With this in mind, if inadequate numbers of professional staff are available, apply only cardiac compression if cardiopulmonary arrest is present.

20. When should I open the chest and do CPR?

Chest compressions raise the venous (right atrial) pressure peaks almost as high as arterial pressure peaks and increase intracranial pressure, thus causing low cerebral and myocardial perfusion pressures. Open-chest CPR does not raise atrial pressures and provides better cerebral and coronary perfusion pressures and flows than external CPR in animals. When applied promptly in operating room arrests, open-chest CPR, which was introduced in the 1880s, yields good clinical results in people. The switch from external to open-chest CPR has not yet improved outcome in humans, probably because its initiation is too late. No comparable studies are available for clinical open-chest CPR in animals. Currently, open-chest CPR should be restricted to the operating room and in selected instances of penetrating thoracic injury.

21. How can I monitor the effectiveness of external thoracic compressions?

Traditionally, the presence of a pulse during thoracic compression has been the hallmark of effective compression. More recently, monitoring of peripheral pulses with quantitative Doppler techniques has shown that the pulse generated during compression is in fact from venous and not arterial flow. In veterinary medicine, monitoring the pulse is the most common technique of monitoring effectiveness.

Pulse oximetry provides information about hemoglobin saturation. During CPR you should see an improvement in oximetry values and mucous membrane color. End-tidal carbon dioxide (CO_2) monitoring has proved to be the most effective means of measuring the effectiveness of CPR. This device fits in-line with the endotracheal tube and measures CO_2 levels. With effective CPR you should see an increased end-tidal CO_2.

22. What can I do if there is no pulse or change in oximetry or end-tidal CO_2?

Consider changing the position of the animal and the force or rate of thoracic compression.

23. How can I train my staff in CPR?

Periodic training sessions in basic life support should be conducted in every veterinary practice. This is not a time-consuming activity, and the benefits are tremendous when the staff can respond quickly and efficiently. An effective means to provide training is to develop an inexpensive CPR animal. Such teaching aids were developed by taking old corrugated anesthetic tubing (trachea), an anesthetic Y-piece (tracheal bifurcation), two anesthetic rebreathing bags (lungs), and implanting them in the chest of a stuffed animal. These devices can be used to practice CPR techniques with your staff. One can place foreign materials in the mouth, practice Jen Chung maneuvers, palpate for pulses, see the thorax expand with each breath, and feel the expanding lungs as you apply chest compression. Practice sessions can be called at any time to simulate a sudden, unexpected arrest.

ADVANCED LIFE SUPPORT

24. Which drugs should I have available in the "crash cart"?

Drugs considered necessary for cardiopulmonary arrest are (1) epinephrine, (2) atropine, (3) magnesium chloride, (4) naloxone, (5) lidocaine, (6) sodium bicarbonate, (7) methoxamine, and (8) bretylium tosylate.

25. What other drugs should I have available?

Drugs that are important in the postresuscitation phase of CPR include (1) dobutamine, (2) mannitol, (3) furosemide, (4) lidocaine, (5) verapamil, (6) sodium bicarbonate, (7) dopamine, and (8) intravenous fluids.

26. What are the indications for emergency drug use during CPR?

1. To initiate electrical activity
2. To increase heart rate
3. To improve myocardial oxygenation
4. To control life-threatening dysrhythmias

27. What is the best route for administration of drugs during CPR?

Each of the four commonly used routes for drug administration during CPR has its advantages and disadvantages.

1. **Intravenous (IV).** The preferred route for drug administration during CPR is the IV route. With central venous catheters, drugs can be rapidly delivered to their site of action via the coronary arteries. In giving IV drugs during CPR, it is important to follow each drug with a bolus of saline or water for injection to encourage the transport of the drug toward the heart because cardiopulmonary arrest usually results in hypotension, vasoconstriction, and hypovolemia. At present no conclusive data support the use of a central venous rather than a peripheral venous route.

2. **Intratracheal (IT).** The IT route has the advantages of accessibility, close proximity to the left side of the heart via the pulmonary veins, and a large surface area for drug absorption. The disadvantages are the increased dosage required for many drugs (often 10 times the dosage given IV), decreased efficacy in the presence of pulmonary disease, and the fact that some drugs cannot be given IT (i.e., sodium bicarbonate).

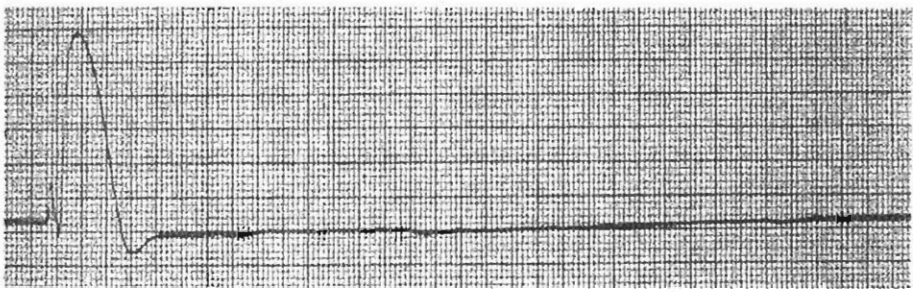
3. **Intraosseous (IO) or intramedullary.** The bone marrow cavity provides extensive venous access to the cardiovascular system. Drugs normally given via the IV route may be given via the bone marrow cavity. The bone marrow cavity is most commonly accessed either through the trochanteric fossa of the femur or the distal cranial femur during CPR.

4. **Intracardiac (IC).** Drugs can be delivered directly to the heart via the intracardiac route. The difficulty of using the IC route comes with the inability of personnel to inject drugs into the heart. Without the apex beat normally present, many find this technique to be most difficult in animals. In addition there are problems with the delivery of drugs into the myocardium instead of the ventricular chambers. Delivery into the myocardium may result in dysrhythmias and laceration of coronary arteries, and requires discontinuance of basic life support while IC injections are attempted.

28. What are the common cardiac rhythms of cardiopulmonary arrest?

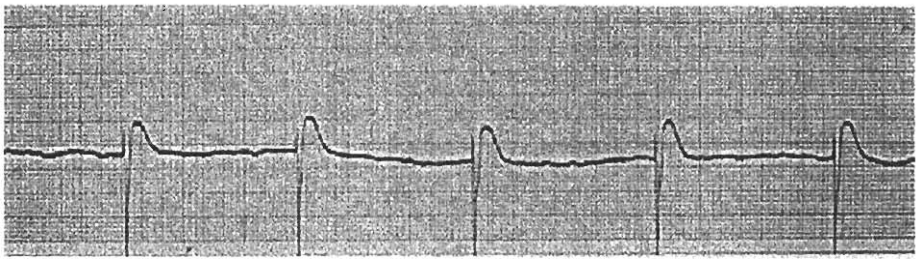
The only way to distinguish the various dysrhythmias of arrest is an electrocardiogram.

1. **Ventricular asystole** is characterized by absence of both mechanical and electrical activity on the electrocardiogram (see figure below).



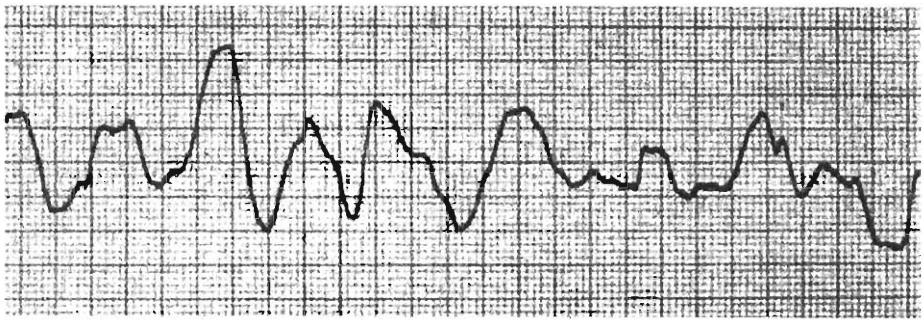
Treatment: epinephrine, atropine.

2. **Pulseless electrical activity (PEA)** (formerly referred to as electromechanical dissociation [EMD]) is characterized by electrical activity without sufficient mechanical activity to cause adequate cardiac output or pulses (see figure below). The failure of contractility is probably due to depletion of myocardial oxygen stores and may be perpetuated by endogenous endorphins.



Treatment: naloxone, epinephrine, megadosage atropine (intratracheal dosage given IV).

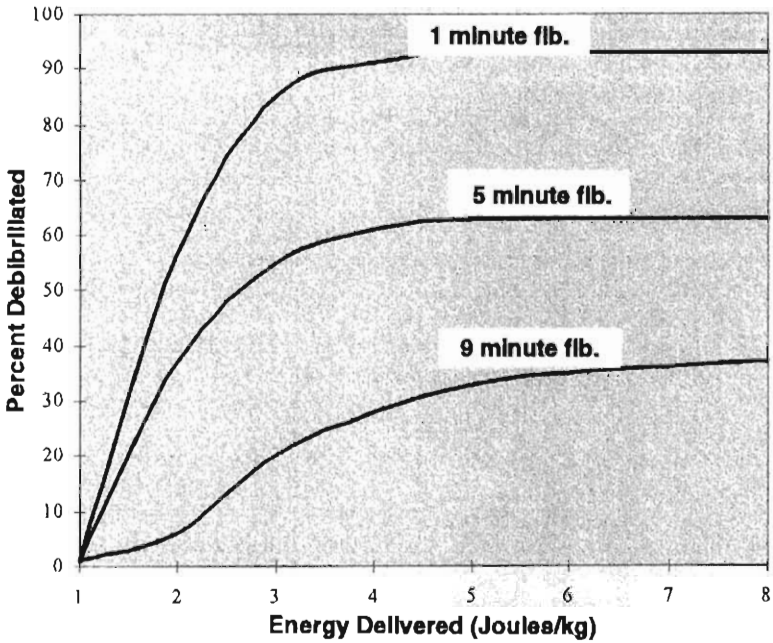
3. **Ventricular fibrillation** is characterized by chaotic, disorganized, ectopic ventricular activity resulting in sustained ventricular systole (see figure below). Because the coronary arteries perfuse the myocardium during diastole, no perfusion takes place as long as the animal has ventricular fibrillation.



Treatment: Electrical DC countershock is the treatment of choice for ventricular fibrillation. If ventricular fibrillation is the first rhythm encountered, sequential attempts at electrical defibrillation should be performed. If ventricular fibrillation is not the first rhythm encountered or if countershock results in persistent ventricular fibrillation or another nonperfusing spontaneous cardiac rhythm, endotracheal intubation should be performed, chest compressions initiated, and an IV line established in preparation for subsequent management of the observed rhythm.

The cardiac response to countershock is largely time-dependent. If countershock can be performed within 3 minutes of the onset of ventricular fibrillation, 70–80% of patients convert to a rhythm associated with adequate perfusion (human data). After 5 minutes of ventricular fibrillation, countershock rarely results in a spontaneous perfusing rhythm; asystole, PEA, or persistent ventricular fibrillation are the usual results.

If countershock fails to convert the ventricular fibrillation, epinephrine should be given (IV or IT). The beneficial effects of epinephrine depend primarily on its α_1-adrenergic effects, which include arterial vasoconstriction and selective redistribution of cardiac output. Epinephrine increases the CPR diastolic aortic-to-right-atrial myocardial perfusion gradient (coronary perfusion pressure) by increasing aortic diastolic pressure and improves the cerebral perfusion gradient by increasing carotid arterial pressure. Chemical defibrillating drugs have unproven efficacy in clinical veterinary medicine. Unfortunately, many veterinarians do not have electrical defibrillators; thus, the chemical defibrillating drugs may be the only option. Drugs that may be tried in ventricular fibrillation include bretylium tosylate or magnesium chloride. These drugs have been reported to be effective in terminating ventricular fibrillation when electrical countershock has failed.



Curves showing estimated sources of defibrillation vs. delivered energy after 1, 5, and 9 minutes of fibrillation in dogs receiving closed-chest cardiac massage and artificial ventilation with epinephrine. (From Yakaitis RW, Ewy GA, Otto GW, et al: Influence of time and therapy on VF in dogs. Crit Care Med 8:157, 1980; with permission.)

29. In using an electrical defibrillator, what important points should be kept in mind?

The electrical defibrillator is the treatment of choice for ventricular fibrillation. It is also a dangerous instrument that can cause injury to the patient and death to the veterinarian if improperly used. The optimal delivered energy to the myocardium is roughly 2–4 joules/kg. In delivering this countershock to the myocardium, it is necessary to "hit" only about 28% of the myocardial cells to defibrillate. Thus, paddle position is not as important as once believed. One should make every effort to reduce transthoracic impedance during electrical defibrillation. The following factors influence impedance:

1. Use large surface area paddles.
2. Countershocks applied close together may be most effective.
3. Use an electrode-skin interface material such as electrolyte paste or gel. Do not use alcohol.
4. Apply pressure to the electrodes.
5. Defibrillate during expiration.

Be careful! Always announce "all clear!," and look around to be sure that nobody is in contact with the animal, table, or instruments.

30. What is the difference between a cat and dog in ventricular fibrillation?

In normal cats, the heart is generally small enough that it may spontaneously convert from ventricular fibrillation to sinus rhythm. Unfortunately, sick cats also may have enlarged hearts. In such cases, electrical defibrillation should be attempted.

31. Which drugs should be used with caution during advanced life support?

1. Calcium enhances ventricular excitability (thus increasing myocardial oxygen requirements); it decreases sinus nodal impulse formation, reduces blood flow to the brain to nearly zero during CPR, causes coronary artery vasospasm, and is an important mediator in the formation of

arachidonic acid and oxygen-free radicals. Currently, use of calcium during CPR is not routinely recommended except under conditions of hyperkalemia or hypocalcemia or when calcium channel blockers have been previously used. $CaCl_2$ results in the longest and most predictable increase in plasma ionized calcium.

2. Isoproterenol is a pure β-agonist drug. It increases myocardial oxygen demands and reduces cerebral blood flow during CPR. Currently, isoproterenol is reserved for patients with atropine-resistant bradycardias.

3. Sodium bicarbonate was once used routinely during CPR, but its empirical use is associated with:

- Increased serum osmolality (8.5% solution = 1500 mOsm).
- The metabolism of sodium bicarbonate results in the formation of increased PCO_2 ($HCO_3^- + H^+ \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_2O$).
- With inadequate ventilation, paradoxical cerebrospinal fluid (CSF) acidosis results (HCO_3^- crosses the blood-brain barrier more slowly than CO_2).
- Sodium bicarbonate shifts the oxyhemoglobin dissociation curve to the left (decreased amounts of oxygen are released to tissues).
- Direct myocardial depression results with alkalosis (decreasing cardiac output).
- Metabolic alkalosis (pH > 7.55) predisposes to cardiac dysrhythmias that may be unresponsive to antiarrhythmic therapy.
- Before giving sodium bicarbonate, be sure the animal has adequate ventilation.
- Ideally, administration of sodium bicarbonate should be based on pH and $PaCO_2$.

Use of buffer therapy depends on the duration of arrest and CPR times. Metabolic acidemia (base deficit) should be corrected, because proper acid-base balance improves cardiovascular resuscitability and cerebral recovery in dogs. After ventricular fibrillation results in no flow for 5 minutes in dogs, metabolic acidemia is mild and transient, and early empirical $NaHCO_3$ administration is not harmful to the heart and may benefit the brain. After longer arrest or CPR times, evidence in animals of improved cardiovascular and cerebral recovery supports the recommendation to accompany epinephrine with an empirical dose of 1 mEq/kg of IV $NaHCO_3$ during CPR, to be followed by correction of monitored base deficit > 5 mEq/kg $NaHCO_3$. This may produce a transient CO_2 load that worsens the arrest-induced myocardial hypercarbia, which may depress cardiac resuscitability. This $NaHCO_3$-induced hypercarbia is usually mild, transient, correctable with hyperventilation, and harmless for the heart when epinephrine is used and apparently was not harmful to the brain.

4. Intravenous fluids are administered during CPR only when hypovolemia is the cause of arrest. Fluid-loading during CPR decreases cerebral blood flow, increases right atrial pressures (resulting in decreased coronary perfusion pressures), and therefore decreases coronary blood flow.

5. Doxapram hydrochloride is a central respiratory stimulant. Its use during CPR is not advised. Often the stimulation of the respiratory center results in transient hyperventilation followed by apnea.

32. What is the dilution of epinephrine during CPR?

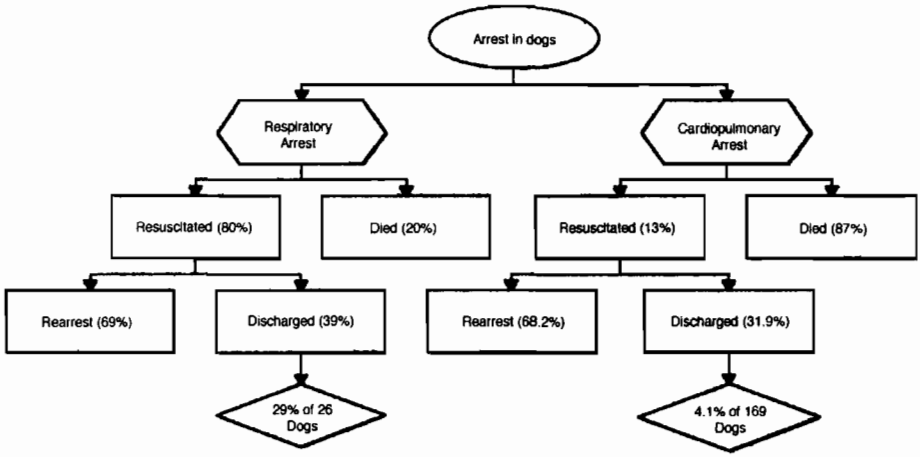
Epinephrine is no longer diluted. The concentration of 1:1000, as packaged, is used with IV, IT, IO, and IC routes.

PROLONGED LIFE SUPPORT

33. What are the main complications after resuscitation?

Recurrence of either respiratory or cardiopulmonary arrest is the biggest concern after resuscitation. In most cases, arrest recurs within the first 4 hours of the first episode (see figure).

After arrest, cerebral resuscitation becomes the next most important complication. Because of the low flow state to the brain during CPR, ischemia and hypoxia lead to cerebral edema. As the heart begins to reperfuse tissues, significant injury products may be released to the systemic circulation.



Cardiopulmonary arrest in dogs. (From Wingfield WE, Van Pelt DR: Respiratory and cardiopulmonary arrest in dogs and cats: 265 cases (1986–1991). J Am Vet Med Assoc 200:1993–1996, 1992; with permission.)

34. What cerebral complications may be expected after cardiac arrest?

In normal brain, autoregulation maintains a global cerebral brain flow of about 50 ml/100 gm brain/minute despite cerebral perfusion pressures (CPP) (i.e., mean arterial pressure minus intracranial pressure) between 50 and 150 mmHg. When CPP drops below 50 mmHg, cerebral blood flow decreases, and the viability of normal neurons seems threatened by CPP < 30 mmHg, global cerebral blood flow < 15 ml/100 gm/minute, or cerebral venous oxygen partial pressures (PO_2) < 20 mmHg. During complete cerebral ischemia, calcium shifts, brain tissue lactic acidosis, and increases in the brain free acids, osmolality and extracellular concentration of excitatory amino acids (particularly glutamate and aspartate) set the stage for reoxygenation injury.

35. What is the pathophysiology of the cerebral injury after resuscitation?

Perfusion failure (i.e., inadequate oxygen delivery) seems to progress through four stages:

1. Multifocal no reflow occurs immediately and seems to be readily overcome by normotensive or hypertensive reperfusion.
2. Transient global "reactive" hyperemia lasts 15–30 minutes.
3. Delayed, prolonged global and multifocal hypoperfusion occurs about 2–12 hours after arrest; global cerebral blood flow is reduced to about 50% of baseline, whereas global oxygen uptake returns to or above baseline levels and cerebral venous PO_2 decreases to < 20 mmHg, reflecting mismatching of oxygen delivery to oxygen uptake.
4. After 20 hours, either normal global cerebral blood flow and global oxygen uptake are restored, both remain low (with coma), or secondary hyperemia develops (postulated to be associated with reduced oxygen uptake), followed by brain death.

Reoxygenation, although essential, also may provide chemical cascades (involving free iron, free radical, calcium shifts, acidosis, excitatory amino acids, and catecholamines) that result in lipid peroxidation of membranes.

Extracerebral derangements, including intoxication from postanoxic viscera, can worsen cerebral outcome. Studies in dogs have shown a delayed reduction in cardiac output following cardiac arrest despite controlled normotension. Pulmonary edema can be prevented by prolonged controlled ventilation.

Blood derangements due to stasis include aggregates of polymorphonuclear leukocytes and macrophages that may obstruct capillaries, release free radicals, and damage endothelium.

36. How do we manage the postresuscitation patient to reduce the adverse complications of CPR?

Careful monitoring is most important during the first 4 hours after arrest. All patients require oxygen administered via oxygen cage, nasal insufflation, or facemask. If CPR was successful, one needs to support the heart during the postresuscitation phase. This support is directed to inotropic support (dobutamine or dopamine), possibly using vasodilator drugs (sodium nitroprusside), and antiarrhythmic drugs (lidocaine). These drugs help to reduce the pulmonary edema usually seen after arrest. In addition, furosemide is usually administered to reduce pulmonary edema. Cerebral hypoxia and ischemia result during CPR. The end result is cerebral edema. Treatment for cerebral edema includes mannitol and usually corticosteroids. Additional drugs that may improve cerebral resuscitation include the following:

- Calcium channel blockers reverse cerebral vasospasm and prevent lethal intracellular calcium influx.
- Barbiturates, which are mild calcium antagonists, decrease arachidonic acid and free fatty acid levels in neurons as well as metabolic demands of the brain. To date, no conclusive evidence supports the use of barbiturates. In addition, the sedation that results makes sequential neurologic assessment impossible.
- Iron-chelating drugs and free radical scavengers. Although experimental at this point, results are promising.

37. How do you know the cerebral outcome of the patient after CPR?

One should always be concerned about irreversible cerebral injury after arrest. Daily neurologic evaluations and assessment are required. Record findings each day to note the patient's progress. Clinical features to observe after arrest include the following:

- Reactivity of the pupils
- Increased responsiveness
- Breathing patterns
- Motor responses
- Motor postures

38. Are certain patients unlikely to be resuscitated?

No studies are currently available in animals, but studies in humans indicate that certain groups of patients do not survive—patients with oliguria, metastatic cancer, sepsis, pneumonia, and acute stroke. Probably animals with these conditions also will not survive.

39. When do we use do-not-resuscitate orders?

Do-not-resuscitate orders must be initiated by the owner. Good client communications are useful whenever an animal is hospitalized. It is probably wise to advise owners that arrest occurs suddenly and unexpectantly. Ask the owner how far you should go if the pet arrests. Record the response, and abide by the owner's wishes.

The decision to stop CPR must be tempered with common sense, client communication, and experience of the resuscitators. Our experience suggests that the mean duration of CPR is generally about 20 minutes.

After more than 30 years of widespread use of CPR, reevaluation of its benefits in terms of survival and quality of life shows it to be a desperate effort that helps only a limited number of patients. For most, CPR is unsuccessful.

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3. RESPIRATORY DISTRESS

Michael S. *Lagutchik*, D.V.M., M.S.

1. Define respiratory distress, dyspnea, tachypnea, orthopnea, hyperventilation, hypoventilation, and apnea.

Respiratory distress is outwardly evident, physically labored respiratory effort that denotes clinically evident inability to ventilate and/or oxygenate adequately. This is currently the preferred term for veterinary patients who present with severe respiratory difficulty.

Dyspnea is the conscious perception of "air hunger" or a sense of "shortness of breath." This term is subjective in nature and is not ideal to use in reference to veterinary patients, because they cannot relay the perception of respiratory difficulty.

Tachypnea is a respiratory rate that is greater than normal.

Orthopnea is an increase in respiratory distress when a patient is lying down or the chest is compressed.

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Tachypnea is a respiratory rate that is greater than normal.

Orthopnea is an increase in respiratory distress when a patient is lying down or the chest is compressed.

Hyperventilation is ventilation that exceeds metabolic demands. Hyperventilation is strictly defined as ventilation causing a reduction in arterial carbon dioxide content ($PaCO_2$) < 35 mmHg, or hypocapnia.

Hypoventilation is ventilation that does not meet metabolic demands. Hypoventilation by definition is ventilation that results in a $PaCO_2$ > 45 mmHg, or hypercapnia. Hypoventilation denotes ventilatory failure.

Apnea is cessation of breathing for an indeterminate period.

2. What is acute hypercapnic respiratory failure?

Hypercapnic respiratory failure is defined as acute respiratory distress resulting in a $PaCO_2$ > 45 mmHg. Typically, it involves abnormalities with central nervous system control of respiration, peripheral nervous system interaction with the respiratory apparatus, chest wall/bellows apparatus, or airways involved with gas transport. Hypercapnic respiratory failure is thus often called *respiratory pump failure* or *ventilatory failure*.

3. What is acute hypoxemic respiratory failure?

Hypoxemic respiratory failure is defined as acute respiratory distress resulting in a PaO_2 < 60 mmHg despite addition of supplemental oxygen of at least 60%. Typically, it involves the alveoli component of the pulmonary system. Hypoxemic respiratory failure also is called *lung failure* or *oxygenation failure*. The five fundamental causes are (1) decreased inspired oxygen content [F_IO_2] (e.g., high altitude ascent or reduction in the F_IO_2 setting on a mechanical ventilator); (2) hypoventilation (e.g., respiratory paralysis, airway obstruction, or atelectasis); (3) diffusion impairment (e.g., severe pneumonia, interstitial fibrosis, or interstitial pulmonary edema); (4) ventilation-perfusion (V/Q) mismatch (e.g., emphysema, alveolar pulmonary edema, pneumothorax, atelectasis); and (5) intra- and extrapulmonary shunting (technically the most severe form of V/Q mismatch; e.g., lung consolidation, atelectasis).

4. What are the initial treatment priorities in any patient with respiratory distress?

Reestablishment of adequate arterial oxygen tension and removal of excessive CO_2 are the overriding aims of the immediate treatment of patients with severe respiratory distress. The major ways in which to achieve this aim, regardless of the underlying cause, are establishing a patent airway, instituting or assisting ventilation, and maintaining adequate oxygen tension by administration of supplemental oxygen to maximize oxygen delivery.

5. I don't have a lot of money for expensive monitoring devices. What are the most useful diagnostic tools in evaluating patients with respiratory distress?

The simplest, least expensive, and often most useful "tools" are a good history, detailed physical exam, and careful chest auscultation. Monitoring devices can never replace good clinical observations and judgment and serve only to augment clinical decision making with quantifiable information. Monitoring devices considered essential for emergency and critical care facilities include arterial blood gas (ABG) analyzers, pulse oximeters, and capnographers. The ability to perform thoracic radiography is also essential.

6. Describe measures that allow differentiation of the various causes of hypoxemia in emergency patients with respiratory distress.

Hypoxemia is diagnosed by the presence of SpO_2 < 90% or ABG analysis that reveals PaO_2 < 60 mmHg. ABG analysis is essential for proper interpretation of causes of hypoxemia. Alternatively, pulse oximetry and capnography can be useful in diagnosis. Hypoxemia with hypercapnia defines hypoventilation as the underlying cause. Hypoxemia with normocapnia implies diffusion impairment, ventilation/perfusion imbalance (V/Q mismatch), or shunt as underlying causes. In veterinary patients, diffusion impairment is rarely severe enough to cause hypoxemia in and of itself. Response to oxygen supplementation usually allows differentiation between V/Q mismatch and shunting. The typical patient with V/Q mismatch demonstrates marked response (i.e., improved PaO_2) with supplemental oxygen, whereas the patient with shunt

shows only minimal, if any, improvement in PaO_2 (i.e., by definition, refractory hypoxemia with < 10 mmHg increase with at least 40% oxygen administration).

7. How do I recognize a patient with severe respiratory distress?

Usually, such patients are not hard to recognize. Abnormal sounds (stridor, wheezes), abnormal posture (orthopnea, head and neck extended, elbows abducted, sternal recumbency), abnormal mucous membrane color (cyanosis or pale), tachypnea, weakness and exhaustion, altered respiratory effort (shallow and rapid, or labored and forceful, or absent), and vigorous resistance to restraint are the typical signs in animals with respiratory distress. However, pets may have significant respiratory compromise and yet outwardly show minimal clinical signs of distress. Cats are more likely to have this type of presentation. Careful and quiet examination is essential to avoid sending the patient into stress-induced overt distress or respiratory arrest.

8. What physical exam findings may help to differentiate the cause or location of the primary respiratory problem?

Patients with a rapid, shallow respiratory pattern frequently have pleural space disease (pleural effusion, hemothorax, pneumothorax). Patients with end-expiratory effort and wheezes on chest auscultation frequently have small airway obstructive disease (asthma). Patients with deep, labored chest movements frequently have pulmonary parenchymal disease (pulmonary edema, pulmonary contusions, space-occupying masses). Patients with obvious stridor, minimal air movement at the nares or mouth, and marked inspiratory effort typically have upper airway obstruction (laryngeal edema or paralysis, foreign body aspiration). These patterns are hardly exclusive. Often patients have multiple problems, and some patients may have serious underlying respiratory problems and yet appear clinically normal.

9. Define cyanosis, its causes, and significance. How is it treated in emergent patients?

Cyanosis develops (1) when blood is insufficiently oxygenated in the lungs; (2) when hemoglobin is unable to carry oxygen; and (3) when blood stagnates in peripheral capillary beds. To be detected clinically, unoxygenated hemoglobin concentration must be > 5 gm/dl of blood. At this level, significant hypoxemia may already be present (≤ 50 mmHg), thus reinforcing the significance of cyanosis in a critical patient with respiratory distress. In addition, anemic patients may not demonstrate cyanosis. Cyanosis is centrally mediated (right-to-left cardiovascular shunts, hypoventilation, airway obstruction, V/Q mismatching, methemoglobinemia) or peripherally mediated (arterial thromboembolism, venous obstruction, arteriolar constriction, low cardiac output, heart failure, shock). Emergency treatment consists of provision of supplemental oxygen and rapid identification and correction of the underlying cause.

10. What nonrespiratory conditions may mimic acute respiratory distress?

Numerous disorders cause tachypnea, orthopnea, and other signs referable to the respiratory system in the absence of true respiratory disease. These disorders can confuse the clinician. Examples include hyperthermia, shock, metabolic acidosis and alkalosis, hyperthyroidism, fear or anxiety, pericardial tamponade, anemia, abdominal organ enlargement or ascites, and abnormalities with central control of respiration from drugs and metabolic or organic central nervous system disease.

11. What are the two broad categories of traumatic respiratory emergencies in dogs and cats?

Blunt thoracic trauma (e.g., vehicular trauma, falls from height) and penetrating trauma (e.g., bullets, bite wounds, penetrating foreign bodies).

12. Categorize the location and most common types of traumatic respiratory emergencies in small animals.

Larynx and major extrathoracic airways. Commonly caused by collars, bite wounds, and gun shot injury; airway obstruction may occur from blood clots, edema, foreign debris, tissue debris, and secretions. Typical signs include labored inspiration, stridor, and cyanosis; aspiration pneumonia may be present.

Chest wall. Rib fractures (including flail chest segments) and open (sucking) chest wounds are not infrequent in patients suffering thoracic trauma.

Pleural space. Pneumothorax and hemothorax are the most common complications seen after chest trauma. Diaphragmatic hernias are infrequent and can be difficult to diagnose.

Pulmonary parenchyma and major intrathoracic airways. Pulmonary contusions are seen in about 45% of blunt trauma cases. Lung lacerations and pulmonary hematomas are uncommon. Intrabronchial hemorrhage carries a grave prognosis and is seen in major chest trauma cases fairly commonly. Rupture or disruption of intrathoracic airways probably occurs frequently, because many cases of pneumothorax have no outward source of air leakage. Blatant disruption of major airways from the parenchyma likely leads to rapid death.

13. What are the three goals of supplemental oxygen therapy in treating hypoxemic patients? When should supplemental oxygen be administered?

The goals are (1) to treat the hypoxemia, (2) to decrease the work of breathing, and (3) to decrease myocardial work. Supplemental oxygen therapy is indicated for virtually any patient with respiratory embarrassment. With conventional delivery methods (see next question), it is not possible to harm a patient with additional oxygen, and it may mean the difference between life and death.

14. Describe the ways in which supplemental oxygen therapy can be administered, listing the advantages and disadvantages of each.

Four methods are commonly used to provide supplemental oxygen: (1) face mask, (2) nasal oxygen insufflation, (3) oxygen cage, and (4) intratracheal oxygen administration.

METHOD	ADVANTAGES	DISADVANTAGES
Face mask	Simple Inexpensive Readily available Provides F_IO_2 of 40–60%	Requires high O_2 flow rates Patient may not tolerate mask Patient must be attended at all times
Nasal oxygen	More freedom of movement for patient	F_IO_2 is not known (22–44%?) Excessive flow may cause gastric dilatation
Oxygen cage	Noninvasive Provides known F_IO_2 in temperature- and humidity-controlled environment Least stressful to patient	Patient physically isolated Opening doors drops F_IO_2 Maximum F_IO_2 is 40–50% at economical flow rates Expensive
Intratracheal oxygen	Can place transtracheal catheter during emergencies F_IO_2 from 40–80%, depending on whether catheter or endotracheal tube is used	Endotracheal tube placement may require sedation or anesthesia Tracheostomy tube may be required Requires continuous monitoring

15. List the common causes of airway obstruction in dogs and cats.

- Trauma
- Infections involving the nasal passages, pharynx, and larynx
- Obstruction with foreign material
- Localized or systemic anaphylaxis with edema formation and bronchoconstriction
- Compressive tumors of the airways and surrounding soft tissues
- Brachycephalic syndrome components (stenotic nares, elongated soft palate, laryngeal malformation, everted laryngeal saccules, hypoplastic [collapsing] trachea)
- Laryngeal paralysis
- Tracheal stenosis

16. List the common pulmonary parenchymal disorders that cause respiratory distress, and briefly describe findings that may aid in diagnosis in the acute setting.

Pneumonia (acute fulminant bronchopneumonia, aspiration pneumonia, and smoke inhalation pneumonia), pulmonary contusions, pulmonary edema, asthma (in cats), and pulmonary thromboembolism are the common parenchymal disorders causing respiratory distress. Patients with pneumonia are usually depressed, anorectic, and febrile and may or may not have a deep, moist, productive cough. Abnormal lung sounds (crackles) may suggest bronchopneumonia. Patients with contusions invariably have a history of trauma, and areas of the chest on auscultation, especially adjacent to rib fractures or skin bruising, may be quiet, reflecting alveolar and small airway filling with blood and edema. Patients with pulmonary edema usually have fine or coarse crackles on auscultation and may have cardiac or other exam findings to suggest either cardiac or noncardiac causes of the edema in addition to historical information suggesting an underlying cause (e.g., congestive heart failure, electric cord shock). Cats with asthma typically have a supporting history and usually have wheezes on chest auscultation and a characteristic end-expiratory effort caused by forcing air in the small airways against partial or complete small airway closure. Patients with pulmonary thromboembolism (PTE) frequently have another significant medical problem that predisposes them to embolize (hyperadrenocorticism, diabetes mellitus, trauma, disseminated intravascular coagulation). The hallmark findings in patients with PTE are acute, severe respiratory distress and minimal radiographic changes and marked response to oxygen supplementation in the absence of signs suggesting another cause.

17. How do I recognize and manage a patient with a pleural space disorder presenting with respiratory distress?

Patients with pleural cavity disease or disruption of the integrity of the chest wall tend to present with characteristic restrictive respiratory pattern (rapid, shallow breathing with other attendant signs of distress). Chest auscultation usually demonstrates generalized loss of lung sounds (muffled). Common causes of pleural space disease include open chest wounds, flail chest, pneumothorax, pleural effusions, hemothorax, and diaphragmatic hernia. Management depends on the cause, but in general, rapid careful thoracentesis is required for pneumothorax, hemothorax, and severe pleural effusions. Cautious handling until definitive surgery is possible is required for patients with diaphragmatic hernias. Chest wall trauma is managed by appropriate wound care with local anesthetic blocks at sites of rib fractures.

18. How do I manage the patient with fulminant pulmonary edema?

Management depends on the pathophysiologic mechanism responsible for the edema formation. Acute cardiogenic edema is managed by (1) minimizing cardiac work (cage rest, sedation, inotropic support); (2) improving oxygenation (supplemental oxygen, bronchodilators, airway suctioning, mechanical ventilation); (3) resolving pulmonary edema (diuretics, vasodilators, phlebotomy); and (4) improving cardiac performance (inotropic support). Management of noncardiogenic edema (due to increased capillary permeability) is more challenging, because the underlying cause often is not found. Oxygen supplementation is the key tool, and mechanical ventilation with positive end-expiratory pressure may be required. Cautious fluid therapy is essential, and diuretics and vasodilators are recommended only if the patient is normovolemic. Cardiovascular support is important, including inotropic support and blood transfusions to maintain oxygen delivery.

19. What are the indications for placement of an indwelling thoracotomy tube (chest tube)?

Indications include intractable persistence of air in the chest due to continued leakage, large volumes of air accumulating in a short time (e.g., tension pneumothorax), or accumulation of fluid (blood, chyle, pus) in significant quantities in the pleural space. Good clinical judgment is required in deciding on placement of an indwelling tube. Tubes are not without potentially serious complications, increase client costs and patient discomfort, and mandate continuous observation. Exact guidelines are impossible, but the author usually places a tube immediately if tension pneumothorax develops and as soon as practicable when large volumes of air or fluid are repeatedly removed from the chest over a period of 6–8 hours, or sooner if the patient is clinically affected.

20. What are the indications for performing a tracheotomy in emergent patients with respiratory distress?

The most common indications are emergency management of extrathoracic airway obstruction, hypoventilation due to CNS and neuromuscular diseases, and severe hypoxemia requiring ventilatory support due to underlying pulmonary disease.

21. What are the indications for mechanical ventilation in patients with respiratory distress?

Mechanical ventilation is indicated for patients with ventilatory failure or severe hypoxemia unresponsive to supplemental oxygen administration by face mask, nasal cannula, or oxygen cage. Specific indications in ventilatory failure are (1) apnea, (2) administration of paralyzing agents, and (3) ineffective respiratory efforts with progressive hypercarbia and acidosis (usually defined as a $PaCO_2 > 60$ mmHg and arterial pH < 7.30), regardless of cause. Specific indications for treating hypoxemic patients include (1) presence of an arterial $PO_2 < 50$–60 mmHg on a test of 100% oxygen and (2) inability to maintain a PaO_2 above 50–60 mmHg with a nontoxic level of oxygen supplementation (< 60% O_2).

22. What is the emergency treatment for acute small airway disease (asthma) in cats?

The mainstays of emergency treatment include oxygen administration, corticosteroids (prednisolone sodium succinate, 10–20 mg/kg IV), and bronchodilators (aminophylline, 2–4 mg/kg IM or slowly IV). If these agents fail to resolve the crisis in 5–15 minutes, additional agents may be necessary, including epinephrine (0.5–1.0 ml of 1:10,000 dilution IM or SQ), beta-adrenergic agonists (terbutaline, 1.25-2.5 mg PO), and parasympatholytics (atropine, 0.04 mg/kg SC or IM).

23. What is the alveolar-arterial oxygen difference? How is it useful in managing a patient with respiratory distress?

The difference between the alveolar oxygen concentration (P_A) and arterial oxygen concentration (Pa), known as the A-a gradient, is a calculation that allows the clinician to estimate adequacy of oxygen transfer from the alveolus to pulmonary capillary blood. In the ideal alveolus, all inspired oxygen rapidly diffuses into the capillary blood, with an A-a gradient of 0. In physiologic systems, with normal shunting of some blood, the A-a gradient may be as high as 10 mmHg. In certain pathologic conditions (diffusion impairment, V/Q mismatching, and shunt), the A-a gradient increases, reflecting inadequacy of oxygen transfer. The alveolar component of the equation is calculated by using the alveolar gas equation:

$$P_AO_2 = (\text{barometric pressure} - 47)F_IO_2 - (PaCO_2/0.8),$$

where P_AO_2 is the expected alveolar partial pressure of oxygen, 47 is the vapor pressure of water, F_IO_2 is the inspired oxygen concentration (21% or 0.21 for room air), and 0.8 is the respiratory quotient. Once P_AO_2 is determined, subtract the measured arterial partial pressure of oxygen (PaO_2) from the P_AO_2 to yield the A-a gradient. Example: The patient has a PaO_2 of 50 mmHg breathing room air and a $PaCO_2$ of 50 mmHg; the barometric pressure is 760 mmHg. The estimated alveolar O_2 tension, from the formula above, is 87 mmHg. Subtract the actual PaO_2 (87–50) to give the A-a gradient, in this case 37 mmHg.

A gradient of 0–10 mmHg is considered normal; 10-20 is considered mild impairment of oxygen exchange; 20–30 is considered moderate impairment; and > 30 is considered severe gas exchange abnormality. Clinically, the A-a gradient may be used to assess gas exchange function over time and is thus useful in monitoring patients with certain types of respiratory distress.

When supplemental oxygen is administered, the A-a gradient as calculated above is not accurate. Dividing the measured PaO_2 by the fraction of inspired oxygen yields the $PaO2/F_IO_2$ ratio, which is accurate. Normal values for this ratio are > 200–250 mmHg; patients with severe respiratory failure have values < 200. Example: a patient with a PaO_2 of 50 mmHg breathing 50% oxygen will have a PaO_2/F_IO_2 ratio of 100 (50/.50), indicating severe respiratory failure.

24. What is the adult (or acute) respiratory distress syndrome (ARDS)? Does it occur in dogs and cats?

ARDS is a life-threatening form of respiratory failure due to acute lung injury. Numerous causes are described in people, and despite recent advances, the mortality rate remains high. Recently, a syndrome similar to human ARDS has been reported in dogs. Human diagnostic criteria that were applicable in this study include severe respiratory distress, severe hypoxemia refractory to supplemental oxygen, bilateral alveolar infiltrates on thoracic radiography, decreased lung compliance, and near-normal cardiac function. These findings reflect the severe pulmonary edema and profound pulmonary inflammatory response characteristic of ARDS. Treatment is nonspecific, aimed at correcting the underlying condition and the hypoxemia (which frequently requires mechanical ventilation with positive end-expiratory pressure), fluid and nutritional therapy, and prevention of secondary infection.

25. What are the most common immediately reversible acute respiratory causes of cardiopulmonary arrest (CPA)?

Clinicians should be alert for tension pneumothorax and obstructive asphyxia. These rapidly developing conditions are immediately reversible and carry a grave prognosis if not corrected immediately. Tension pneumothorax typically is seen in trauma patients or mechanically ventilated patients. It is characterized by rapid-onset of hypotension, hypoxia, high airflow resistance (in ventilated patients), subcutaneous emphysema, and reduced lung sounds. Obstructive asphyxia is typically seen after foreign body aspiration, laryngeal paralysis, retropharyngeal abscessation, or cervicofacial trauma.

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4. PATHOPHYSIOLOGY OF CONGESTIVE HEART FAILURE

Wayne E. *Wingfield*, D.V.M., M.S.

1. What is heart failure?

Heart failure in the small animal results from the combined effects of chronic cardiac insufficiency and attempts by the neurohumeral system to compensate. Peripheral venous congestion (i.e., pulmonary edema) results when the left ventricle begins to fail, systemic venous congestion (i.e., ascites, hepatic congestion, and rarely, peripheral edema) occurs when the right ventricle begins to fail, and generalized heart failure results when both right and left ventricles fail.

2. What are the four common mechanisms accounting for heart failure in small animals? List common causes for each.

1. Pressure or volume overload (mitral valvular insufficiency, systemic hypertension)
2. Myocardial failure (dilated cardiomyopathy)
3. Diastolic failure (hypertrophic cardiomyopathy)
4. Cardiac dysrhythmias (atrial fibrillation, ventricular fibrillation)

3. Describe the predominant underlying cause of heart failure for the various cardiac diseases of small animals.

SYSTOLIC HEART FAILURE	DIASTOLIC HEART FAILURE	VALVULAR DISEASES	RHYTHM DISTURBANCES	CARDIOVASCULAR SHUNTS
Dilated cardiomyopathy	Pericardial effusion	Endocardiosis	Bradyarrhythmias	Patent ductus arteriosus
	Hypertrophic cardiomyopathy	Endocarditis	Tachyarrhythmias	Ventricular septal defect
	Restrictive cardiomyopathy	Valvular dysplasia		Atrial septal defect
	Hyperthyroidism	Valvular stenosis		

4. Define the relationship between pressure and flow as they relate to vascular resistance.

The heart generates pressure and flow. Both must be maintained within certain limits to produce viable organ function. Thus the relationship between pressure and flow is defined by vascular resistance.

$$\text{Vascular resistance} = \frac{\text{Pressure}}{\text{Flow}}$$

5. How can I use the relationship between vascular resistance, pressure, and flow in the clinical use of cardiac drugs?

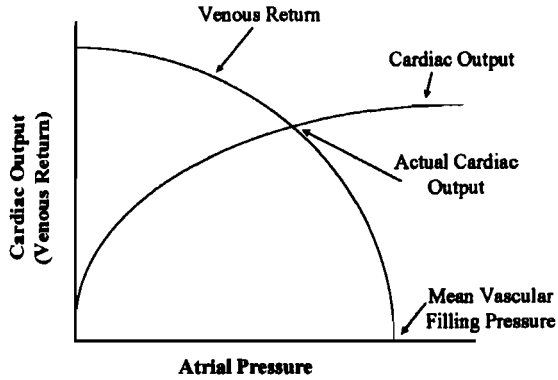
Arterial vasoconstriction improves blood pressure, but it also decreases blood flow and possibly tissue perfusion. Arterial vasodilation decreases blood pressure but improves blood flow and tissue perfusion.

6. What is cardiac output? What are its determinants?

Cardiac output is the total forward blood flow coming from the heart and is the product of stroke volume and heart rate. The three determinants of stroke volume are (1) preload, (2) afterload, and (3) contractility.

7. What is preload?

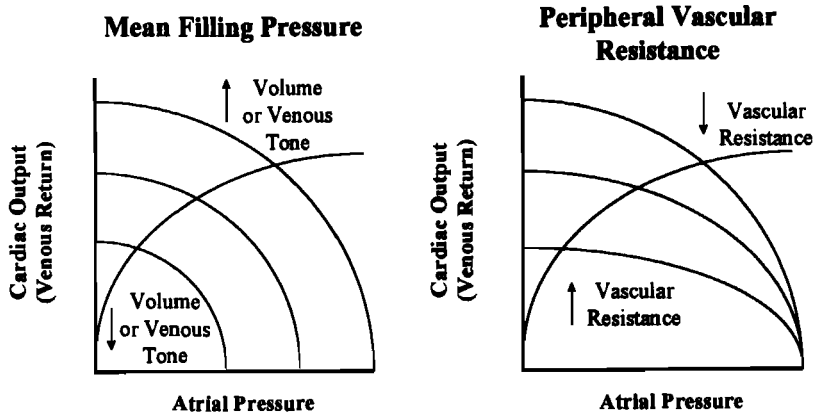
The stretch or load placed on a myocardial fiber before contraction is termed preload. Within limits, preload increases myocardial fiber shortening and stroke volume. Atrial pressure is a clinical measure of the amount of preload. The Frank-Starling (cardiac output) curve describes this relationship.



The actual cardiac output is determined by the intersection of the cardiac output and the venous return curves. Cardiac output changes when either the cardiac output or the venous return (preload) curve begins to shift.

8. What two extracardiac factors affect venous return to the heart? What are the determinants of these two factors?

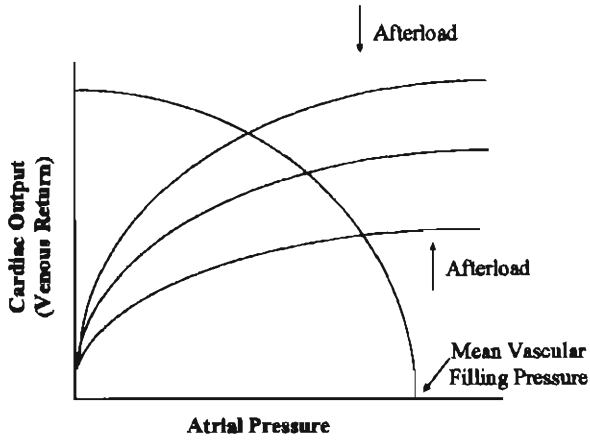
Peripheral vascular resistance, determined by arterial vascular tone and blood viscosity, and mean vascular filling pressure, determined by vascular volume and venous vascular tone.



Changes in preload as a response to changes in venous return.

9. What is afterload?

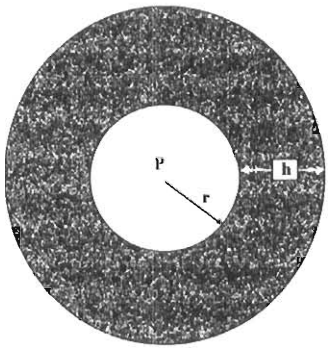
Afterload is the peak load or stress developed in the ventricular wall during systole. The myocardial fibers must develop tension equal and opposite to afterload for myocardial fiber shortening to occur. The total amount of work by the myocardium is related directly to the amount of afterload that it develops and the degree of myocardial fiber shortening or cardiac stroke volume. For any given amount of myocardial work, there is an inverse relationship between afterload and stroke volume. As myocardial afterload increases, stroke volume and cardiac output decrease, and vice versa (see figure at top of next page).



A change in afterload results in a shift of the cardiac output curve.

10. What factors determine cardiac afterload?

The LaPlace relation determines cardiac afterload. This relation predicts that wall stress in a sphere is directly proportional to pressure and radius of the sphere and inversely proportional to wall thickness. Thus, afterload is largely a function of systolic pressure. A decrease in systolic pressure increases cardiac output. In addition, systolic pressure is affected by aortic impedance (i.e., wall stiffness) and peripheral vascular resistance.



$$\text{Systolic Wall Stress (Afterload)} = \frac{\text{Systolic Pressure (P) X Radius (r)}}{\text{Wall Thickness (h)}}$$

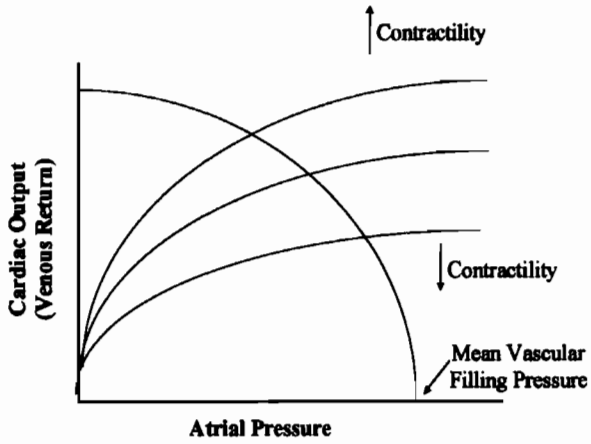
Afterload is equal to ventricular wall stress during systole and is determined by the systolic pressure (P), ventricular radius (r), and wall thickness (h).

11. What is contractility? How is it influenced?

Contractility is the intrinsic property of cardiac muscle that allows it to change myocardial fiber shortening and stroke volume independently of cardiac loading (i.e., afterload and preload). Changes in contractility are reflected in changes in cardiac output. (See figure at top of next page.)

12. How is myocardial contractility modulated?

Sympathetic tone to the heart modulates contractility. This tone is mediated by the β_1 receptors that alter calcium influx during myocardial contraction. Inotropic drugs change myocardial contractility by altering the amount of calcium available for contraction. Cardiac hypertrophy



Changes in contractility shift the cardiac output curve.

also modulates cardiac contractility to a point. Loss of myocardial mass decreases contractility, and myocardial hypertrophy increases contractility.

13. What happens to the Frank-Starling (cardiac output) curve in congestive heart failure?

Pathologic changes in the myocardium result in a downward, rightward shift in the cardiac output curve (low-output heart failure) or downward, leftward changes in the venous return curve (hypovolemic shock) (see figure in question 7).

14. What are the three neurohumeral phases in heart failure?

1. Cardiac injury or insufficiency
2. Activation of neurohumeral responses to injury or insufficiency
3. Neurohumeral overcompensation

15. What happens during cardiac injury or insufficiency?

The injury or insufficiency, which may be either congenital or acquired, primary or secondary, ultimately results in hemodynamic overload on the heart. The two types of hemodynamic overload are (1) pressure overload (stenotic heart valves or systemic hypertension) and (2) volume overload (valvular insufficiencies, patent ductus arteriosus, ventricular septal defects. In most cases this neurohumeral response goes unnoticed clinically.

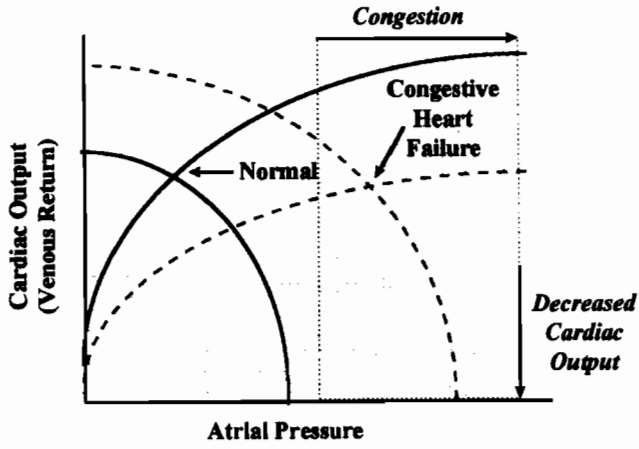
16. How does the body activate the neurohumeral responses to injury or insufficiency? List some of the effects of each.

Many responses are activated in response to myocardial injury or insufficiency:

- Renin-angiotensin (vasoconstriction to increase blood pressure and cardiac output)
- Aldosterone (volume expansion via retention of sodium and thus water)
- Sympathetic nervous system (vasoconstriction, increased heart rate, increased contractility)
- Vasopressin (ADH) (water retention to expand volume)
- Atrial natriuretic peptide (ANP) (vasodilation, decreased venous congestion)
- Myocardial hypertrophy (increased myocardial mass, increased chamber dilation to increase contractility)

17. How does overcompensation adversely affect animals in heart failure?

High venous filling pressures in the atria result in venous pooling in the lungs (left atrium) or peripheral venous system (right atrium). In addition, arterial vasoconstriction impairs tissue perfusion. This state is called congestive heart failure (CHF). (See figure at top of next page.)



Congestive heart failure results from chronic myocardial insufficiency or injury and neurohumeral responses.

18. What strategies are used in treating animals with CHF?

Optimize cardiac performance by manipulating the four determinants of cardiac output:

- Reduce venous congestion (preload).
- Improve cardiac output (preload, afterload, and contractility).
- Normalize heart rate and rhythm (heart rate).
- Slow progression of the disease (preload, afterload, contractility, and heart rate).

19. How is venous congestion reduced?

Venous congestion is reduced by decreasing preload, which decreases atrial pressures and thus pulmonary and/or systemic venous congestion. Decreasing preload also may reduce cardiac output. There are two means to reduce preload: (1) decrease vascular volume (diuretics, salt-restriction) and (2) decrease venous tone (venous or mixed vasodilator drugs). Both strategies result in a leftward shift in venous return curve (see figure in question 8).

20. How can cardiac output be improved?

Cardiac output can be improved by reducing preload, increasing contractility, or decreasing afterload. Preload is reduced as mentioned in question 19. Contractility is increased with positive inotropic drugs, which shift the cardiac output curve upward and leftward (see figure in question 17). Positive inotropic drugs are especially indicated with evidence of systolic dysfunction. Arterial and mixed vasodilator drugs reduce afterload and result in an upward shift of the cardiac output curve.

21. How does one normalize heart rate and rhythm?

One should make every effort to identify the cause of dysrhythmia and treat the cause. Treating the dysrhythmia does not alleviate the cause. Slowing tachyarrhythmias with digitalis or antiarrhythmics may be required in some cases. In addition, third-degree atrioventricular (AV), severe second-degree AV, and sick sinus rhythms may require implantation of a pacemaker.

22. Describe the clinical classification of patients with heart failure.

Of the many schemes to describe the degree of heart failure in animals, the one that has withstood the test of time and experience is the clinical classification of the New York Heart Association, which is taken from human medicine but helps the clinician to decide the severity and therapeutic needs of animals in heart failure. Of interest, most new heart failure schemes relate to the New York Heart Association scheme. The classification is as follows:

Class I	No obvious exercise limitations.
Class II	Slight exercise limitation or coughing with routine physical activity.
Class III	Comfortable at rest but clinical signs develop during minimal physical activity.
Class IV	Clinical signs of heart failure are evident at rest and any exercise is severely limited.

23. How can one slow progression of heart failure?

Neurohumeral responses to CHF drive the progression of failure. To slow progression, one must minimize neurohumeral responses. Little clinical evidence is currently available in animals, but angiotensin-converting enzyme (ACE) inhibitors and beta antagonists, as well as digoxin, improve survival in humans.

24. What are the goals in providing fluid therapy to a patient with congestive heart failure?

The principles governing appropriate fluid therapy begin with determining the cause and severity of the heart failure. One must determine the need either to reduce or to remove accumulated fluid and, at the same time, to reduce sodium and water retention while still supporting adequate tissue perfusion.

25. Which two intravenous fluids are normally administered to animals with congestive heart failure?

- 2.5% dextrose in 0.45% sodium chloride
- 5% dextrose in water (D5W)

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5. SHOCK

Ronald S. Walton, D.V.M.

1. Define shock in small animals.

Shock is a critical imbalance between the delivery of oxygen and nutrients to the cell and utilization of oxygen and nutrients by the cell. Inadequate tissue perfusion and removal of cellular waste products lead to a failure of oxidative metabolism that can involve deficits of oxygen delivery, transport, utilization, or a combination of all three. Shock may be any syndrome, disease state, or injury that results in a critical decrease in effective blood flow. Lack of effective blood flow leads to derangement in cellular metabolism and ultimately cell death. When left unchecked, shock results in global cellular dysfunction, leading to entire organ dysfunction, progressing to multiple organ dysfunction and failure, and culminating with death.

2. What are the immediate concerns for a patient in shock?

The three most important concepts in dealing with shock are summarized in the acronym **VIP**:

V = **V**entilation to ensure a patent airway and maximize oxygenation and oxygen carrying capacity of the blood.

I = **I**nfusion of fluids to restore vascular volume.

P = Maintenance of myocardial **p**umping function to restore cardiac output and blood flow.

3. Name the four pathophysiologic classifications of shock.

1. Hypovolemic
2. Cardiogenic
3. Distributive
4. Traumatic

4. Give an example of each of the four classifications of shock, and note which is most commonly seen in small animals.

Blood volume, vascular resistance, vascular capacitance, and pump function determine the pattern of blood flow. Each of the four pathophysiologic classifications can be related to one or more of these determinants.

Hypovolemic shock is the most common form of shock in small animals. A typical patient has volume loss due to hemorrhage, severe volume loss, third spacing of fluids, or volume loss due to diuresis, as in severe diabetic ketoacidosis.

Cardiogenic shock is a form of shock seen in heart failure characterized by pump failure and high central venous pressures. Pump failure may be related to cardiomyopathy, arrhythmias, and valvular abnormalities. The key features of cardiogenic shock are systemic hypotension, elevated heart rate, increased central venous pressure, increased oxygen extraction, and decreased cardiac output. The pump failure may be related to valvular and/or myocardial incompetence. In some classifications, obstructive forms of shock, such as heartworm disease, pericardial tamponade, and pulmonary thromboembolism, are also classified as cardiogenic shock because of a general failure of forward blood flow.

Distributive shock is a form of vasogenic shock seen with sepsis, anaphylaxis, neurogenic causes, and adverse pharmacologic/toxic reactions.

Traumatic shock is a form of shock associated with extensive tissue trauma. Hypovolemic shock is often a component of traumatic shock. A traumatic insult causes extensive capillary damage with extensive plasma loss in the tissues. Extensive tissue injury also initiates an inflammatory response by the body due to release of endogenous mediators of inflammation. Pain associated with extensive injury can result in inhibition of the vasomotor center and interfere with the normal vasoconstriction response.

5. During the course of the physical examination, how do you determine the classification of shock?

A patient with hypovolemic, cardiogenic, or obstructive shock typically has cool extremities, pallor of the mucous membranes, hypotension, and tachycardia. A patient with distributive shock also may present in this manner during the late stages. Typically, a patient with distributive shock has warm extremities, hyperemic mucous membranes, normotension to hypertension, and tachycardia.

6. What constitutes a minimal database before initiation of therapy in an emergent patient with clinical signs of shock?

Most patients present with some form of hypovolemic shock. Before initiation of fluid therapy, hematocrit (packed-cell volume [PCV]), total solids, blood glucose, blood urea nitrogen (BUN; Azostick), and urine specific gravity (USG) should be considered the minimal database. All of the tests except USG (2 drops of urine) can be performed on the blood remaining in the hub of the catheter as it is placed in the patient (4–5 drops of blood). This small amount of information provides a good idea about patient status at the beginning of therapy. If possible, one should draw a sample large enough to provide adequate evaluation beyond these basic parameters to understand the physiologic status of the animal.

7. Describe the changes seen in measurement of packed-cell volume (hematocrit) immediately after significant acute hemorrhage. What changes occur with time?

PCV immediately after a hemorrhagic episode may appear normal. With time the PCV falls as a result of loss of red cell mass and redistribution of interstitial and intracellular volumes to the vascular space. Once the hemorrhagic episode is stabilized, the final change in PCV can take hours to develop. Early overinterpretation of values can underestimate the severity of the hemorrhagic episode. Classically, the PCV change is 14–36% by the end of 2 hours, 36–50 % by the end of 8 hours, and only 63–77% by the end of 24 hours. Always expect that the actual red-cell mass is lower than measured in an acute hemorrhagic shock patient in the first day or two of therapy.

8. What is the core-to-toe-web temperature gradient? How is it used?

Toe web temperature is typically $\leq 4°C$ less than core temperature. Use of the gradient between core temperature and toe web temperature gives an approximation of peripheral perfusion. As perfusion decreases, toe web temperature decreases and the gradient between core and toe web increases. Similarly, as perfusion improves, the gradient decreases.

Core temperature – toe web temperature = gradient

9. What two parameters are used to evaluate the amount of oxygen available to an animal? Which is the more important? Why?

Partial pressure of oxygen in arterial blood (PaO_2) and arterial oxygen content (CaO_2) are used to evaluate available oxygen. CaO_2 is more important because it represents the total amount of oxygen contained in a sample of blood. Oxygen content represents both oxygen bound to hemoglobin and oxygen dissolved in plasma. The measured amount of oxygen bound to hemoglobin is the primary determinant of oxygen content; oxygen dissolved in plasma plays a very small role. PaO_2 measures only the amount of oxygen dissolved in plasma and does not depend on hemoglobin concentration. Therefore, a severely anemic animal may have a normal PaO_2 but considerable oxygen debt due to low CaO_2.

10. What is the basic premise of oxygen delivery? Why is it so important?

Oxygen delivery is the product of cardiac output, oxygen-carrying capacity of the blood, and arterial saturation. The product of these factors is crucial, and each parameter warrants careful attention. Although we tend to focus our efforts on cardiovascular volume resuscitation to improve output, we cannot forget the critically important role that correction of hemoglobin concentration and oxygen saturation plays in the overall outcome. High-volume resuscitation with non–oxygen-containing fluid temporarily improves oxygen delivery by mechanically enhancing cardiac output. This effort eventually fails as oxygen content continues to decrease.

11. What is central venous pressure? How is it measured?

Central venous pressure (CVP) is the measure of the luminal blood pressure in the intrathoracic jugular vein as it enters the right atrium. The CVP represents a measure of the relative ability of the heart to pump the venous return. Measurement of CVP can be expressed in centimeters of water (cmH_2O) or millimeters of mercury (mmHg). Typically, CVP is measured with a water column manometer in veterinary patients. An imaginary line is drawn from the estimated region of the right atrium and the manometer to serve as the zero reference mark. The difference between the meniscus of the water column and the zero point is the measured CVP (cmH_2O). However, a standard mechanical pressure transducer can be applied to the central venous catheter to measure the CVP directly (mmHg). Most published values in dogs and cats are expressed as cmH_2O. To convert mmHg to cmH_2O, multiply the value by 1.36. *Note:* In cats, caudal vena caval pressures can serve as an accurate indicator of CVP when a jugular catheter cannot be placed.

12. What is normal CVP in dogs and cats?

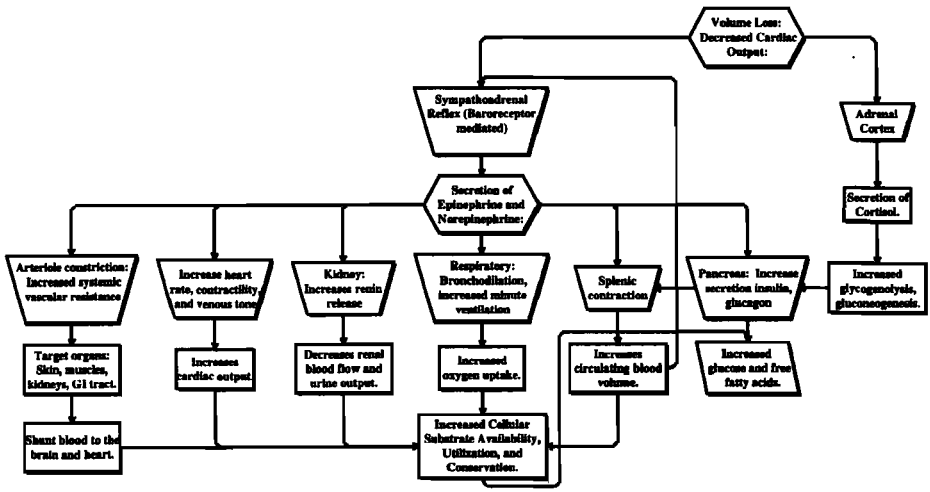
The normal CVP for dogs and cats ranges from 0–10 cmH_2O. Values < 0 cmH_2O indicate relative hypovolemia and values > 10 cmH_2O indicate relative hypervolemia.

13. What are the four determinants of CVP?

Intrathoracic pressure, intravascular volume, right ventricular function, and venous tone.

14. What are the body's initial hemodynamic responses to volume loss?

The loss of effective circulating volume leads to a decrease in arterial systolic, diastolic, and pulse pressure along with an increase in pulse rate and a decrease in cardiac stroke volume, which leads to a decrease in cardiac output. Reflex tachycardia ensues in an attempt to maintain blood pressure. In response to decreasing cardiac output, baroreceptor-mediated initiation of the sympathoadrenal reflex occurs. This reflex initiates the release of norepinephrine, epinephrine, and cortisol from the adrenal gland, leading to increased cardiac output. Increases in contractility, heart rate, and venous tone are responsible for the initial increase in cardiac output. Arteriolar vasoconstriction in skin, muscle, kidney, and gastrointestinal tract allows blood to be shunted centrally to the heart and brain. Decreased renal blood flow secondary to activation of the renin-angiotensin-aldosterone system reduces urinary output and fluid loss and increases retention of sodium and water. The release of antidiuretic hormone and aldosterone also promotes volume conservation. Cortisol and catecholamines promote release, mobilization, and conversion of energy substrates to help meet metabolic demands. The diagram below illustrates these initial steps.



Compensatory responses to volume loss.

15. Blood flow to which organ is the most highly preserved of all organ systems in shock?
The brain.

16. What are the main consequences of the cellular energy deficit in patients with shock?
Lack of oxygen delivery leads to a general failure of energy-dependent functions of the cell. The end result is cell swelling and death. Adenosine triphosphate (ATP) is the primary "currency" of metabolism, and failure to deliver adequate oxygen and nutrients to the cell slows and stops the production of this vital chemical. Life itself depends on continual production and availability of ATP to run the energy-dependent mechanisms of cell function. Normal aerobic metabolism yields the highest amount of energy (ATP) per gram of nutrients, whereas anaerobic metabolism yields the least. Anaerobic metabolism also increases the yield of metabolic waste products, especially pyruvate and lactate. The switch of global energy production from oxygen-dependent (aerobic) to oxygen-independent (anaerobic) metabolism results in only a short-term solution for inadequate energy product. As the shock episode is prolonged, so are the deleterious changes. The energy-dependent sodium-potassium-ATPase pump of the cell membrane evenutally fails, leading to ionic gradient failure and loss of transmembrane potential. As a result of ionic pump failure, intracellular accumulations of ions and water occur. These cells swell in response, leading to cell membrane disruption and cell death.

17. What laboratory parameter can be used to assess tissue perfusion in shock?
Lactate. Mild systemic hypoperfusion has been associated with lactate levels of 3–5 mmol/L; moderate hypoperfusion with values of 5–10 mmol/L and severe hypoperfusion states often demonstrate values greater than 10 mmol/L. Plasma lactate concentration generally falls with adequate volume resuscitation. While not universally available, plasma lactate levels can be a useful guide in directing therapy.

18. What is GI $PiCO_2$?
GI $PiCO_2$ is gastrointestinal intraluminal partial pressure of carbon dioxide. Monitoring involves placement of a tonometry catheter into the lumen of the GI tract (colon, stomach, or small intestine). Measurements of GI $PiCO_2$ reflect the energy status of the GI mucosa. The GI mucosa is at high risk for inadequate perfusion during shock and resuscitation. Measurement of this parameter can help guide adequacy of resuscitation.

19. Define systemic inflammatory response syndrome (SIRS).
The systemic inflammatory response is a generalized inflammatory response to a variety of severe systemic insults. Current defining criteria for SIRS include two or more of the following:

- Temperature > 103.5°F or < 100.0°F
- Heart rate > 160 beats/min (dog) or > 250 beats/min (cat)
- Respiratory rate > 20 breaths/min or $PaCO_2$ < 32 mmHg
- White blood cell count > 12,000 or < 4,000 cells or > 10% nucleated cells/band neutrophils

20. Describe the basic inflammatory components of shock.
Inflammatory changes, which develop during shock, vary greatly. To some degree, however, all forms of shock have an aspect of inflammation. Ischemia and reperfusion are components of every form of shock state, regardless of etiology. In evaluating the ischemia-reperfusion aspect of shock, successful hemodynamic resuscitation initiates proinflammatory mediators, chemotactic cytokines, and activation of leukocytes. Once the animal is reperfused, we seldom recognize an inflammatory response, because rapid hemodynamic correction of hypovolemic and cardiogenic shock episodes results in a minimal inflammatory response. However, prolonged hypoperfusion and significant tissue trauma exhibit profound inflammatory changes during reperfusion. A systemic inflammatory response then results in elevated levels of proinflammatory mediators such as cytokines, eicosanoids, kinins, and complement. These substances activate endothelial cells and leukocytes. Activated endothelial cells and leukocytes can upregulate the expression of cellular adhesion molecules, integrins, and selectins, resulting in adhesion of activated leukocytes to

endothelial cells. Activated endothelial cells also can release nitric oxide, which may induce substantial vasodilatation and exacerbate efforts to improve resuscitation. The activated leukocytes release destructive oxygen free radicals, which cause further damage to tissues and microcirculation. Although the hemodynamic components of shock are readily reversible, the systemic inflammatory components often are not.

21. What is septic shock?

A form of distributive shock secondary to the systemic inflammatory response caused by severe infection. Bacteria or bacterial toxins cause the classic form. Other microorganisms that can initiate septic shock include fungal, protozoal, and viral organisms. The characteristic findings are hypotension and perfusion abnormalities that persist despite adequate fluid therapy. By definition, patients with clinical evidence of infection and signs of shock are in septic shock.

22. When should you suspect septicemia or septic shock?

When patients present with tachycardia, hypotension, hypovolemia, fever or hypothermia, high or low white blood cell count, and signs of multiple organ involvement. In such patients, perfusion and cardiac output often fail to improve despite adequate fluid therapy.

23. What are the classic changes in systemic vascular resistance (SVR) and cardiac output in early septic shock?

In early septic shock (hyperdynamic phase), SVR is decreased and cardiac output is increased. The increase in cardiac output is a compensatory response to the falling SVR.

24. What are the indications for sympathomimetic therapy in the treatment of septic shock?

Sympathomimetic therapy is appropriate when aggressive fluid therapy (high CVP or high pulmonary wedge pressure [PWP]) has failed to restore tissue perfusion, pulse quality, arterial blood pressure, or cardiac output. The goals of therapy are to restore cardiac output and tissue perfusion, to increase oxygen delivery, to maintain systemic blood pressure in vital circulation, and to limit excessive vasoconstriction or vasodilatation.

25. Briefly discuss the sympathomimetic drugs commonly used to treat septic shock.

Dobutamine is the drug of choice. It restores cardiac output and oxygen delivery more reliably than dopamine. Although it is a potent $beta_1$ and $beta_2$ agonist, dobutamine has fewer alpha effects than dopamine. The usual dosage range is 5–15 μg/kg/min.

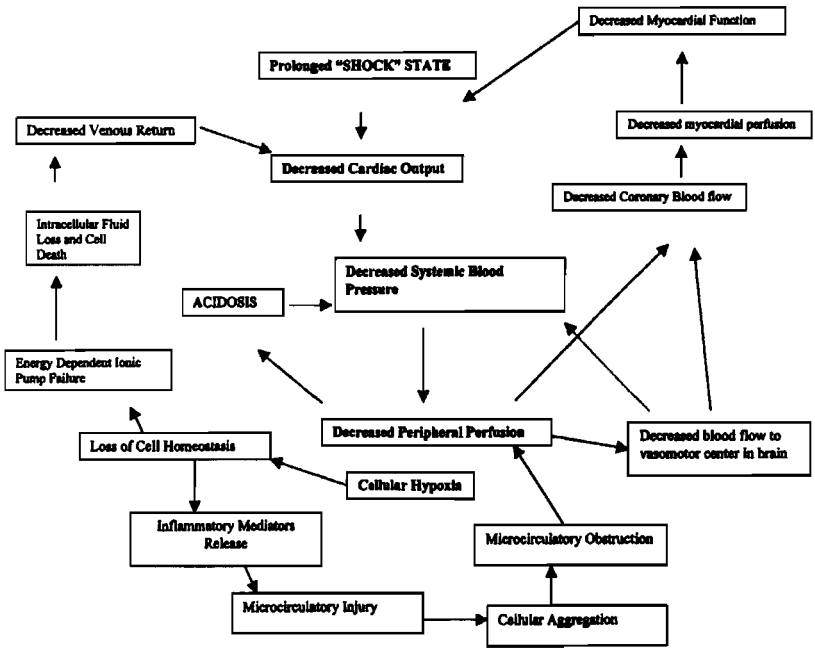
Dopamine is also a potent beta agonist, but in addition it has strong $alpha_1$ and $alpha_2$ effects as well as dopaminergic properties. Constant-rate infusion (CRI) at 1–3 μg/kg/min enhances perfusion to renal and visceral circulation via dopaminergic effects. If dopamine is used for cardiovascular and blood pressure support, the dose is increased to 3–10 μg/kg/min. This and higher doses of dopamine increase cardiac output and blood pressure. However, the renal and visceral perfusion-enhancing properties are often blunted or overridden at higher dosages.

Other sympathomimetic drugs include epinephrine, norepinephrine, phenylephrine, dopexamine, and ephedrine. The first three agents cause profound vasoconstriction and tend to be reserved for the most refractory cases of hypotension. Dopexamine is principally a $beta_2$ and dopaminergic agonist without alpha agonist activity. The usual dosage range is 5–20 μg/kg/min by CRI. Dopexamine increases cardiac output, decreases peripheral vascular resistance, and improves visceral perfusion without the peripheral vasoconstriction effects of dopamine.

26. What is meant by the term "vicious cycle of shock"?

Prolonged shock triggers a cascade of events. Decreased cardiac output leads to decreased blood pressure. As the driving pressure decreases, so do peripheral perfusion and microcirculatory response. Poor venous return leads to decreased filling pressure for the heart. The resultant increase in myocardial work can lead to further failure of myocardial function secondary to decreased coronary perfusion. Prolonged tissue perfusion deficit leads to microcirculatory damage, cellular aggregation, microcirculatory obstruction, and cellular hypoxia. Loss of cellular ionic gradients due to

energy-dependent ionic pump failure and increased intracellular accumulation of ions and fluid cause cell swelling and membrane disruption, which lead to loss of intracellular fluids and ions. An overall metabolic acidosis and accumulation of toxic mediators further destroy the metabolic machinery. Normal compensatory mechanisms fail, resulting in decreased cardiac function and failure to maintain sympathetically induced arterial and venous vasoconstriction. As the metabolic machinery of the cell is destroyed and regulatory mechanisms meant to preserve homeostasis fail, no manner of resuscitation effort can restore the failing system and death results.



Cycle leading to irreversible shock.

27. How can septic shock and cardiogenic shock appear similar?

In the hypodynamic (late) phases of septic shock, cardiac index is decreased and pulmonary capillary resistance is increased. Combined, these factors can markedly decrease cardiac output and increase CVP, appearing quite similar to right heart failure. Patients typically have cool extremities due to decreased perfusion and tachycardia. The prognosis is poor.

28. What are the primary goals of treatment for septic shock?

The primary goals are to maximize tissue oxygen delivery because of the increased oxygen demand. You must improve the hemodynamic status and correct the underlying metabolic abnormalities. Then you must aggressively seek and eliminate the source of infection.

29. What are the primary goals of treating hemorrhagic shock?

Stop continued loss, restore volume, and restore oxygen-carrying capacity.

30. What are the key factors in the treatment of cardiogenic shock?

Reduction of preload and/or afterload, improvement of myocardial contractility, and control of serious arrhythmias.

31. What is neurogenic shock?

Neurogenic shock results from acute loss of sympathetic vascular tone, which leads to arteriolar and venous dilatation. Neurogenic shock may result from spinal cord injury and even excessive

administration of general anesthetics. This form of vasogenic or distributive shock may be refractory to standard fluid therapy. An alpha agonist may be needed to treat refractory hypotension.

32. What is anaphylactic shock?

A type of vasogenic shock characterized by an antigen–antibody reaction that occurs immediately after a sensitized patient is exposed to the antigen. The resulting reaction is a decrease in venous return due to venous dilation, which pools blood in capacitance vessels. Accompanying venous dilation is systemic arterial dilation, which decreases systemic blood pressure. Capillaries become increasingly permeable, and hypovolemia results from the capillary leak of plasma into tissues. Angioedema, laryngeal edema, bronchospasm, and urticaria also may be seen.

33. What type of shock is pericardial tamponade?

Obstructive, pericardial tamponade physically compresses the heart within the pericardial sac. This compression limits the amount of blood that can enter the heart during diastole and subsequently limits the stroke volume, leading to a decrease in cardiac output.

34. What happens to the GI tract in shock? What protective methods can be used?

The GI tract is prone to mucosal ulceration and sloughing during periods of shock when visceral blood flow is reduced. The mechanism of GIT damage is complex and multifactorial, ranging from loss of normal protective barriers and self-destruction due to hydrogen ions, pancreatic proteases, and bile acids to mucosal cell death due to hypoxia. Ultimately, mucosal permeability is increased, and tissue penetration of acid, bacteria, and endotoxin exacerbates the condition. Protective efforts are focused on ensuring or reestablishing adequate visceral perfusion and oxygenation. Monitoring perfusion can be instituted with a GI tonometry catheter (GI-PiCO_2; see question 18). The protective actions of H_2 blockers, proton pump inhibitors, mucosal patching, and mucous stimulatory drugs are controversial, but all can aid in the treatment and amelioration of signs and symptoms. Pharmacologic manipulations alone, however, cannot take the place of adequate restoration of visceral circulation, perfusion, and oxygen delivery.

35. Briefly discuss the development of acute renal failure in shock.

Renal failure is commonly seen in shock patients. Depending on the stage and degree of renal injury, patients may present with any of the following: initial high urine output, low tubule pressure and sodium retention, damage to renal parenchyma, renal dysfunction, fulminant failure, and/or anuria. During shock, glomerular filtration rate falls and renal cortical blood flow is reduced. Renal hypoperfusion leads to ischemic damage, causing tubular necrosis and edema, which often obstructs tubules. Loss of renal tubular function leads to increasing metabolic acidosis, hyperkalemia, and impaired clearance of drugs and other compounds. As the renal perfusion pressure continues to decline, further releases of renin, angiotensin, and aldosterone magnify the problem. Urine output typically is used as an index of adequate renal perfusion. When in doubt, a urinary catheter should be placed to measure urine output. The goal of treatment should be 1–2 ml/kg/hr of urine. Fluid therapy is the hallmark of treatment. If volume therapy alone fails to restore urine output, aggressive efforts with diuretics and dopamine are indicated.

36. What does the term "shock lung" mean?

Because they receive the entire cardiac output, the lungs are involved in the inflammatory components of shock more than any other system. Acute respiratory distress syndrome (ARDS) is the term used to describe lung injury caused by the systemic inflammatory response. Inflammatory mediators and activated leukocytes from throughout the body target the pulmonary vascular endothelium and cause an activation of the pulmonary vascular endothelium. Pulmonary capillaries can then become plugged by leukocytes. Activated leukocytes directly damage the capillary endothelium, exacerbating the inflammatory process. This exacerbation can lead to ventilation–perfusion mismatching, increased shunt fraction, and increased capillary leak.

37. What are the characteristics of an "ideal" resuscitative fluid for patients in shock?

The ideal fluid would be safe, readily available, reasonable in cost, and easy to administer; it would require no special handling, provide volume and vascular retention, and have the capability of oxygen carriage and delivery.

38. What is the fluid of choice for treating patients in shock?

Fluid administration is the cornerstone of effective therapy for patients with noncardiogenic shock. Although the exact fluid may be controversial, depending on the author, the basic principle is the same. Crystalloids (containing sodium) are the initial fluid of choice. They are easy to administer, readily available, inexpensive, and effective. Shock initially should be treated aggressively with fluid containing an adequate amount of sodium because of the relatively high concentration of sodium in extracellular fluid. Readily available and commonly used isotonic solutions include 0.9% sodium chloride, lactated Ringer's solution, Plasmalyte, and Normosol-R.

39. Why may Plasmalyte or Normosol-R have an advantage over Ringer's lactate solution for patients in shock?

Ringer's lactate solution uses lactate as its primary buffer, which depends on active hepatic metabolism for conversion to bicarbonate. In shock patients, hepatic metabolism can be markedly impaired. Normosol-R and Plasmalyte contain acetate and gluconate as their primary buffers. Acetate and gluconate are metabolized primarily by the skeletal muscle to bicarbonate. Although blood cell flow to skeletal muscle is decreased in shock, acetate and gluconate can be converted to bicarbonate easily as circulation is restored. As the circulatory system and peripheral perfusion are reestablished, the liver is presented with an excess of lactate to metabolize (lactic acidosis) and may not be able to do so adequately.

40. What is hypertonic saline? When is it used?

Hypertonic saline is a crystalloid fluid with a supraphysiologic amount of sodium. The typical sodium concentration is 3–7%. A dose of 4–5 ml/kg of 7% hypertonic saline has been shown to be an effective acute volume expander in dogs. It acts by drawing water from the intracellular and interstitial spaces into the vascular compartment. These changes cause a rapid but transient increase in intravascular volume. When combined with a synthetic colloid such as dextran 70, the volume-expanding effects can be prolonged. The contraindications for hypertonic saline are hypernatremia, hyperosmolality, cardiogenic shock, and renal failure. Hypertonic saline is used only for the rapid emergency restoration of volume and must be followed with definitive treatment, because the effects of hypertonic saline are only temporary.

41. What volume of crystalloid fluid is used to resuscitate a shock patient?

The volumes for cats and dogs are different in the published literature. In dogs, shock volumes of fluid are reported at 50–90 ml/kg/hr or up to complete blood volume per hour. In cats, volumes are reported at 40–60 ml/kg/hr or approximately complete plasma volume per hour. The difference between cat and dog resuscitation volume is unclear in the literature. Typically these volumes should be regarded as indicators of volume "to be prepared to deliver" in an hour, but treatment should be titrated to the volume needed by the individual patient. A highly effective method is to deliver shock fluid volumes in one-fourth shock volume increments. One-fourth of the calculated shock volume is delivered every 15 minutes with monitoring of the deviation from the baseline packed cell volume and total protein. Few patients require 90 ml/kg/hr using this method, and volume overload is unlikely.

42. What is a standard volume of infusion for a synthetic colloid solution in patients in shock?

The standard volume of colloid, whether synthetic or natural, is generally 10–20 ml/kg/day. This volume is typically given over 4–6 hours but may be given faster if needed.

Often the infusion of a synthetic colloid in the fluid therapy program allows a reduction in the crystalloid fluid requirement by 40–60%.

43. What is oxyglobin? When is it used in a shock patient?

Oxyglobin is a member of a group of compounds know as hemoglobin-based oxygen carriers (HBOC). The molecule is polymer of bovine hemoglobin that recently was approved for use in dogs in the United States. The HBOCs have evolved from more than 50 years of research into acelluar blood replacement solutions. The oxygen-carrying characteristics of this product are similar to those of blood with several important differences. Oxyglobin binds and releases oxygen more readily than whole blood, requires no typing or cross-matching, requires no special administration set or filter, does not depend on levels of 2,3-diphosphoglycerate to regulate its oxygen-binding site, and is shelf-stable for more than 1 year at room temperature. Oxyglobin has demonstrated its effectiveness in restoring oxygen delivery in anemic dogs or dogs in hemorrhagic shock. Recent research has demonstrated that Oxyglobin administered at low doses improves oxygen delivery to tissues by increasing the transfer of oxygen across the interstitial fluid barrier and by reaching tissues that red blood cells cannot. Label directions must be followed closely. Oxyglobin has significant colloidal osmotic properties and can induce circulatory overload if administered too rapidly or in excess of recommended dosages.

44. What is the rationale behind low-volume resuscitation in hemorrhagic shock?

The rationale is simple: administration of small volumes of fluids during traumatic or hemorrhagic shock reduces the risk of disrupting clotted vasculature and exacerbating hemorrhage until definitive care is available. Although this concept recently has been popularized based on one paper, no currently available data determine how low or for how long a patient can be maintained before irreversible shock will result. The efficacy and safety of this theory are unproved in the clinical setting and warrant further study.

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6. ACUTE GASTRIC DILATATION-VOLVULUS

Wayne E. *Wingfield*, M.S., D.V.M.

1. What characterizes the dog with acute gastric dilatation-volvulus (GDV)?

The dog with acute GDV has varying degrees of malposition of the stomach, rapid accumulation of gas within the stomach, increased intragastric pressure, and shock. Death is common.

2. Is "bloat" the same thing as GDV?

Dog owners frequently refer to GDV as "bloat." The name may be slightly misleading to veterinarians, most of whom consider bloat a problem of ruminants with a frothy, fermentation etiology. Frothy bloat is not seen in dogs or cats.

3. Which animals are more prone to GDV?

Large- and giant-breed dogs, especially purebreds, seem to be at higher risk for GDV. The frequency of GDV appears to range from 2.9–6.8 per 1000 dogs. The most common breeds with GDV include the Great Dane, Weimaraner, Saint Bernard, Gordon setter, Irish setter, and standard poodle. Domestic cats and nonhuman primates also are reported to develop GDV.

4. What is the risk that a large-breed dog will develop GDV during its lifetime?

The likelihood of developing GDV is 21.6 for giant breeds and 24% for large breeds, assuming a normal life span of 8–10 years. The Great Dane has the highest incidence and is at greatest risk for GDV (42.4%).

5. Describe what is known about risk factors for GDV in dogs.

Increasing adult weight of the breed, based on breed standards, is a significant risk factor; that is, body weight (e.g., obesity) is less important than breed weight as a risk factor for GDV. The pattern of risk suggests that body conformation, particularly a narrow and deep thoracic cavity, may influence the risk of GDV for specific breeds. Reduced thoracic width-to-depth ratios, depth of the abdomen, and female sex correlate positively with incidence of GDV. Unfortunately, when these breed conformational characteristics are included in a multiple regression analysis, none is associated with incidence of GDV.

6. What temperament or personality trait is negatively associated with GDV?

Happiness!

7. How is diet related to the cause of GDV?

To date, there is no conclusive evidence that diet causes GDV. No specific diets or feeding practices have been shown to increase the occurrence of GDV in dogs.

8. What causes GDV?

The cause is unknown. Researchers have implicated locally active peptides such as gastrin, gastric myoelectric dysfunction, and abnormal esophageal sphincter function. Certainly a gastric bacterial disease (e.g., *Clostridium perfringens*) does not lead to rapid accumulation of gas.

9. What is the composition of the gas in the stomach of a dog with GDV?

Air collected from the stomach of dogs with GDV is most consistent with room air. The gas is apparently accumulated through aerophagia.

10. What physical examination findings most likely point to the diagnosis of GDV?

- Cranial abdominal distention with tympany.
- Retching with inability to vomit.

- Inability to pass an orogastric (stomach) tube. This criterion is often misinterpreted. Inability to pass a stomach tube suggests a diagnosis of GDV, but if the tube is passed and gas is relieved, GDV is not ruled out. One should consider passing of the orogastric tube more of a therapeutic than a diagnostic procedure.

11. What is the radiographic view of choice for the diagnosis of GDV?

Right lateral recumbency.

12. Which laboratory parameter can give you an idea of what to expect in terms of gastric necrosis and prognosis?

A strong association between plasma lactate concentration and outcome of dogs with GDV is reported. A dog with a plasma lactate concentration < 6 mmol/L is likely to survive, whereas a dog with GDV and a plasma lactate concentration > 6 mmol/L has an almost equal chance of either surviving or dying. A significant number of dogs with elevated plasma lactate concentrations also have gastric necrosis. Trends in serum lactate are more important than a point-in-time lactate.

13. How should you initiate treatment for GDV?

There are two important initial treatments for GDV:

- Decompress the stomach.
- Begin treatment for shock (see chapter 5).

14. Describe how you pass the stomach tube in dogs with GDV.

Do not stress the dog unnecessarily. Use a moderately large, flexible tube (e.g., foal stomach tube). Measure the distance from the tip of the nose to the last rib, and place a piece of tape on the tube to indicate how far to pass the tube. Place the dog in a sternal position, insert a mouth gag (e.g., a full roll of 2-inch tape), lubricate the tube, and slowly and gently pass the tube. You will see the dog swallow the tube, and as the tube is advanced, you can palpate the trachea and the tube as it extends down the esophagus. At the gastroesophageal junction, resistance may be encountered. Do not force the tube into the stomach. Try twisting the tube as you advance it through the junction. If you apply too much force, you may rupture either the esophagus or the stomach. Once the tube is in the stomach, place one end of the tube into a bucket of warm tap water, and gas will be seen escaping. Have an assistant gently press on the cranial abdomen and evacuate as much gas as possible. Attach a stomach pump to the tube, and lavage the stomach until all contents are removed and the effluent is clear. As you prepare to remove the tube, kink the tube. Slowly remove the tube and then the mouth gag.

15. What should you do if you cannot pass the orogastric tube?

Gastric decompression is a mandatory part of GDV treatment. The simplest means to decompress is to trocarize the stomach. Percuss the cranial abdomen until you detect a resonant area, which is generally located on the right lateral abdominal wall. Clip the hair from the area, apply a quick surgical preparation of the skin, and insert a 14–16-gauge, 1- or 1.5-inch needle. Gas should evacuate through the trocar. Most commonly you will now be able to pass the orogastric tube and thoroughly evacuate and then lavage the stomach.

16. If you radiograph the abdomen of a dog with GDV and find evidence of free gas, what are the likely sources ?

If you have performed gastrocentesis, air probably leaked into the abdominal cavity. The other source of gas is a ruptured stomach. Either way, the animal is a surgical patient.

17. Which gastropexy surgical technique should be used?

Numerous gastropexy techniques are described in the veterinary literature, but the two most favored techniques at this time are the belt-loop, modified circumcostal, or circumcostal gastropexy. All have relatively low recurrence rates (< 6.9%). Use of the tube gastrostomy is reported to have a higher morbidity rate associated with premature tube removal, development of

cellulitis around the tube, and alteration of gastric myoelectric activity. The most critical factors in the success rate are probably the surgeon's familiarity with the technique and the ability to perform it proficiently with minimal anesthesia time.

18. Should pyloric surgery be performed to prevent recurrence and to accelerate gastric emptying?

No. Studies in normal dogs have shown that neither pyloroplasty nor pyloromyotomy significantly alters gastric emptying; in fact, both may delay emptying. In addition, there is no evidence, to date, that delayed gastric emptying or pyloric lesions are factors in the disease. These findings strongly suggest that pyloric surgery in GDV is contraindicated, unless gastric outflow obstruction can be demonstrated.

19. What should you do when you find evidence of gastric ischemia or necrosis?

Gastrectomy of nonvital tissue must be performed. The area most frequently involved is on the greater curvature where the short gastric arteries attach to the spleen. The experience of most surgeons suggests that when a gastrectomy is required, the mortality rate is increased, probably because of prolonged shock, anesthesia time, and delay in seeking professional assistance by the dog owner.

20. Does splenectomy prevent recurrence of GDV in dogs?

No. Removal of the spleen does not prevent recurrence of GDV. At the time of surgery, partial or total splenectomy may be indicated in dogs with evidence of splenic infarcts.

21. What are the most common postoperative complications in dogs with GDV?

- Shock
- Pain management
- Surgical complications
- Cardiac dysrhythmias
- Hypokalemia

22. What are the most common cardiac dysrhythmias after GDV surgery?

Premature ventricular contractions and ventricular tachycardia are the most common dysrhythmias. They are often difficult to control unless shock is first resolved. In most cases, lidocaine and procainamide are used to control these dysrhythmias. Occasionally a dog may go into atrial fibrillation postoperatively. In this case, there may be an underlying etiology (e.g., dilated cardiomyopathy). Atrial fibrillation sometimes converts to a sinus rhythm when shock is resolved or through administration of calcium channel blockers, adenosine, or, rarely, quinidine.

23. Outline precautions that the owner should take to reduce future risk of bloat.

- Feed several smaller meals each day rather than one large meal.
- Minimize exercise and excitement before and after feeding.
- Know how to identify the clinical signs of bloat, and have an emergency number for a veterinarian immediately available.
- Owners of high-risk dogs should be encouraged to discuss the pros and cons of prophylactic gastropexy.

CONTROVERSIES

24. Should you radiograph the dog's abdomen before proceeding to surgery?

For: Radiography confirms the diagnosis and possibly suggests other complications that may be encountered in surgery. Gastrocentesis may lead to accumulation of free air within the abdomen and should not be regarded as a ruptured stomach.

Against: Radiography is expensive, time-consuming, and stressful to the dog with GDV. Given certain breed characteristics, risk factors, and positive findings on physical examination, the dog should be taken to surgery.

25. Would you expect the cardiac output and mean arterial pressure to be increased, decreased, or normal in clinical GDV dogs?

Classically, the experimental dog is used to define a dog in shock with hypotension and decreased cardiac output. Recently, measurements of dogs with clinical GDV, taken before surgery, showed cardiac output and mean arterial pressure (MAP) to be slightly lower than, but not statistically different from, normal or anesthetized dogs.

26. Is MAP a useful parameter in monitoring dogs with GDV?

In clinical GDV, upon derotation of the stomach, the cardiac output significantly increases, presumably by restoration of venous return. Systemic vascular resistance decreases at the same time, and MAP does not significantly change. This should remind us that pressure does not necessarily correspond with flow!

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7. ANAPHYLAXIS

Michael S. Lagutchik, D.V.M., M.S.

1. Define systemic anaphylaxis.

Systemic anaphylaxis is an acute, life-threatening reaction resulting from generation and release of endogenous chemical mediators. The effects of these mediators on various organ systems (primarily the cardiovascular and pulmonary systems) cause the clinical signs in emergent patients.

2. Of the three types of anaphylaxis, which is most important in the emergent patient?

Anaphylaxis may occur systemically or locally. The term anaphylaxis commonly is used to describe three separate clinical entities: systemic anaphylaxis, urticaria, and angioedema. Systemic anaphylaxis results from generalized massive release of mast cell mediators and is the most severe form. Urticaria and angioedema are localized variants of immediate hypersensitivity.

3. Briefly describe urticaria and angioedema.

Urticaria is characterized by wheal or "hive" formation involving superficial dermal blood vessels with varying degrees of pruritus. Angioedema involves deeper vessels in the skin with edema formation in the deeper layers of the skin and subcutaneous tissues. Although not common, urticaria and angioedema may progress to systemic anaphylaxis.

4. What basic mechanisms lead to anaphylaxis?

Two general mechanisms result in mast cell and basophil activation and anaphylaxis. Anaphylaxis is most commonly immune-mediated. Less frequently, nonimmune interactions induce anaphylaxis, a syndrome termed *anaphylactoid reaction*. There is essentially no difference in patient management, but recognizing the difference allows more complete understanding of potential causes and aids in more rapid recognition of the condition.

5. What is the pathophysiologic mechanism of immune-mediated (classic) anaphylaxis?

On first exposure to an antigen in susceptible individuals, immunoglobulin E (IgE) is produced and binds to surface receptors of effector cells (mast cells, basophils). On second exposure to the antigen, the subsequent antigen–antibody complex triggers calcium influx into the effector cell with initiation of an intracellular cascade of events that ultimately results in degranulation of preformed chemical mediators and generation of newly formed mediators. These mediators are responsible for the pathophysiologic events in anaphylaxis.

6. How is the mechanism of nonimmune-mediated anaphylaxis different from classic anaphylaxis?

Anaphylactoid reactions are caused by two separate mechanisms. The more common is direct activation of mast cells and basophils by drugs and other chemicals (i.e., idiosyncratic pharmacologic or drug reactions). Further effects are similar to the classic anaphylaxis described above. Prior exposure is not required. Less commonly, activation of the complement cascade results in the generation of anaphylatoxins (C3a, C5a) that cause degranulation of mast cells with release of histamine, enhance smooth muscle contraction, and aid in release of hydrolytic enzymes from polymorphonuclear leukocytes.

7. Describe the primary mediators involved in anaphylaxis, and the major effects of each.

Primary mediators are preformed; they exist in circulation and tissues. Primary mediators include histamine (vasodilatation; increased vascular permeability; and bronchial, gastrointestinal, and coronary artery smooth muscle constriction); heparin (anticoagulation; possibly bronchospasm, urticaria, fever, and anticomplement activity); eosinophil and neutrophil chemotactic

factors (eosinophil and neutrophil chemotaxis); proteolytic enzymes (kinin generation, initiation of disseminated intravascular coagulation; activation of complement cascade); serotonin (vasoactive events); and adenosine (bronchospasm, regulation of mast cell degranulation).

8. What are the secondary mediators of anaphylaxis?

Secondary mediators are generated by eosinophils and neutrophils and other mechanisms after activation by primary mediators. The major secondary mediators are metabolites of arachidonic acid (prostaglandins and leukotrienes) and platelet-activating factor. These mediators include prostaglandins E_2, D_2, and I_2 (prostacyclin); leukotrienes B_4, C_4, D_4, and E_4; thromboxane A_2, and platelet-activating factor. The majority of these mediators induce vasodilatation; increase vascular permeability; potentiate generation of histamine, bradykinin, leukotrienes, and chemotactic factors; cause bronchoconstriction; promote platelet aggregation; stimulate chemotaxis of eosinophils and neutrophils; induce cardiodepression; increase airway mucus production; induce platelet release; and increase release of granules from polymorphonuclear cells. Some, however, (prostaglandin D_2, prostaglandin I_2, and products of eosinophils) function to limit the hypersensitivity response.

9. List the common causes of anaphylaxis in dogs and cats.

Immune-mediated anaphylaxis

Bites of venomous insects and reptiles (bees, spiders, snakes)

Vaccines

Hormones (insulin, vasopressin, corticotropin, betamethasone, triamcinolone)

Antibiotics (penicillin derivatives, chloramphenicol, gentamicin, tetracycline, trimethoprim-sulfonamide combinations, cephalosporins, many others)

Anesthetic agents (acepromazine, ketamine, barbiturates, lidocaine, opiate narcotics, diazepam)

Parasiticides (piperazine, diethylcarbamazine, thiacetarsamide, ivermectin)

Other commonly used drugs (aminophylline, L-asparaginase, dextrans, allergen extracts, amphotericin B)

Blood and blood components

Anaphylactoid reactions

Iodinated radiocontrast agents

Nonsteroidal antiinflammatory drugs (aspirin, ibuprofen)

Opiate narcotics

Mannitol

Dextrans

10. What are the target organs of an anaphylactic response in both cats and dogs?

Major target organs depend on the type of anaphylaxis. Local anaphylaxis (urticaria and angioedema) generally elicits cutaneous and gastrointestinal responses. The most common cutaneous signs are pruritus, edema, erythema, and the typical "wheal and flare" reaction. The most common GI signs are nausea, vomiting, tenesmus, and diarrhea. The major target organs in systemic anaphylaxis are the liver in dogs and the respiratory and gastrointestinal tracts in cats.

11. How do I recognize clinical systemic anaphylaxis in dogs and cats?

The clinical manifestations of systemic anaphylaxis differ significantly in dogs and cats.

In **dogs**, the earliest signs of anaphylaxis are often initial excitement, with vomiting, defecation, and urination frequently reported. With progression, respiratory depression or distress and collapse related to muscle weakness and cardiovascular collapse develop. Death may occur rapidly (i.e., within 1 hour). As the liver is the major target organ in dogs, severe hepatic congestion with portal hypertension is a common finding on necropsy. There is seldom time to evaluate the liver appropriately before death for these findings to be helpful.

In **cats**, the earliest reported sign of anaphylaxis is severe pruritus, especially of the face and head. As bronchoconstriction and pulmonary edema are the typical sequelae in cats, severe respiratory distress is the most common sign. Other signs include laryngeal edema and upper airway

obstruction, profuse salivation, vomiting and incoordination. Ultimately, severe respiratory and cardiac involvement leads to collapse and death.

12. If I don't recognize early anaphylaxis or it has advanced before the patient reaches me, what may happen?

Anaphylactic shock is the terminal phase of anaphylaxis, due to a combination of vasculogenic, neurogenic, and endotoxic changes involving multiple organ systems. The most severe changes involve the cardiovascular and pulmonary systems. Primary and secondary mediators induce microcirculatory vascular changes that lead to peripheral pooling of 60–80% of the blood volume. Also critical in anaphylaxis is increased vascular permeability with leakage of intravascular volume. Mediators also cause hypovolemia, dysrhythmias, depressed myocardial contractility, and pulmonary hypotension, which eventually lead to tissue hypoxia, metabolic acidosis, and cell death. Clinical signs of anaphylactic shock are not pathognomonic; they resemble signs from any cause of severe cardiopulmonary collapse.

13. How soon does anaphylaxis develop?

Anaphylaxis usually occurs almost immediately after or within a few minutes of exposure to the inducing agent. However, it may be delayed for several hours. In people, anaphylaxis is reported to reach peak severity in 5–30 minutes.

14. How do you diagnose systemic anaphylaxis?

Diagnosis is based on history, physical exam, and clinical signs. Maintaining a high index of suspicion is essential for rapid identification and initiation of treatment. The key tip off is rapid progression of clinical signs related to the target organ system in each species, usually with a history of recent exposure to a known inducer of anaphylaxis.

15. If immediate recognition and treatment are the hallmarks of successful management of anaphylaxis, what other differential diagnoses must be ruled out quickly?

Conditions that must be ruled out rapidly in patients presenting with severe signs consistent with systemic anaphylaxis include acute pulmonary events (asthma attack, pulmonary edema, pulmonary embolus, spontaneous pneumothorax, foreign body aspiration, and laryngeal paralysis) and acute cardiac events (supraventricular and ventricular tachyarrhythmias, septic and cardiogenic shock).

16. What is the initial treatment for systemic anaphylaxis?

Immediate therapy includes establishment of a patent airway and vascular access, aggressive fluid therapy, and administration of epinephrine. Depending on severity, airway management may require nothing more than providing supplemental oxygen or may require orotracheal intubation or tracheostomy. Mechanical ventilation may be required in severely affected patients with compromised (edematous) airways, pulmonary edema, and bronchoconstriction. Vascular access, preferably central venous, is critical for administration of fluid therapy and drugs. Aggressive fluid therapy should be based on the extent of shock, but the clinician should be prepared to administer shock doses of isotonic crystalloid solutions and possibly colloids.

17. Why is epinephrine considered the drug of choice in treating systemic anaphylaxis?

Epinephrine is the cornerstone of therapy for anaphylaxis because it relieves bronchoconstriction, supports arterial blood pressure, inhibits further mast cell degranulation, improves cardiac contractility and heart rate, and improves coronary artery blood flow.

18. What is the recommended dose and route of administration of epinephrine in anaphylactic shock?

The recommended dose is 0.01–0.02 mg/kg given intravenously. This is equivalent to 0.01– 0.02 ml/kg of 1:1,000 epinephrine hydrochloride. If vascular access is not available, this dose can be doubled and given intratracheally. In severe cases with refractory hypotension and

bronchoconstriction, the dose can be repeated every 5–10 minutes, or a constant-rate infusion can be established at a rate of 1–4 mg/kg/min.

19. What are adjunct therapies for management of systemic anaphylaxis?

Adjunctive therapy for anaphylaxis includes use of antihistamines, glucocorticoids, and additional supportive measures, as needed, for hypotension, pulmonary edema, bronchoconstriction, and arrhythmias. Although antihistamines and glucocorticoids are too slow to be helpful in the initial management, they play an important role in preventing late-phase reactions and complications caused by secondary mediators. Diphenhydramine (5–50 mg/kg slowly IV or intramuscularly twice daily) is the most commonly used antihistamine. Some authors recommend concurrent use of H_2 antagonists (e.g., cimetidine, 5–10 mg/kg orally 3 times/day). Dexamethasone sodium phosphate (1–4 mg/kg IV) and prednisolone sodium succinate (10–25 mg/kg IV) are the most commonly used glucocorticoids. Dopamine (2–10 mg/kg/min) may be needed for cardiac or pressor support. Aminophylline (5–10 mg/kg IM or slowly IV) is recommended in patients with persistent bronchoconstriction.

20. If the initial treatment for systemic anaphylaxis is successful, is the patient "out of the woods"?

By no means is it safe to discharge patients with systemic anaphylaxis. Late-phase reactions are common in patients recovering from the immediate effects of systemic anaphylaxis. These late-developing events are induced by secondary mediators, and may occur 6–12 hours after the initial attack. Meticulous attention to patient monitoring, aggressive treatment for shock and pulmonary complications, and use of antihistamines and glucocorticoids are usually recommended to prevent this potentially fatal complication. It is advised to hospitalize the patient for at least 24 hours and to monitor aggressively for signs of impending complications.

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8. HYPOTHERMIA

Ronald S. *Walton*, D.V.M., M.S.

1. Define hypothermia in small animals.

Hypothermia is defined as a subnormal body temperature in a homoeothermic animal. The normal body temperature should be > 99.5°F (37.5°C) for dogs and 100.0°F (37.8°C) for cats.

2. How is the severity of hypothermia graded?

- Mild: 90–99°F (32.3–37.2°C)
- Moderate: 82–90°F (27.8–37.5°C)
- Severe: core temperature < 82°F (27.8°C).

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3. Name the four primary mechanisms by which heat is lost from the body.

- Convection
- Conduction
- Radiation
- Evaporation

4. Of the four primary mechanisms for heat loss, which is most common in small animals?

Radiation accounts for the majority of heat loss under normal conditions. Radiation is the exchange of heat between objects in the environment that are not in direct contact with the skin. Relative temperature determines the direction of heat transfer.

5. How is body temperature maintained in normal dogs and cats?

Body temperature is regulated by the central nervous system, more specifically the hypothalamus. Decreasing body temperature causes behavioral and physiologic responses in dogs and cats. The common behavioral responses are heat-seeking and minimizing body surface area by curling up. Physiologic responses to decreasing body temperature start with piloerection and peripheral vasoconstriction. These responses attempt to conserve body heat by shifting blood flow centrally. Shivering thermogenesis and increased metabolic rate are the next efforts to increase temperature. When these methods fail, heat is lost and core body temperature falls.

6. How can thermoregulation be impaired?

The thermoregulatory system can be impaired by four primary mechanisms: metabolic, peripheral, local, and pharmacologic. Altered plasma osmolality combined with metabolic derangement such as diabetic ketoacidosis and uremia may lead to centrally mediated hypothermia. Hypothalamic function can be affected by various CNS processes (traumatic, degenerative, neoplastic, and congenital) and induce a hypothermic state. Pharmacologic agents (e.g., phenothiazines and barbiturates) can induce hypothermia by impairment of central thermoregulation.

7. Define core body temperature. How is it measured?

Core body temperature is a measure of central body temperature unaffected by the vasoconstrictor effect of peripheral vasculature. Core body temperature can be measured rectally, esophageally, tympanically, or from a central intravenous catheter equipped with a thermistor. Rectal temperature may be falsely low if the thermometer is in cold feces.

8. What factors predispose an animal to hypothermia?

Factors that decrease heat production or increase heat loss predispose to hypothermia. Factors involved in decreased heat production include age (neonates), trauma, immobility, cachexia, anesthesia, cardiac disease, impaired central thermoregulation, endocrine disorders (hypothyroidism, hypoadrenocorticism, hypoglycemia, and hypopituitarism), and neuromuscular disorders. Factors that predispose to increased heat loss are trauma, burn injury, immobility, environmental exposure, cold water immersion or wetting anesthesia, surgery, contact with cold surfaces, and exposure to chemical agents/toxicosis (e.g., barbiturates, alcohol, phenothiazines, ethylene glycol).

9. What is the primary cause of dehydration in hypothermic animals?

Cold diuresis.

10. What is cold diuresis?

Hypothermia causes an initial central hypervolemia due to peripheral vasoconstriction. Tubular sensitivity to antidiuretic hormone is reduced and tubular reabsorption of sodium and glucose are impaired. The tubular fluid is essentially glomerular filtrate, which does not adequately clear nitrogenous waste products. Diuresis is promoted through increased excretion of sodium, glucose and water. Cold diuresis can rapidly dehydrate hypothermic patients. This phenomenon can be seen with only a 2–3°C drop in core body temperature.

11. What clinical findings are commonly seen in hypothermic patients?

The hypothermic patient may present with various clinical signs, depending on the degree and length of exposure. Common clinical signs include obtundation, weak-to-absent pulse, slow or undetectable heart rate, muscle stiffness, and shallow and infrequent respiration. Bowel sounds may be decreased or absent. Shivering may be observed in mild cases but is absent at body temperatures < 31°C. Normal cerebral functions are impaired at < 32°C. Cardiac arrhythmias are seen at < 30°C. Peripheral reflexes are lost at < 27°C. At body temperatures < 26°C dogs have absent pupillary light reflexes and loss of consciousness.

12. What are the three key reflex responses used to conserve body heat?

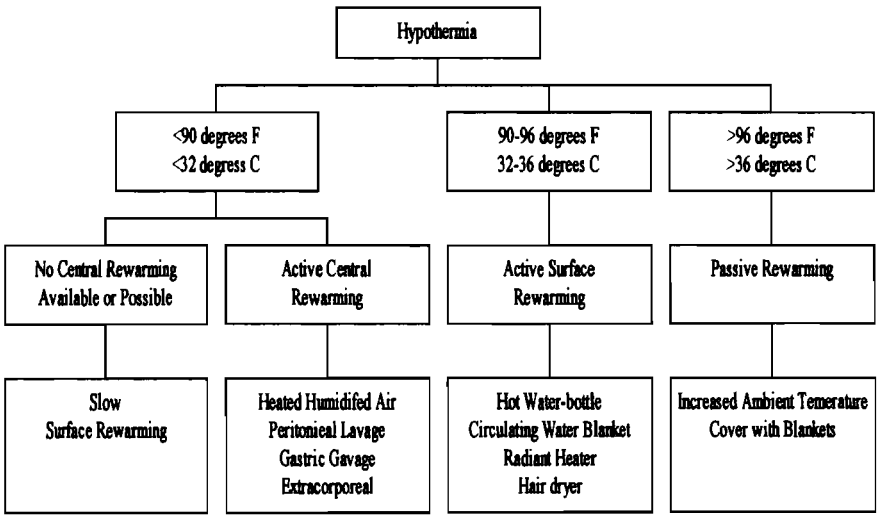
Piloerection, vasoconstriction, and shivering.

13. What happens to mentation as hypothermia progresses?

Gradually, cerebral blood flow is reduced and at temperatures approximately 2–5°C below normal patients can become agitated, uncooperative, uncoordinated, somnolent, stuporous, and eventually comatose as the temperature drops below 30°C.

14. What is the key decision in how to rewarm a patient?

The primary decision is whether to rewarm the patient passively or actively. Passive rewarming is noninvasive and involves simply covering the patient in a warm environment. Active rewarming often requires specialized equipment or facilities. The flow chart below provides a guideline to rewarming options in small animals.



Management of hypothermia. (Adapted from Haskins SC: Thermoregulation, hypothermia, hyperthermia. In Ettinger SJ, Feldman EC (eds): Textbook of Small Animal Medicine. Philadelphia, W.B. Saunders, 1995, p 28.)

15. Discuss active rewarming and guidelines for its use.

Active rewarming delivers heat directly to the core of the body. The current options for active rewarming include extracorporeal rewarming, heated intravenous fluids, warm peritoneal lavage, and warm gastrointestinal irrigation. Active rewarming becomes necessary when cardiovascular instability is present or the core body temperature is below 92°F (33.3°C).

16. Discuss passive rewarming and guidelines for its use.

Passive rewarming is suitable for mild cases of hypothermia in a previously healthy patient. Passive rewarming consists simply of increasing the ambient temperature and covering the patient with a blanket.

17. What common clinical pathologic changes are associated with hypothermia?

Glucose. Hyperglycemia is seen early because of increased cortisol release and increased sympathetic activity. When hypothermia persists, hyperglycemia is due to insulin resistance, which occurs at temperatures < 30°C. Prolonged hypothermia results in hypoglycemia due to impaired gluconeogenesis and hepatic glycogen depletion.

Electrolyte abnormalities. Electrolyte changes are unpredictable and vary from patient to patient. Prolonged hypothermia tends to lead to hyponatremia and hyperkalemia, probably because of decreased function in the cell membrane sodium–potassium–adenosine triphosphatase pump. If this is the case, total body levels of sodium and potassium are close to normal.

Acid–base status. Decreased tissue perfusion and increased use of muscle tissue during shivering leads to accumulation of lactic acid and subsequent metabolic acidosis. Hepatic metabolism of lactate also is decreased. In mild cases of hypothermia, the patient may exhibit a mixed metabolic acidosis and respiratory alkalosis. If hypothermia persists, consciousness is depressed and results in reduction of respiratory rate, which may lead to development of respiratory acidosis.

Coagulation abnormalities. The effects of hypothermia on blood coagulation are complex. Experimentally, hypothermia has produced variable alterations in functional clotting factors in dogs. Hypothermia has been shown to prolong both activated partial thromboplastin time (APTT) and prothrombin time (PT) in humans. Hypothermia also causes reversible platelet dysfunction. Severe hypothermia may even lead to development of disseminated intravascular coagulation (DIC). DIC usually occurs secondary to rewarming with increased fibrinolytic activity, vascular endothelium damage, and decreased factor and platelet function.

18. What is the reason for observed thrombocytopenia in hypothermic patients?

Platelets are sequestered in the liver and spleen.

19. How could a hypothermic patient have a markedly abnormal bleeding time and clinical evidence of coagulopathy but normal APTT and PT tests?

The PT and APTT function via a temperature dependent enzyme system. The clotting prolongation is proportional to the number of steps in the cascade. The laboratory analysis is conducted at 37°C. Once the blood is warmed to 37°C, the APTT and PT may be within the normal range. Bleeding times are prolonged due to induced thrombocytopenia and depressed platelet function. The only effective treatment is rewarming—not administration of clotting factors.

20. What electrocardiographic abnormalities are commonly associated with hypothermia?

Early in the course of hypothermia, atrial arrhythmias are common. Ventricular arrhythmias occur in cases of prolonged hypothermia. Common ventricular arrhythmias are premature ventricular contractions (PVCs) and ventricular tachycardia. In severe cases of hypothermia, when core temperature drops below 28°C, ventricular fibrillation is common. Ventricular fibrillation secondary to hypothermia is often refractory to electrical defibrillation.

21. What common complications are seen during and after active rewarming?

When a moderately-to-severely hypothermic patient is rewarmed actively, many systemic complications are possible. The patient should be closely monitored for the following:

1. **Temperature afterdrop.** The core temperature continues to drop after the patient is removed from the cold environment, possibly because of the return of cold peripheral blood to the heart and continued conductance of heat from the warmer core region to the cooler peripheral tissue.

2. **Rewarming shock.** Many factors are involved in this phenomenon. Metabolic factors include lactic acidosis due to decreased perfusion. Electrolyte abnormalities (hyponatremia and hyperkalemia) due to cold diuresis may be a feature of reperfusion injury. Coagulation abnormalities range from prolongation of clotting times to DIC. Cardiac dysrhythmias such as PVCs and ventricular fibrillation are seen in severe cases. Pulmonary complications, such as pneumonia secondary to increased viscosity of pulmonary secretions and capillary leakage, are common. Other systemic derangements include increased intracranial pressure due to cerebral edema, pancreatitis, rhabdomyolysis, and acute renal tubular necrosis. Sepsis may result from bacterial translocation

across ischemia-damaged barriers such as skin and gastrointestinal tract. Combined with decreases in phagocytic and migratory function of polymorphonuclear cells is a marked decrease in clearing of translocated organisms.

22. How is the efficacy of drugs affected by hypothermia?

Most drug efficacy is temperature-dependent. Protein binding increases with hypothermia, and hepatic and renal metabolism decrease. Increased dosages may be required to achieve normal response. As rewarming occurs, these increased dosages may initiate signs of toxicity.

23. How should parenteral medications be given in a hypothermic patient?

Parenteral medications should be given only intravenously. Medications given intramuscularly or subcutaneously have poor absorption due to peripheral vasoconstriction, and oral medications are poorly absorbed because of hypomotility of the gastrointestinal tract.

24. Is hypothermia protective in traumatized patients?

When it is induced prior to shock, hypothermia has the protective effect of reducing the use of adenosine triphosphate (ATP) while the body's stores of ATP are still normal. Traumatically injured patients have depleted their ATP stores before hypothermia occurs.

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9. HEAT STROKE

Tim Hackett, D.V.M., M.S.

1. What is heat stroke?

Heat stroke is a severe elevation in body temperature (104.9–109.4°F [40.5–43.0°C]) occurring after exposure to elevated ambient temperatures. Heat stroke is caused most commonly when animals are confined in overheated automobiles or kept outdoors on hot, often humid, sunny days without adequate shelter. Exertional heatstroke may occur when animals are exercised in hot, humid weather or have an impaired ability to dissipate heat.

2. How is normal temperature maintained?

Thermal homeostasis is a balance between heat-gaining and heat-dissipating mechanisms controlled by the thermoregulatory center in the hypothalamus. Heat gain is a function

across ischemia-damaged barriers such as skin and gastrointestinal tract. Combined with decreases in phagocytic and migratory function of polymorphonuclear cells is a marked decrease in clearing of translocated organisms.

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2. How is normal temperature maintained?

Thermal homeostasis is a balance between heat-gaining and heat-dissipating mechanisms controlled by the thermoregulatory center in the hypothalamus. Heat gain is a function

of environmental temperature and metabolic heat. Heat is lost through behavioral mechanisms, changes in circulation, evaporative cooling, and radiation. With increasing body temperature, radiation and convection from the skin are facilitated by peripheral vasodilatation and increased cutaneous circulation. Animals seek shelter and assume body postures to maximize radiant and conductive heat loss. Lacking significant sweat production for evaporative cooling, dogs and cats rely heavily on panting for heat loss. Panting increases dead space ventilation and thus evaporative heat loss in the upper respiratory passages without changing alveolar ventilation.

3. What factors are associated with increased risk of heat stroke?

Various conditions can impair the animal's ability to dissipate heat. Humid conditions or upper airway obstruction reduce normal respiratory evaporative heat loss. Animals with brachycephalic conformation, laryngeal paralysis, tracheal collapse, or mass lesions obstructing airflow may not be able to dissipate heat. Conditions causing hypovolemia or decreased cardiac output decrease cutaneous circulation and convective heat loss from the skin. Because of the insulating effects of body fat, obesity impairs convection and decreases heat loss.

4. What differential diagnoses should be considered in an animal with a temperature above 40.5°C?

In most cases, clinical signs and a history of confinement, forced exercise, and extreme temperatures or humidity are sufficient to diagnose heat stroke. Inflammatory diseases such as meningitis and encephalitis may cause extreme hyperthermia. Mass lesions involving the hypothalamus and thermoregulatory center also should be considered. Malignant hyperthermia is uncommon in dogs but may be associated with exposure to inhalation anesthetics such as halothane. Unwitnessed seizure activity and muscle tremors associated with poisons such as strychnine or metaldehyde also may cause severe hyperthermia.

5. What are the presenting clinical signs of heat stroke?

Owners report excessive panting, collapse, vomiting, ataxia, hypersalivation, diarrhea and seizures. Initial physical exam findings include tachypnea, tachycardia, hyperdynamic arterial pulses, and hyperemic, dry mucous membranes. These findings correspond with increased cardiac output as blood is shunted to the periphery in an attempt to increase convective heat loss. Rectal temperatures are usually between 40.5–43.0°C (104.9–109.4°F). Later, as heat stroke worsens, signs include profound CNS depression and circulatory shock. A weak pulse, gray mucous membranes, vomiting, and diarrhea signal impending organ failure. Marked respiratory effort may lead to shallow respirations, seizures, coma, and death.

6. What laboratory abnormalities are expected in patients with heat stroke?

Animals suffering from heat stroke often experience hypotonic fluid loss leading to hypovolemic hypernatremia. Biochemical profiles may reflect major organ damage. Elevated levels of blood urea nitrogen (BUN) and creatinine are seen with acute renal tubular necrosis. Hepatic injury causes elevations in aspartate transaminase (AST), alanine transaminase (ALT), and serum bilirubin. Thermal injury to muscles may cause rhabdomyolysis with marked increase in serum creatinine phosphokinase (CK) and AST. Blood glucose is often very low and may require supplementation.

Packed cell volume and total solids are often elevated because of dehydration. Thrombocytopenia, increased fibrin degradation products (FDs), and prolonged prothrombin (PT) and partial thromboplastin times (PPT) indicate disseminated intravascular coagulation (DIC).

Blood gas analysis is variable. Early in heat stress, animals may pant without affecting alveolar ventilation. As heat stress progresses to heat stroke, respiratory effort may become more forceful and respiratory alkalosis may develop. As the hyperdynamic phase of heat stroke progresses to vasomotor collapse, metabolic acidosis results from increased lactic acid production and corresponding elevation in blood lactate.

The presence of renal casts or glucosuria in the face of normal-to-low serum glucose may suggest significant tubular damage. Myoglobinuria suggests rhabdomyolysis and exacerbates acute tubular necrosis.

7. Do any laboratory or physical exam findings suggest a poor prognosis?

In a review of 42 cases of heat-induced illness in dogs, serum cholesterol, albumin, and total protein were significantly lower in nonsurvivors compared with survivors. Serum total bilirubin, creatinine, and the frequency of ventricular arrhythmias also were higher in nonsurvivors.

8. What is the most important initial therapy in stabilizing a heat stroke patient?

Lowering the core body temperature. The animal should be taken out of the heat and moved into the shade or indoors to a cool area. Soaking the coat with cool water and providing a fan maximizes evaporative cooling. Placing cool compresses near the axillary and femoral vessels also helps. It is absolutely imperative that first responders not overcool the animal. Cooling attempts should be discontinued when the core temperature reaches 39.5°C (103°F). The goal is to decrease the core temperature to 39°C (102°F) in 30–60 minutes.

9. Can a patient be cooled too rapidly?

Yes! Cold water immersion, topical alcohol, or other aggressive methods of cooling should be used with extreme caution. Normal thermoregulatory mechanisms are often deranged, and as the animal cools, normal heating mechanisms are impaired. Severe hypothermia can follow if the temperature is not monitored closely. If the temperature falls below normal, the animal should be wrapped in dry linens and monitored closely.

10. Discuss other ways to lower body temperature.

Massaging the animal helps to increase peripheral blood flow, vasodilation, and cooling. Chilled intravenous fluids, iced gastric lavage, and cold water enemas have been described as ways to lower core body temperature without causing peripheral vasoconstriction. One study concluded that cold peritoneal lavage was more effective at lowering body temperature than evaporative cooling techniques. Another study demonstrated that evaporative cooling was more effective than iced gastric lavage. Peritoneal and gastric lavage are more difficult to perform in conscious animals than evaporative cooling and should be reserved for cases when core temperature does not respond to less invasive cooling techniques.

11. Why stop cooling the animal when the temperature reaches 39.5°C (103°F)?

When the body temperature drops below 39°C (102°F), the animal may begin to shiver, thus producing more heat. Rapid external cooling also may cause peripheral vasoconstriction, making convective heat loss less efficient. Cerebral edema and thermal damage to the hypothalamus make it difficult to maintain thermal homeostasis. Continuous monitoring of core temperature is imperative to guide therapy and to prevent iatrogenic hypothermia.

12. Should a rapid infusion of intravenous fluids be started immediately?

Early in heat stress and heat stroke actual fluid deficits may be relatively minor. With increased cardiac output and peripheral vasodilation, additional fluids may lead to fluid overload and pulmonary or cerebral edema. Hypotension may improve with cooling alone, because peripheral vasoconstriction increases circulating blood volume. Because of the wide range of potential presentations and complications, fluid needs should be assessed individually. Factors such as overall hydration, central venous pressure, electrolyte balance, and urine output should be assessed.

13. How about the use of antiinflammatory drugs? Corticosteroids?

No. Heat stroke is a form of nonpyrogenic hyperthermia; as such, the hypothalamic temperature set point is normal. The use of antipyretics such as dipyrone, aspirin, and flunixin

meglumine is contraindicated. These drugs act on the hypothalamic set point and may contribute to iatrogenic hypothermia. They also may worsen gastrointestinal ulceration and ischemic damage to the kidneys.

Corticosteroid use is unproven, although its use for specific complications such as cerebral edema may be warranted.

14. What complications should be anticipated in animals with heat stroke?

Core temperatures at or above 43°C (109°F) may result in irreparable organ damage. Oxidative phosphorylation is uncoupled, cellular membrane function is impaired, and enzymes are denatured. Kidney damage is common because of direct thermal injury to the renal tubular epithelium, decreased renal flow, and hypotension and thrombosis associated with DIC. Clinically, BUN and creatinine levels are increased, and renal tubular casts are seen in the urine. Oliguria and anuria may develop.

Hypotension and thermal injury also affect the gastrointestinal tract, causing gastric and intestinal ulceration. Disruption of the normal mucosal barrier may lead to bacteremia and sepsis. Liver damage, as evidenced by increased levels of AST, ALT and serum bilirubin, may result from thermal injury or prolonged splanchnic hypotension.

Disseminated intravascular coagulation is a common complication of heat stroke. Endothelial cell damage occurs causing elevated endothelin, circulating intercellular adhesion molecule-1, and von Willebrand factor-antigen. Heat can also cause widespread cell necrosis leading to inactivation and consumption of platelets and coagulation factors. Thrombocytopenia, increased fibrin degradation products, and prolonged prothrombin and partial thromboplastin times also are seen.

Nerve tissue is susceptible to thermal injury. With direct effects of the heat on endothelium, thermal injury may cause brain hemorrhage and edema as well as thrombosis and infarction of cerebral tissue. Prolonged exposure to high temperatures leads to neuron death and permanent brain damage.

15. How long after successful cooling can the above complications be a problem?

Clinical signs related to the above complications may develop 3–5 days after apparent recovery. Changes in mental status, oliguria, vomiting, bloody diarrhea, icterus, dyspnea, and petechiation should alert the clinician to the possibility of significant complications. Continuous monitoring well past resolution of the hyperthermia is mandatory.

16. How should complications be managed?

Acute renal failure should be aggressively treated with intravenous fluids to restore hydration and to improve glomerular filtration rate. Central venous pressure and urine output should be followed regularly in all patients with heat stroke. If oliguric renal failure is present, intravenous furosemide and a constant-rate infusion of dopamine may be given to improve urine output.

Patients with signs of liver failure or gastrointestinal damage should receive supportive care to maintain fluid and electrolyte balance. Because of the risk of bacterial translocation across damaged tissues, broad-spectrum, nonnephrotoxic antibiotics should be started.

Fresh frozen plasma should be used to replace clotting factors in patients with DIC. Subcutaneous injections of heparin may be indicated to prevent microvascular thrombosis associated with DIC.

Seizures are initially treated with intravenous diazepam. Coma or other signs of cerebral edema may be managed with intravenous dexamethasone.

17. Discuss ways to prevent heat stroke.

Heat stroke is most likely to occur when animals are confined in a hot environment. Owners should be educated about the risks of keeping animals in cars or under the sun without adequate shade or water. Animals with preexisting airway problems or obesity should be exercised carefully, preferably not during the hottest times of the day. When possible, underlying problems such as laryngeal paralysis and obesity should be corrected.

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II. Trauma

Section Editor: Wayne E. Wingfield, M.S., D.V.M.

10. TREATMENT PRIORITIES IN TRAUMA

Wayne E. Wingfield, M.S., D.V.M.

1. Define trauma.

Trauma is any insult to the body. Obviously, the variety of insults is tremendous. Encounters with automobiles, animal fights, leghold traps, burns, weapons such as guns or arrows, and abuse are common traumatic injuries seen by veterinarians.

2. Why is trauma such an important topic?

Trauma is the leading cause of death of small animals. Experience in veterinary emergency and critical care facilities has shown that many deaths can be prevented through an organized approach to care. A well-defined systematic approach includes appropriate triage by body systems, careful evaluation of the animal, prompt and aggressive resuscitation, definitive treatment, and a team-oriented approach between the veterinarian and veterinary technician.

3. Define triage.

Triage, derived from the French word *trier*, means to pick or cull and originally described how French traders sorted wool into various categories according to quality. In veterinary medicine, triage is used to treat the most severely injured patients first and to define the most life-threatening injury. In other words, given an animal with severe respiratory distress and an open fracture to the femur, the respiratory distress is more life-threatening and must be treated immediately.

4. What is the "golden hour"?

At the moment the trauma insult is delivered, the clock begins ticking. The golden hour is the first hour after injury. Ideally, all traumas are evaluated systematically, life-threatening injuries are identified, and treatment is instituted. In veterinary medicine there are three intervals in which death results from trauma:

- The first interval occurs within minutes of the trauma. Rarely are such animals seen in the veterinary hospital.
- The second interval occurs within the first 3–4 hours of trauma. This is the most common presentation in the veterinary hospital. Prompt, aggressive treatment can make a difference in survival.
- The third interval is after 3–5 days. With attention to detail, recognition of hidden injuries, and appropriate monitoring, the veterinarian can prevent unnecessary deaths in this group.

5. Define mechanism of injury.

The mechanism of injury refers to the events and conditions that lead to both known and unknown traumatic injuries. Significant mechanism of injury is associated with a higher likelihood of multiple trauma.

Significant Mechanisms of Injury

BLUNT TRAUMA	PENETRATING TRAUMA
Hit by an automobile	Gunshot wounds
Kicked by a horse	Arrow penetration
Animal abuse	Foreign body penetration
Falling from a moving vehicle	Animal bite wounds

6. What is multiple trauma?

Multiple trauma refers to significant injuries to more than one major body system. Most animals with significant mechanisms of injury also have multiple trauma. No matter how good the animal looks on presentation after a major mechanism of injury, a high index of suspicion for multiple injury is critical.

7. What are the initial steps in managing the traumatized animal?

- Alert the veterinarian(s) and veterinary technician(s) that an animal is on its way or has arrived at the hospital.
- Quickly obtain a history of the incident, including mechanism of injury.
- If possible, have the receptionist, veterinary technician, trained paraprofessional, or veterinary student stay with the owner of the animal. The owner is also feeling traumatized and needs attention.
- Transfer the animal to a specific area of the hospital designated and equipped to diagnose and treat the trauma patient.
- Assess the ABCDs (see next question) and intervene as necessary.
- Collect the vital signs as quickly as possible (see chapter 1).
- Collect blood and urine samples for the emergency minimum database and baseline laboratory testing.

8. What are the ABCDs of trauma?

- **A = Airway**. Airway patency is evaluated by listening for vocalizations and looking in the mouth for signs of obstruction (blood, emesis, or foreign debris). Fortunately, airway obstructions are not common in small animals. For all trauma animals, supplemental oxygen is continuously administered if it does not unduly stress the animal. The means by which oxygen is administered ranges from face mask to nasal insufflation, oxygen tent, or just blowing oxygen by the nares if the animal does not tolerate other means.
- **B = Breathing**. Ventilation is assessed by observing for symmetric rise and fall of the thoracic walls and by auscultating for bilateral breath sounds. The thoracic walls should be gently palpated for evidence of subcutaneous emphysema or fractured ribs. If possible, oxygen saturation as assessed by pulse oximetry is useful in determining the need for thoracocentesis.
- **C = Circulation**. Circulatory function is assessed by noting the animal's mental status, mucous membrane color and character (cool and clammy vs. warm and dry), vital signs, and presence, character, and rhythm of the femoral arterial pulses. If possible, electrocardiographic monitoring should be started, and vascular access is established to begin volume resuscitation.
- **D = Disabilities**. The animal's neurologic status should be assessed and recorded. Especially important is an evaluation of the cranial nerves for evidence of brain trauma and peripheral reflexes for evidence of spinal or peripheral nerve injury. At this stage also note any abnormal motor postures (e.g., decerebrate rigidity, decerebellate or Schiff-Sherrington posture).

9. Describe the type of intravenous access you should establish in an animal with major trauma.

Use a large-bore (16-gauge or greater) intravenous catheter. Often more than one catheter may be required. The cephalic veins, recurrent tarsal (lateral saphenous) vein in dogs, or

medial saphenous (femoral) vein in cats is most commonly chosen for catheterization. Jugular venous catheterization is useful for administering hypertonic solutions and for measuring the central venous pressure but may be too stressful for most animals when first presented to the hospital.

10. What is an adequate minimum database in the trauma patient?

Each hospital should establish its own minimal database. We use the following baseline parameters in each emergency patient: Packed cell volume, total solids (protein), blood glucose, activated clotting time, and, if at all possible, urine specific gravity. These parameters are monitored for changes during therapy.

11. Are other laboratory parameters useful?

Not really. Although samples from most trauma victims should be sent to the laboratory for complete blood count and biochemical profile, baseline packed cell volume should determine preexisting anemia, urinalysis may detect preexisting renal disease and hematuria, and blood glucose showing hypoglycemia may alert the veterinarian to sepsis. No laboratory test defines injury, and initial laboratory studies rarely influence management or disposition.

12. List, in order of priority, the body systems important in trauma.

- **Arterial bleeding**. Realistically, if the animal has arrived at the hospital, the degree of arterial bleeding probably is not significant. More likely you will see evidence of bleeding in the area of a fracture, but arterial bleeding may not become evident until you begin fluid therapy and raise the blood pressure.
- **Respiratory system**. Undoubtedly the respiratory system is the most important body system in trauma. The variety of injuries includes pneumothorax, pulmonary contusions, hemothorax, flail chest, and diaphragmatic hernia. Usually there are multiple injuries to the respiratory system (e.g., pneumothorax with pulmonary contusions).
- **Cardiovascular system**. Two components of the cardiovascular system need attention in the trauma patient: (1) the pump and (2) volume. If the pump is abnormal (e.g., significant arrhythmias or valvular disease), it may not be capable of handling the volume administered for shock.
- **Hemorrhage and transfusion**. Definitive control of venous and/or arterial hemorrhage is accomplished. Packed cell volume and total solids are reassessed to avoid excessive hemodilution. If necessary, a transfusion is administered.
- **Neurologic system**. Three components of the neurologic system are evaluated: (1) brain, (2) spinal cord, and (3) peripheral nerves.
- **Musculoskeletal system**. Fractures are not emergencies. The blood loss and tissue injury surrounding a fracture are more likely to lead to the demise of the animal than the broken bone(s). Occasionally you encounter luxations that cause extreme pain (e.g., elbow luxation) and may prevent alleviation of shock until the luxation is reduced. If a splint can be correctly applied using the principle of immobilizing the joint above and below the fracture, the fracture can be immobilized at this stage.
- **Other injuries**. The veterinarian is faced with identifying and deciding the approach to abdominal injuries (e.g., ruptured liver, kidney, spleen, or urologic injuries). Clues to the existence of such injuries are associated with abdominal pain, and often such animals are difficult to stabilize.

13. Should a thoracic radiograph be taken as soon as possible to rule out pneumothorax or diaphragmatic hernia?

No. Radiography can be stressful to the animal as it is held in place. Thoraco- or abdominocentesis can determine the presence of abnormal substances in the two major cavities. Early radiography may provide a false sense of security if no evidence of pulmonary contusions is seen. It may be 12–24 hours before radiographic evidence of these contusions is seen.

14. How is tissue perfusion assessed clinically?

Organ perfusion is not democratic. Blood is preferentially distributed to coronary and carotid arteries. If cardiac output is adequate, blood is then delivered to the liver, kidneys, mesenteric organs, and finally the skin. Evidence of urine output is evidence of adequate renal perfusion, and warming of extremities usually suggests adequate perfusion to the skin. Elevated blood lactate levels also provide evidence of poor tissue perfusion.

15. What fluids should be used for initial resuscitation?

The mainstay of fluid resuscitation is rapid crystalloid infusion. Colloid solutions (e.g., dextrans, hetastarch) are costly and have not proven advantageous in reducing mortality. Hypertonic saline solutions may lead to prompt rises in blood pressure and may even raise the cardiac output, but their duration is apparently less than 24 hours. Whole blood and, eventually, recombinant hemoglobin, serve to temporize patients with massive blood loss.

CONTROVERSIES

16. Should fluid resuscitation be withheld to minimize bleeding in the trauma patient?

Only one report currently recommends delaying fluid resuscitation until major vascular injuries have been controlled. This study of humans with penetrating thoracic injuries argued that the increase in perfusion pressure dislodges clots and overcomes hemostatic mechanisms, allowing uncontrolled hemorrhage. Numerous letters to the editor have disputed these findings by noting the excessive times in the emergency department and the lack of patient stratification by degree of shock. No clinical veterinary studies are available at present. Because most veterinarians do not do emergency thoracic and abdominal surgery, low-volume resuscitation cannot be recommended.

17. What is the role of pneumatic antishock garments or wrapping extremities to increase venous return during shock?

The pneumatic antishock garment was once believed to autotransfuse blood from the extremities to the central circulation. The use of these garments and wraps to increase blood flow appears also to increase peripheral vascular resistance and may be detrimental with major thoracoabdominal injuries. These techniques have no role in veterinary emergencies.

18. What is a secondary survey?

The secondary survey involves a detailed evaluation of potential life-threatening injuries. The secondary survey includes a head-to-toe physical examination, possible radiographs, further laboratory testing, and special diagnostic tests.

19. What is a tertiary survey?

A thorough reevaluation of the animal is completed after 12–24 hours. The purpose is to identify hidden, previously diagnosed injuries and to note the progress of the animal since admission to the hospital.

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11. ARTERIAL BLEEDING

Wayne E. *Wingfield*, M.S., D.V.M.

1. By what mechanisms does arterial bleeding occur?

- Blunt trauma
- Penetrating trauma
- Iatrogenic trauma
- Orthopedic injuries
- Surgical trauma

2. What is the kinetic energy of a bullet? Why is it important in penetrating injuries?

The kinetic energy (K) of a bullet is determined by the following equation:

$$K = \frac{1}{2} MV^2$$

where M = mass and V = velocity. The tissue energy is related to the square of the velocity. Thus, a high-velocity bullet causes more damage and requires more extensive debridement than a bullet of smaller mass and lower velocity.

3. When is arterial bleeding seen in animals hit by a car?

Any animal experiencing trauma is at risk for arterial bleeding. If the bleeding is severe, the animal will not survive to arrival at the veterinary hospital. Most arterial bleeding is noted when intravenous fluids are administered and the blood pressure is rising. In most cases, the arterial bleeding is noted with open fractures of the distal radius or ulna, tibia, or fibula.

4. How do you recognize arterial bleeding?

Arterial blood usually has a brighter red color than venous blood. In addition, arterial bleeding usually spurts with each heartbeat, whereas venous bleeding usually oozes from the wound.

5. What is the first response to managing arterial bleeding of a distal extremity?

Arterial bleeding of a distal extremity is best managed by applying pressure to the wound site. Blind clamping should be avoided to prevent unnecessary soft tissue or nerve injury. In trauma this is usually done by applying a 4×4 gauze sponge over the wound and applying tape and gauze around the extremity. Surgical ligation of the artery is usually unnecessary at this stage of triage. It is more important to assess respiratory and cardiovascular function and to begin intravenous fluid resuscitation before considering definitive control of bleeding.

6. Which arterial injury bleeds more—a complete transection or an incomplete transection? Why?

The incomplete transection bleeds more because, unlike the complete transection, it does not have the ability to undergo retraction, vasoconstriction, and thrombosis.

7. What are the three anatomic layers of an artery?

Tunica intima, tunica media, and tunica adventitia.

8. What is the mechanism of arterial injury from blunt trauma?

As the arterial wall is stretched, the elastic adventitial and muscular layers remain intact as the tunica intima fractures. Blood dissects beneath the intima, resulting in an intimal flap that occludes the lumen.

9. Should a tourniquet be used to control arterial hemorrhage?

If at all possible, avoid placement of a tourniquet. The tourniquet occludes collateral circulation, making distal ischemia worse. If improperly applied, it may allow arterial inflow and impede venous return, thus making the bleeding worse.

10. Should you ligate or repair an injured artery surgically?

Tough question. In a perfect world, surgical repair makes good sense. In the real world, veterinarians generally are not trained in the surgical repair of vessels. Repairs must be precise, involve use of very small suture material, and require magnification of the surgical site. Surgical skill is mandatory. For most arterial bleeding from extremity fractures, surgical ligation is done. Fortunately, collateral circulation is usually more than adequate to prevent distal ischemia. Obviously, if you are in surgery and have damaged an artery, you must combine surgical judgment with skill to make this decision.

11. If you are going to attempt surgical repair, what are the initial steps?

Using specialized vascular clamps, obtain proximal and distal control of the injured vessel.

12. What are the surgical steps in arterial repair?

Debridement, removal of thrombi, careful arterial reconstruction, and soft-tissue coverage.

13. What is the most common intraabdominal arterial injury in veterinary patients?

Who knows? No reports in the veterinary literature detail this information. Anecdotal experience suggests that the most common arterial injury is probably to smaller intrahepatic or intrasplenic arteries. Occasionally an avulsed kidney may be identified at surgery (but probably more often at necropsy).

14. Define compartment syndrome.

Compartment syndrome is the consequence of elevated pressure in a confined or limited space. Pressures are elevated because of an increase of interstitial fluid or of cell swelling. Space is limited because of a decrease in the size of the compartment or an increase in its contents. As a result, circulation, function, and viability of the tissues or structures within the space are compromised. In the extremities, the increased pressure decreases capillary blood flow and may lead to tissue necrosis. In this syndrome, neurologic injury occurs first, because nerves are most sensitive to ischemia. Systemic manifestations of the compartment syndrome include hyperkalemia, myoglobinuria, and sepsis.

15. List the five key features of the abdominal compartment syndrome.

1. Elevated ventilatory pressures
2. Elevated central venous pressure
3. Decreased urine output
4. Massive abdominal distention
5. Reversal of these derangements with abdominal decompression

16. If you suspect compartment syndrome of a limb, what is the initial treatment?

Prompt fasciotomy.

17. Which injury is most likely to show compartment syndrome?

Anecdotally, rattlesnake envenomations are most likely to show compartment syndrome.

18. Does compartment syndrome occur in sites other than the extremities?

Yes. Compartment syndrome occurs in any confined space, including the skull, orbit, kidney, or abdomen.

19. What is crush syndrome?

Crush syndrome refers to the systemic manifestations associated with crush injuries, which are caused by continuous prolonged pressure on the body, usually the extremities. The systemic manifestations of crush syndrome include hyperkalemia, myoglobinemia, and anuric renal failure. In most patients, hemoconcentration, oliguria, and uremia are present.

20. Why does a crush injury lead to acute renal failure?

There are three theories for the development of renal failure after such an injury:

1. Myoglobin precipitation within the renal tubules with mechanical tubular obstruction.
2. Direct injury by the iron molecule of the heme moiety in combination with free radical formation.
3. Renal hypoperfusion and acidemia due to inadequate resuscitation and leading to prerenal failure.

Although each of the above theories has enthusiastic supporters, it is more probable that all three contribute to renal failure and that their combination aggravates renal cell damage.

21. What is the treatment for the acute renal failure of crush injuries?

- Aggressive fluid resuscitation.
- Mannitol and sodium bicarbonate increase diuresis, scavenge oxygen free radicals, and alkalinize the urine to prevent myoglobin precipitation.
- Renal or peritoneal dialysis may be required with anuria.

22. Can Doppler signals over an artery be used to rule out an arterial injury?

No. Doppler signals are not reliable for arterial injury or adequate perfusion.

23. What injury is most likely to result in arterial bleeding in the thorax?

No data are available to answer this question in veterinary medicine. In patients with blunt or penetrating trauma, the injury causing death probably involves the aorta or pulmonary arteries. The surgical procedure that seems most likely to result in arterial bleeding is surgical repair of a patent ductus arteriosus.

24. Significant swelling in the early postoperative period is suggestive of what complication?

Venous thrombosis.

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12. RESPIRATORY EMERGENCIES

Elisa M. Mazzaferro, M.S., D.V.M.

1. Name the four most common injuries associated with thoracic trauma.

- Pneumothorax
- Pulmonary contusions
- Rib fractures or flail chest
- Diaphragmatic hernia

2. What respiratory pattern is characteristic in patients with thoracic trauma?

Many patients with thoracic trauma and associated injuries have a respiratory pattern typically associated with restriction of breathing. Breathing appears rapid and shallow, often with a pronounced expiratory effort. If flail chest is present, paradoxical chest wall motion may be apparent.

3. What is a tension pneumothorax?

A tension pneumothorax occurs when intrapleural pressure exceeds atmospheric pressure because of a one-way flap valve in either an airway (bronchopleural fistula) or the chest wall (pleurocutaneous fistula). The alternate opening and closing of the valve allows the negative intrapleural pressure during inspiration to aspirate air that cannot leave during expiration because the valve closes. Once the rise in intrapleural pressure exceeds atmospheric pressure, the tension pneumothorax is rapidly progressive and fatal.

4. What is the most appropriate treatment for patients with a tension pneumothorax?

When a patient presents with a tension pneumothorax, immediate alleviation of the intrapleural pressure via therapeutic thoracocentesis is necessary. This goal is best accomplished by quickly clipping a small area on the thoracic wall, aseptically scrubbing the area, and inserting a 20–22-gauge needle or catheter between the seventh and ninth intercostal spaces. The needle or catheter should be suctioned continually while a chest tube is prepared and placed.

5. Name the categories of thoracic injuries associated with thoracic trauma.

- Closed vs. open thoracic trauma
- Pleural cavity disease
- Parenchymal lung involvement
- Thoracic wall involvement
- Tracheobronchial tree injuries
- Cardiovascular abnormalities

6. List the signs of pericardial injury secondary to thoracic trauma.

- Premature ventricular contractions (most common)
- Acute tamponade
- Venous congestion
- Inadequate venous return
- Decrease in cardiac output
- Increased central venous pressure
- Jugular vein distention
- Muffled heart sounds
- Loss of apex beat
- Electrocardiographic abnormalities

7. List five possible sequelae of thoracic trauma.

1. Posttraumatic pulmonary insufficiency
2. Tracheobronchial infection
3. Bullae
4. Lung lobe torsion secondary to consolidation or abscessation
5. Ventricular arrhythmias

8. Why do many dogs with thoracic trauma not present initially with cardiac arrhythmias?

The most common posttraumatic arrhythmia is premature ventricular contractions (PVCs). Because of increased sympathetic stimulation and cathecholamine release during the stress of

injury, sympathetic tone overrides ventricular automaticity, masking myocardial injury and arrhythmias. Arrhythmias may not be apparent for 12–24 hours after trauma. Changes on an electrocardiogram (ECG) indicative of myocardial injury include arrhythmias and ST-segment (J-point) depression (suggestive of myocardial ischemia). The cardiac enzyme troponin-T can be qualitatively measured in traumatized dogs. Its presence in plasma is supportive of myocardial damage, alerting the emergency clinician that arrhythmias are more likely.

9. What is a flail chest?

A flail chest occurs when two or more adjacent (contiguous) ribs have been fractured in two or more places, resulting in chest wall instability. The "flail" segment causes paradoxical chest wall motion in which the segment moves inward during inspiration and outward during expiration. The pain associated with the flail segment significantly diminishes ventilatory capacity.

10. What is the most appropriate treatment for flail chest?

Previous treatments for flail chest included external or surgical stabilization of the flail segment. However, external stabilization severely restricts respiration, and surgical stabilization using metal fixators is prone to breakdown or osteomyelitis. We have found that local anesthesia dorsal and ventral to each fracture and blockade of the ribs cranial and caudal to the flail segment markedly improve respiratory function by alleviating pain. A total of 0.75 mg/kg in cats and a total of 1.5 mg/kg in dogs of 2% lidocaine or bupivicaine can be infused up to 3 times daily. Intercostal nerve blocks for single rib fractures can be performed at the proximal and distal margin of the fractured rib and at the ribs cranial and caudal to the fractured rib.

11. What clinical signs are associated with pulmonary contusions?

- Rapid shallow restrictive respiratory pattern
- Open-mouthed breathing or dyspnea
- Cyanosis
- Tachypnea
- Frothy bloody fluid from the nose or mouth
- Harsh lung sounds

Clinical signs of pulmonary contusions may not develop for 4 hours after the initial injury and may worsen for 24–36 hours after the initial injury.

12. What clinical signs indicate that a patient with thoracic trauma is developing severe pulmonary contusions during hospitalization?

The astute clinician should watch closely for signs of changing respiratory pattern and rate. As pulmonary contusions develop, the lung loses its capacity to expand adequately. A restrictive, tachypneic respiratory pattern becomes apparent. Rapid shallow respirations with a pronounced expiratory component are observed as tidal volume falls. The mucous membranes may become pale with continued hypoxia or hemorrhage. Arterial hypoxemia ($PaO_2 < 60$) and hypercapnia ($PCO_2 > 60$) are associated with severe ventilation-perfusion mismatching, pulmonary shunting in collapsed or atelectic lung areas, and diffusion impairment due to interstitial and alveolar fluid accumulation.

13. What pathologic changes are associated with the development of pulmonary contusions?

- Edema
- Increased vascular permeability
- Hemorrhage
- Atelectasis

14. How do you treat a patient with severe thoracic trauma?

- Airway management is achieved through suctioning or endotracheal intubation (if trauma to the airway is present)
- Administer oxygen to increase arterial oxygen content.
- Drain the pleural space if pneumothorax or hemothorax is present.
- Stop ongoing hemorrhage.
- Initiate fluid support for volume replacement.

15. Name three types of pneumothorax.

1. **Tension pneumothorax** (see question 3).

2. **Simple pneumothorax** usually is associated with nonpenetrating trauma. Damage to the lung parenchyma results in leakage of air into the pleural space. In most cases, the leak is self-limiting, requiring conservative management with thoracocentesis.

3. **Open pneumothorax** results from penetrating injuries to the chest wall that allow communication of the pleural space and the atmosphere. Severe hypoventilation results. If the wound is small relative to the size of the glottis, adequate ventilation can be maintained. If the wound is large relative to the size of the glottis, severe hypoventilation results. Open wounds should be managed with immediate coverage, insertion of a thoracic drain, and aspiration of the pleural space.

16. What are the radiographic signs of a pneumothorax?

- Elevation of the heart away from the sternum
- Increased lung density
- Retraction of lungs away from thoracic wall

17. Why does a diaphragmatic hernia occur in patients with thoracic trauma?

Forceful impact against the abdomen while the glottis is open is associated with diaphragmatic hernia.

18. What are the radiographic signs of a diaphragmatic hernia?

- Loss of diaphragmatic line
- Absence of caudal heart border
- Increased soft tissue density within thorax
- Presence of gas-filled bowel loops within thorax

19. When is treatment of a diaphragmatic hernia a surgical emergency?

In most cases, the patient is stabilized before surgery to repair the diaphragmatic hernia. However, if a gas-filled viscera such as the stomach is entrapped, venous return to the heart is impeded. Organ entrapment involving the liver or spleen also can cause tissue necrosis and unresponsive shock. If the stomach is within the thorax, the patient is unresponsive to initial stabilization with oxygen support and intravenous fluid therapy; exploration of the thorax is a surgical emergency and should not be delayed. Mechanical ventilation is necessary during surgery and may be required postoperatively in patients with severe pulmonary contusions.

20. Why are bite wounds to the thorax severe emergencies?

Any penetrating wound to the thorax can cause tension pneumothorax and injury to intrathoracic structures such as the heart, lung parenchyma, great vessels, and thoracic duct. Additionally, bite wounds are contaminated with external debris and bacteria, causing foreign bodies and infection. Penetrating bite wounds to the thorax should be explored, carefully debrided, and lavaged thoroughly once the patient is stabilized. Broad-spectrum antibiotics should be administered immediately to decrease the risk of pyothorax.

21. When is placement of a chest tube indicated?

Continued accumulation of free air within the pleural space that is refractory to therapeutic thoracocentesis requires placement of a chest tube.

22. Describe the placement of a chest tube.

Placement of the chest tube should be performed in a way that minimizes stress:

1. Use fentanyl, 1 μg/kg intravenous bolus, or propofol, 2–4 mg/kg IV, for sedation and chemical restraint.

2. Prepare the skin aseptically on the side of the thorax generating the greatest amount of free air.

3. Infuse local anesthetic (0.75 mg/kg 2% lidocaine) near the proximal tenth intercostal space, directed cranioventrally so that the chest tube will enter the mid-thorax between the seventh and ninth intercostal spaces.

4. Place a 12–30-French, trocharized fenestrated tube by making a stab incision with a scalpel blade at the proximal tenth intercostal space and tunneling the tube under the skin to the seventh to ninth intercostal space. Ask an assistant to pull the skin cranioventrally to aid tunneling.

5. Compress the thorax over the sternum to increase intrathoracic pressure while placing the trochar through the body wall.

6. Once the trochar enters the pleural space, the tube should be pushed off of the trochar in a cranial-ventral direction. The tip should lie at approximately the third intercostal space, just cranial to the heart.

7. Connect a Christmas tree adapter (connected to extension tubing), three-way stopcock, and 60-ml syringe to the chest tube.

8. Perform suctioning immediately.

9. Secure the chest tube with a horizontal mattress suture. Then place a second pursestring suture in the skin at the entrance point, and secure with a Chinese finger trap.

10. The chest tube can be suctioned every hour or more frequently, as needed, or connected to a Pleurivac continuous suction system.

11. Lidocaine, 0.75 mg/kg, followed by bupivicaine, 0.75 mg/kg, can be flushed into the chest tube 3 times daily to alleviate patient discomfort.

23. If a trocharized tube is not available, what alternate method of placement can be used?

A red rubber tube can be clamped in the distal tips of a Rochester carmault forceps. The carmault is placed through the stab incision in the skin and tunneled as with the trochar. With blunt force, the tips of the carmault are inserted through the chest wall at the seventh intercostal space. The red rubber tube is then inserted into the pleural cavity and directed cranially and ventrally to the third intercostal space. The wide end of the tube is attached to the Christmas tree adapter and suctioning apparatus to facilitate evacuation of the thorax.

24. Describe therapeutic or diagnostic thoracocentesis in patients with thoracic trauma.

1. Clip a 4-inch-square section of fur from each side of the thorax.

2. Prepare each area quickly and aseptically.

3. Insert a 1–1.5-inch, 18–20-gauge needle in the mid thorax between the seventh and tenth intercostal space, carefully avoiding the caudal border of each rib.

4. Once the needle is inserted into the pleural space, it should be placed parallel with the thoracic wall to avoid penetrating the lung parenchyma.

5. Attach a piece of IV extension tubing to the hub of the needle at one end and a three-way stopcock at the other end.

6. Connect a 60-ml syringe to the three-way stopcock, and slowly aspirate for air or fluid.

7. If negative pressure is observed, the needle should be redirected in several spots, because pockets of air may restrict breathing and cause lung collapse. Once negative pressure is obtained, the entire procedure should be repeated on the other side of the thorax.

25. Name three consequences of pulmonary contusions.

1. Small airway and alveolar collapse
2. Hemorrhage
3. Right-to left shunting

Small airway collapse, alveolar collapse, right-to-left shunting and hemorrhage into the alveolar space result in decreased systemic oxygen content and lead to hypoxia.

26. What are the indications for exploratory thoracotomy in patients with thoracic trauma?

- Open wounds
- Penetrating foreign bodies
- Persistent severe hemorrhage into the pleural space
- Massive hemoptysis
- Recurrent cardiac tamponade
- Persistent rapid accumulation of air in the pleural space refractory to negative suctioning

27. What thoracic injuries are commonly associated with fights?

- Subcutaneous emphysema
- Pulmonary contusions
- Open bite wounds
- Pneumothorax
- Rib separation or fracture
- Myocardial contusions

28. Are glucocorticoids indicated in the treatment of pulmonary contusions?

Controversial. Damage to the lungs results in release of arachidonic acid from membranes. Arachidonic acid can be metabolized through cyclooxygenase and lipoxygenase to prostaglandins and leukotrienes, resulting in severe inflammation and further damage to the pulmonary endothelial membrane. Glucocorticoids, however, predispose the patient to secondary bacterial infections. Their use in the treatment of pulmonary contusions is not advocated at this time.

29. Are diuretics necessary for proper treatment of pulmonary contusions?

Diuretic therapy potentially decreases edema formation but may heighten tissue hypoxia by causing dehydration. Fluid therapy is warranted in many patients with pulmonary edema but must be titrated carefully to improve intravascular volume without contributing to pulmonary leakage and edema and dilution of available proteins.

30. What types of fluid therapy may be used in patients with pulmonary contusions?

Widespread controversy surrounds the use of either crystalloids or colloids in patients with thoracic trauma and pulmonary contusions. Crystalloid fluids can be administered to expand intravascular volume at ¼ to ½ calculated shock dose (90 ml/kg/hour). However, dilution of intravascular proteins may allow the fluid to leak out of damaged alveolar vessels, accumulating in the interstitial space and alveoli and thus contributing to pulmonary edema and decreased diffusion capacity. Colloid fluids can be used (5 ml/kg increments) to help maintain intravascular fluid volume. Controversy exists whether large-molecular-weight particles leak out of the damaged pulmonary vasculature and contribute to pulmonary edema fluid by drawing fluid into the interstitium and alveoli. Colloids and crystalloids can be used judiciously in hypotensive small-volume resuscitation in patients who are at extreme risk for fatal pulmonary contusions and require intravascular fluid support. The choice between crystalloids and colloids depends on the severity of pulmonary contusions and hypovolemic shock. The following end-point parameters should be closely monitored: blood pressure, capillary refill time, central venous pressure, and arterial oxygenation (PaO_2).

31. When are Heimlich valves indicated in treatment of patients with pneumothorax?

Heimlich valves require sufficient positive pleural pressure during expiration to effectively evacuate air through the valve. Small dogs and cats may not generate adequate positive intrapleural pressure during expiration to allow airflow through the valve. Therefore, the use of Heimlich valves is contraindicated.

32. When should thoracic radiographs be performed in patients with pneumothorax and pulmonary contusions?

Initial diagnosis of pneumothorax should be based on visual observation of tachypnea; rapid, shallow, and restrictive respiratory pattern; muffled heart and lung sounds on thoracic auscultation; and respiratory distress. Thoracic radiographs should be performed only after initial stabilization with oxygen, thoracocentesis (to relieve respiratory distress and confirm pneumothorax), and alleviation of respiratory distress.

33. In patients with diaphragmatic hernia, what are the causes of respiratory distress?

- Herniation of abdominal organs compresses the thoracic viscera and causes pulmonary atelectasis.

- Loss of functional lung capacity may result from atelectasis and pleural effusion.
- Pulmonary contusions and other concurrent injuries result in hypoxemia.
- Gastric tympany associated with herniation of the stomach into the thorax compresses the thoracic viscera and impedes venous return to the heart, resulting in decreased cardiac output and decreased lung capacity.

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13. TRAUMATIC MYOCARDITIS

Steven L. *Marks*, B.VSc., M.S., M.R.C.V.S.

1. Define traumatic myocarditis. What is the suspected pathophysiology?

Traumatic myocarditis is a generic term used to describe cardiac arrhythmias after blunt or non-penetrating thoracic trauma. A combination of processes affecting the myocardium leads to the arrhythmias. The cause of the arrhythmias is unknown but may be multifactorial, including reperfusion, shock, neurologic injury, and sympathetic stimulation. Myocarditis is not usually present; necrosis or contusion is more common and often results from multiple forces to the heart after blunt trauma.

2. What forces to the heart may cause arrhythmias?

- Unidirectional
- Compression
- Indirect
- Decelerative
- Concussive

- Loss of functional lung capacity may result from atelectasis and pleural effusion.
- Pulmonary contusions and other concurrent injuries result in hypoxemia.
- Gastric tympany associated with herniation of the stomach into the thorax compresses the thoracic viscera and impedes venous return to the heart, resulting in decreased cardiac output and decreased lung capacity.

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Steven L. *Marks*, B.VSc., M.S., M.R.C.V.S.

1. Define traumatic myocarditis. What is the suspected pathophysiology?

Traumatic myocarditis is a generic term used to describe cardiac arrhythmias after blunt or non-penetrating thoracic trauma. A combination of processes affecting the myocardium leads to the arrhythmias. The cause of the arrhythmias is unknown but may be multifactorial, including reperfusion, shock, neurologic injury, and sympathetic stimulation. Myocarditis is not usually present; necrosis or contusion is more common and often results from multiple forces to the heart after blunt trauma.

2. What forces to the heart may cause arrhythmias?

- Unidirectional
- Compression
- Indirect
- Decelerative
- Concussive

3. When should myocardial trauma be suspected?

Myocardial trauma should be suspected after any non-penetrating thoracic injury, including blunt trauma leading to rib fractures, flail chest, pulmonary contusions, pneumothorax, hemothorax, chylothorax, or diaphragmatic hernia. Penetrating thoracic injuries also may lead to myocardial changes. Traumatic myocarditis is seen more commonly in dogs, and arrhythmias may not occur until 24–48 hours after injury.

4. What is the clinical evidence of traumatic myocarditis in dogs and cats?

Often no clinical signs are present with traumatic myocarditis. Clinical signs may be related to thoracic trauma, but they are not specific for myocardial damage. Arrhythmias may be associated with pulse deficits, lethargy, and hypotension.

5. What adjunctive diagnostic testing should be performed if traumatic myocarditis is suspected?

Additional diagnostics should be considered only after triage and thorough examination of the patient. Thoracic radiographs and electrocardiography should be considered to evaluate thoracic trauma. Other diagnostic testing should be considered as dictated by clinical findings, including thoracocentesis, blood gas analysis, electrolytes, echocardiography, and pulse oximetry.

6. What diagnostic test appears to be useful in myocardial injury secondary to thoracic trauma?

Myocardial troponin T levels.

7. What is the role of the electrocardiogram (ECG) in traumatic myocarditis?

The ECG is a valuable tool for both the diagnosis and monitoring of cardiac arrhythmias. Supraventricular tachyarrhythmias, ventricular arrhythmias, and bradyarrhythmias have been documented in posttraumatic cases. Reported arrhythmias include ventricular tachycardia, accelerated idioventricular rhythms, ventricular premature complexes, atrial fibrillation, sinus rhythm with bundle branch blocks, and atrioventricular block.

8. What are the most common arrhythmias after trauma?

Ventricular tachycardia and accelerated idioventricular rhythms.

9. What is an accelerated idioventricular rhythm?

An accelerated idioventricular rhythm is one of the most common posttraumatic cardiac arrhythmias in dogs and may occur within 48 hours of injury. The mechanism is unknown but may be related to autonomic disturbance or reperfusion injury. An abnormal automaticity may explain why an underlying ventricular rhythm overtakes the normal pacemaker. Generally the rate of this rhythm is < 150 beats/minute; it is often preceded by a pause in the sinus rate. Accelerated idioventricular rhythm is often misdiagnosed as ventricular tachycardia and treated with antiarrhythmic agents. This rhythm does not lead to hemodynamic instability; it is self-limiting and requires no treatment.

10. Describe treatment criteria for arrhythmias associated with traumatic myocarditis.

Treatment for arrhythmias is a common dilemma facing the emergency clinician. Treatment of arrhythmias should be based on clinical assessment of the patient. Basing therapy solely on the ECG rather than on the patient may lead to over treatment. Antiarrhythmic agents are not without complications and may be arrhythmogenic. All antiarrhythmic agents can also cause myocardial depression. Therapy, therefore, should be based on clinical signs, perfusion, and blood pressure. Underlying problems, such as hypovolemia, electrolyte disturbances, acid-base disorders, or pain should be addressed prior to considering antiarrhythmic

therapy. If clinical signs of supraventricular tachycardias are present, calcium channel blockers or beta-blockers may be considered. If ventricular tachycardia is suspected, treatment criteria include rate (> 150 beats/ minute), multifocal QRS complex morphology, and presence of R on T phenomenon.

11. Which antiarrhythmic agents may be used for trauma-induced arrhythmias?

TACHYCARDIA	BRADYCARDIA
Supraventricular	Atropine
Propranolol	Glycopyrrolate
Esmolol	Dopamine
Diltiazem	Isoproterenol
Procainamide	Theophylline
	Aminophylline
Ventricular	Terbutaline
Lidocaine	
Procainamide	
Mexiletine	
Magnesium sulfate	
Esmolol	
Propranolol	

12. Can animals with traumatic myocarditis be anesthetized?

The evaluation for anesthesia should be based on thorough physical examination. Anesthesia should not be considered until the patient is stable and malignant arrhythmias are controlled. The classification adopted by the American Society of Anesthesiologists can be applied to animals with traumatic injuries:

Class I: Normal patient with no systemic disease.
Class II: Patient with mild systemic disease.
Class III: Patient with severe systemic disease that limits activity.
Class IV: Patient with incapacitating systemic disease that is a threat to life.
Class V: Moribund patient not expected to survive 24 hours.

In young and otherwise healthy animals a minimal database of packed cell volume, total protein, and glucose is suggested. In animals older than 5 years, a more extensive database, including biochemical profile, may be indicated. In trauma patients, electrocardiography and thoracic radiographs should be considered. Other specific diagnostic tools for cardiopulmonary trauma may include central venous pressure, arterial blood pressure evaluation, blood gas analysis, and pulse oximetry.

Choice of anesthetic agents should be based on clinical evaluation of the patient. All anesthetic agents can change the electrophysiologic properties of the heart and should be used cautiously. The use of inhalant anesthetics has the advantage of concurrently providing oxygen. Of these agents, halothane has the greatest potential for being arrhythmogenic via catecholamine sensitization of the myocardium. Injectable agents that are known to be arrhythmogenic, such as xylazine, should be avoided. The benzodiazepines, opioids and propofol may be the safest injectable induction agents. Low dosages of thiobarbiturates also may be tolerated.

13. How should patients be monitored?

Patient monitoring should be based on the patient's clinical condition. Continuous ECG monitoring is valuable to assess the progression of arrhythmias. Other parameters such as blood pressure, arterial blood gas analysis, central venous pressure, packed cell volume, and total protein should be monitored as needed.

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14. FLUID SELECTION IN TRAUMA

Wayne E. *Wingfield*, M.S, D.V.M.

1. Where is water located in the body?

Most water is located in the intracellular compartment (~ 66%). The extracellular compartment contains about 34% of the body's water. The extracellular compartment is further subdivided into the intravascular (~ 25%) and interstitial (~ 75%) spaces.

2. What governs the distribution of water in the body?

The semipermeable membranes between the fluid compartments allow rapid equilibrium of free water and low-molecular-weight solutes (< ~ 40,000 Da). The particles (solutes) that are unable to pass through this semipermeable membrane generate oncotic pressure. This relative difference in oncotic pressure governs fluid distribution between compartments.

3. What happens when free water is infused into the intravascular space?

When dextrose in water (D5W) is infused, the dextrose is metabolized, leaving free water. When infused into the intravascular space, free water equilibrates with the extracellular and intracellular compartments in proportion to their relative water volumes. In other words, most water moves to the intracellular compartment (~ 75%) and relatively little remains in the intravascular space of the extracellular compartment.

4. Should D5W be used as a resuscitation fluid in shock?

No. As mentioned above, most water quickly moves to the intracellular space. In shock, the goal is to expand the intravascular space to provide volume for improving cellular perfusion and metabolism.

5. What is "third-spacing" of fluids?

The "third space" refers to the extracellular fluid that is nonfunctional, i.e., it does not participate in the transport of nutrients to nor waste products from the body cells. With burn injuries, crushing of tissue, severe soft tissue infections, postoperative wounds, pyometra, peritonitis, and hemorrhagic (traumatic) shock, significant amounts of extracellular fluid are sequestered, resulting in significant decreases in interstitial and plasma volume. Attempts to restore extracellular

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The "third space" refers to the extracellular fluid that is nonfunctional, i.e., it does not participate in the transport of nutrients to nor waste products from the body cells. With burn injuries, crushing of tissue, severe soft tissue infections, postoperative wounds, pyometra, peritonitis, and hemorrhagic (traumatic) shock, significant amounts of extracellular fluid are sequestered, resulting in significant decreases in interstitial and plasma volume. Attempts to restore extracellular

and intracellular compartments with intravenous fluids result in further sequestration of additional fluid in the nonfunctional third space. The end result often is massive weight gain. In acute injury, resolution of third-spacing begins 48–72 hours after the insult. This resolution is associated with resorption, diuresis, and weight loss, often leading to cardiovascular and/or pulmonary complications.

6. What are crystalloid fluids?

Crystalloid fluids contain sodium chloride and other physiologically active solutes. Sodium is the major component, and the distribution of sodium determines the distribution of the infused crystalloid.

7. How are crystalloid fluids redistributed when administered intravenously?

Because there is no difference in osmolality between the infused crystalloid and body fluids, there is no driving force to cause water to diffuse into the intracellular compartment. The intact membrane between the interstitial space and the intravascular space is permeable to ions and small particles. The membrane surrounding the intracellular space is relatively impermeable to ions and small particles. Consequently, the extracellular space is the distribution space for isotonic crystalloids. In healthy adult humans, only one-fourth of the crystalloid volume infused remains in the intravascular space after 1 hour. In critically ill or injured humans, only one-fifth or less may remain in the circulation 1–2 hours after infusion.

8. What happens to the packed cell volume (hematocrit) in shock?

Acute blood loss leads to a progressive fall in the packed cell volume (PCV) because of redistribution of interstitial and intracellular volumes to expand the intravascular volume. By 2 hours, 14–36% of the ultimate PCV change has occurred; in 8 hours, 36–50%; and in 24 hours, 63–77%. With redistribution of resuscitation crystalloids, the PCV again rises. The total serum protein levels show similar changes. Depleted intravascular volume is restored through movement of interstitial fluid to the intravascular space. Catecholamines stimulate arteriolar vasoconstriction, which diminishes capillary bed hydrostatic pressure and favors influx of interstitial fluid into the vascular tree distal to the arteriolar vasoconstriction. Subsequently, lymphatic flow returns plasma proteins to the intravascular space. This increase in lymphatic flow is enhanced when crystalloid fluids move to the interstitial space, thus increasing interstitial pressure. In addition, increased albumin synthesis and spontaneous diuresis secondary to volume expansion aid in the expansion of intravascular volume.

9. When crystalloids are used for shock resuscitation, how much volume is required?

The volume of crystalloid required to attain adequate volume replacement varies from 3–5 to 12 times the blood volume lost.

10. How are the so-called "shock volumes" determined for dogs and cats?

The answer is controversial. Traditionally, the shock volume for dogs is said to be 90 ml/kg/hr. The shock volume for cats is said to be 44 ml/kg/hr. However, to determine these values, whole blood volume is used in dogs and plasma volume in cats. Anecdotal experience has shown the dog's traditional shock volume (90 ml/kg/hour) is rarely required for resuscitation. More than likely consideration should be given to recommending plasma volume (50 ml/kg/hour) as the shock volume for dogs.

Estimates of Volumes in Dogs and Cats

	DOGS	CATS
Total body water	717 ± 17 mk/kg	596 ± 50.5 ml/kg
Red blood cell volume	36.9 ± 6 ml/kg	17 ± 3.2 ml/kg
Plasma volume	50.7 ± 4.3 ml/kg	44.3 ± 5 ml/kg
Whole blood volume	88.7 ± 8.3 ml/kg	60.1 ± 9d.3 ml/kg

11. What are the most commonly used crystalloids?

If a survey were completed, Ringer's lactate probably would be the most commonly used crystalloid in veterinary practices. As a balanced electrolyte solution, it probably is not the best choice. With only 130 mEq/L of sodium, Ringer's lactate is hyponatremic and hypotonic (osmolality = 273) to small animals. A more balanced solution for small animals is Normosol-R (Abbott Laboratories). The table below lists the crystalloid solutions and their compositions.

Electrolyte Composition (mEq/L) of Plasma vs. Commonly Used Crystalloid Fluids

	PLASMA	0.9% SALINE	RINGER'S LACTATE	NOROMSOL-R
Sodium	145	154	130	140
Chloride	110	154	109	98
Potassium	4–5	—	4	5
Calcium and magnesium	5/2	—	3/0	0/3
Osmolality	300	308	273	295
pH	7.386	5.7	6.7	7.4
Buffer	$NaHCO_3$ 20–22	—	Lactate 28	Acetate 27 Gluconate 23

12. What are the buffers in crystalloid fluids? Why are they there?

The buffers in Ringer's lactate and Normosol-R are precursors to bicarbonate. Thus, as they are metabolized, bicarbonate is formed and helps to resolve metabolic acidosis. Lactate is metabolized predominantly by the hepatic circulation, whereas acetate and gluconate are metabolized by skeletal muscle and peripheral tissues. In shock, hepatic blood flow is reduced; thus lactate may not be adequately metabolized.

13. What are the major pitfalls in crystalloid resuscitation?

One must avoid inadequate fluid administration and excessive hemodilution. In addition, crystalloid fluids must be carefully administered when the animal has either pulmonary injury (i.e., contusions) or brain trauma.

14. What is meant by excessive hemodilution?

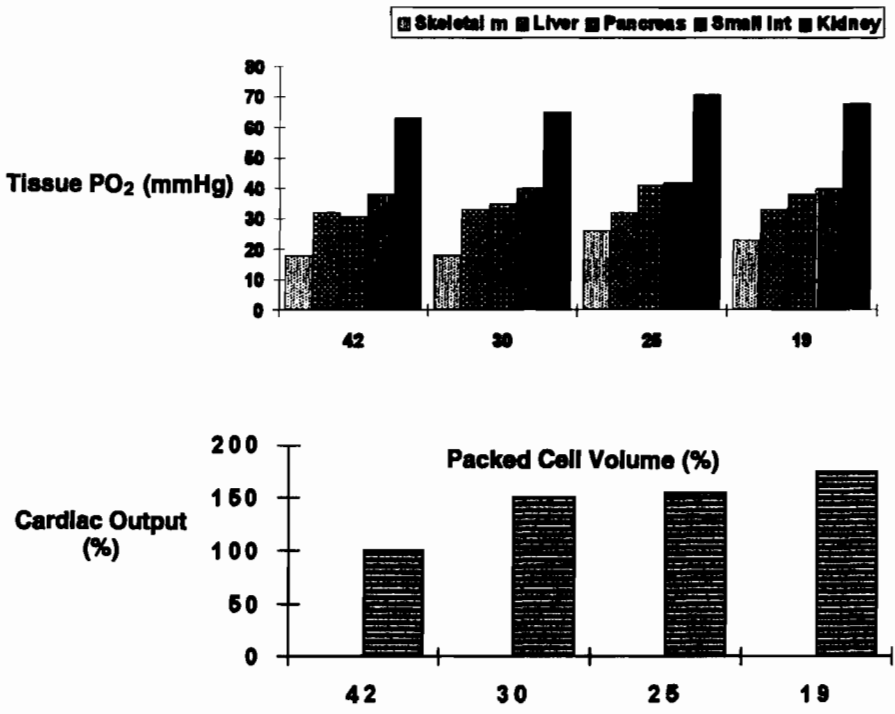
As mentioned above, when crystalloids are used in shock resuscitation, they contribute to the dilution of red blood cells and plasma proteins. This dilution can affect tissue oxygenation and obviously may lead to interstitial edema. Currently, packed cell volumes in shock patients should be maintained above 20%, and total protein values are kept at least at the level of 50% of the starting value. In other words, do not allow the PCV to fall below 20% or the total protein below 50% of its initial value.

15. Is hemodilution detrimental to cardiac output and tissue oxygenation?

Within limits, hemodilution improves cardiac output and increases tissue oxygenation (see figures at top of following page).

16. What is hypertonic saline? How is it used for shock resuscitation in small animals?

Concentrated (> 0.9%) crystalloid solutions containing sodium and chloride are called hypertonic saline. They are useful because they require smaller volumes of fluid for resuscitation, have decreased risks of edema, and improve the ability to deliver effective volume resuscitation in nonhospitalized patients. In animal studies and human clinical trials of hemorrhagic shock, hypertonic saline has proved effective.



Effects of hemoduilution on cardiac output and tissue oxygenation.

17. List the advantages and disadvantages for hypertonic saline in shock resuscitation.

ADVANTAGES	DISADVANTAGES
Significantly improved hemodynamics Increases cardiac output Improves peripheral blood flow and distribution Increases oxygen delivery Improves coronary, mesenteric, and renal artery blood flow	Induces hyperntaremia
Promotes urine production	Induces hyperchloremia
Lowers intracranial pressure	Hyperosmolar (7.5% = 2400 mOsm)
Reduces peripheral and central nervous system edema	Induces hypokalemia
Has a more sustained hemodynamic effect	May produce a nonrespiratory acidosis (hyperchloremic acidosis)
Reduces initial and subsequent fluid volumes	Cardiac dysrhythmias are reported
Corrects metabolic abnormalities	Anaphylaxis
Improves survival	Impaired renal function may be worsened

18. What are colloids?

Colloids are high-molecular-weight substances that, because of their size, do not readily cross capillary walls. They are retained in the vascular space and exert an osmotic force (colloid osmotic force or colloid oncotic force) that helps to retain fluid in the intravascular space.

19. What are the two main types of colloids? Give examples of each.

Hematogenous colloids	Synthetic colloids
Whole blood	Dextrans
Plasma	Hydroxyethyl starch
Packed red blood cells	Pentastarch
	Albumin

20. What is the rationale for use of colloids in shock?

Colloids are more effective than crystalloids for increasing intravascular volume.

21. Are only synthetic colloids administered for shock resuscitation?

No. When the synthetic colloids are administered, water is drawn from the interstitial and intracellular spaces, which need to be rehydrated. Thus a combination of colloids and crystalloids is usually given.

22. What are dextrans?

The dextrans are high-molecular-weight polysaccharides originally obtained from the juice of sugar beets. The two most commonly used products are dextran-70 (average molecular weight [AMW] = 70,000 Da) and dextran-40 (AMW = 40,000 Da). Because albumin has an AMW of 69,000 Da, dextran-70 appears to be an ideal substitute based on size. However, a more useful measure of size is the number average molecular weight (NAMW), which for dextran-70 may be as low as 39,000 Da.

23. What is hydroxyethyl starch?

Hydroxyethyl starch (Hetastarch) is a synthetic starch with an AMW of 480,000 Da and an NAMW of 69,000 Da. In a review of nine studies, hydroxyethyl starch increased plasma volume by 70–200% of the volume infused, with a mean expansion of 141%.

24. What is the duration of clinical effects of the various synthetic colloids?

- Plasma half-life of dextran-70 is 25.5 hr, and duration of clinical effect is approximately 24 hr.
- Plasma half-life of dextran-40 is 2.5 hr; duration of clinical effect ranges from 20 min (particle sizes of 18,000–23,000) to 12 hr (particle sizes of 55,000_69,000).
- Plasma half-life of hydroxyethyl starch is 25.5 hr, and duration of clinical effect is 12–48 hr.

25. What adverse effects are associated with synthetic colloids?

- The use of dextrans and hydroxyethyl starch is associated with increased risk of bleeding in animals and people. At present, the degree of bleeding abnormalities appears to be related to dosage; such abnormalities are readily reversible. Animals at risk for bleeding include those with thrombocytopenia, abnormal platelet function, von Willebrand factor deficiency, and factor VIII:c deficiency.
- The incidence of anaphylactic reactions (skin erythema, hypotension, respiratory distress, cardiac arrest) to hydroxyethyl starch in humans is estimated at 0.007%. The incidence of dextran anaphylactic reactions in humans varies from 0.03–4.7%. No reports are found in available veterinary literature.
- Dextran-40 is associated with acute renal failure in humans.
- Serum amylase levels in humans rise 2–4 times normal during hydroxyethyl starch infusion and may persist for 5 days. Hyperamylasemia is a normal response to degrade the product and does not indicate that the animal has pancreatitis. One must use serum lipase to diagnose and follow pancreatitis in animals after administration of hydroxyethyl starch.
- Synthetic colloids are contraindicated in animals with congestive heart failure because of the potential for profound volume expansion and edema formation.

CONTROVERSIES

26. Should you use colloids or crystalloids when treating an animal with pulmonary contusions?

The most important consideration in fluid resuscitation of an animal with pulmonary contusions is the potential for increased hemorrhage and thus a worsening of respiratory compromise. In selecting a fluid for pulmonary contusions, one must remember that there is a severe pulmonary capillary leak which would allow even the large colloid molecules to leak into the interstitium. In a meta-study from humans with pulmonary contusions, there is a clear advantage to using crystalloid fluids. The key in treating pulmonary contusions is very careful monitoring.

27. Which fluid is thought to provide a cerebral protective effect following brain injury?

Hypertonic saline (7.5%) is thought to be the fluid of choice in severe head trauma.

28. Which fluid should be used to treat shock—crystalloid or colloid?

The appropriate resuscitation fluid is more than a topic of debate; it is a passionately fought war. The table below provides a brief summary of the salient arguments. As in all wars, the truth is likely somewhere in the middle.

The Colloids vs. Crystalloids War

	CRYSTALLOIDS	COLLOIDS
Hemodynamic effects	Require larger volumes	Direct intravascular volume expansion Smaller volumes required Improve cardiac output Improve oxygen transport
Risk for pulmonary edema	Small risk with excessive hemodilution May cause more edema if capillaries are leaky	Theoretically may leak from the capillaries and promote increased edema Causes no more edema than crystalloids
Clinical outcome	No advantage over colloids in survival (humans)	No advantage over crystalloids in survival (humans)
Expense	Much less expensive than colloids	Significantly more expensive than crystalloids
Conclusions	If the goal is to expand the whole extracellular space, use crystalloids	If the goal is to expand the intravascular volume, use colloids

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15. BLOOD TRANSFUSIONS

Michael S. *Lagutchik*, D.V.M., M.S.

1. What are the immediate treatment priorities in patients with major hemorrhagic shock?

Rapid restoration of intravascular pressures, cardiac output, and blood oxygen content are the immediate priorities in resuscitation from hemorrhagic shock. Administration of blood or blood products is effective in all three areas.

2. What alternatives are available to increase oxygen-carrying capacity of the blood?

Alternatives include homologous and autologous blood transfusions, and red blood cell substitutes (see question 21).

3. What are common causes of blood loss anemia in critically ill dogs and cats?

- Trauma
- Coagulopathies (congenital factor deficiencies, anticoagulants, liver disease)
- Platelet disorders (thrombocytopenia, von Willebrand's disease, drugs, thrombopathies)
- Splenic rupture (trauma, neoplasia, torsion)
- Gastrointestinal hemorrhage (ulceration, neoplasia, endoparasites, foreign bodies, hemostatic disorders)
- Epistaxis (neoplasia, infection, hemostatic disorders)

4. What are the general indications for blood transfusions in critically ill or injured patients?

Red cell transfusion is indicated whenever the oxygen-carrying capacity is insufficient to meet metabolic requirements. Insufficiency may be due to loss of red cells, decreased hemoglobin concentration, or poor tissue perfusion from numerous causes. General indications include acute and chronic blood loss, hemolytic anemias, decreased red cell production, and refractory shock.

5. At what packed cell volume (PCV) should a transfusion of whole blood or packed red blood cells be considered?

The need for transfusion is determined by the time to onset of anemia (acute or chronic), cause and degree of anemia, potential for further loss of blood, response to other supportive therapies, and cardiac, pulmonary, and renal status of the patient. Do not fall into the trap of transfusing at a "magic" number. Evaluate the patient and decide the need for a transfusion based on the patient's need for increased tissue oxygen delivery.

6. What hematocrit value should cause concern about the patient's ability to transport oxygen effectively?

Although somewhat controversial, most authors agree that serious abnormalities related to oxygen transport develop below a PCV of 20% and may be irreversible if allowed to continue uncorrected. Many recommend a cut-off of 20–30%. When the hematocrit is < 30%, ventricular function is depressed, but oxygen extraction and central venous PO_2 remain normal until the

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hematocrit reaches 20%, perhaps even lower. In trauma cases especially, it may be better to transfuse earlier rather than later to avoid a serious game of catch-up.

7. What is a good target hematocrit value when transfusing blood?

See the preceding question. It is seldom necessary, and some argue that it may be detrimental, to transfuse a patient to a normal PCV. As the hematocrit increases, blood viscosity also increases. Increased blood viscosity may not be desirable in a patient with poor tissue perfusion due to shock or acute hemorrhage.

8. List specific parameters that suggest the need for blood transfusion in dogs and cats with acute blood loss.

- Acute loss of > 30% of blood volume (30 ml/kg)
- Packed cell volume (hematocrit) < 20%
- Plasma protein concentration < 3.5 gm/dl
- Ongoing blood loss unresponsive to crystalloid/colloid therapy
- Conditions noted in hypovolemic shock without loss of oxygen-carrying capacity, but, if persistent and unresponsive to therapy, may respond to blood administration
  - Pale mucous membranes
  - Prolonged capillary refill time (> 2.0 sec)
  - Increased heart rate (> 180 beats/min)
  - Increased respiratory rate (> 60 breaths/min)
  - Decreased arterial blood pressure (MAP < 80 mmHg)
  - Decreased central venous pressure (< 0 cmH_2O)

9. What are the current recommendations concerning the need for blood transfusions in people? Are they applicable to veterinary patients?

According to the National Institute of Health Consensus Conference on Perioperative Red Cell Transfusions, attitudes have changed concerning the need for red cell transfusions in people:

- If the hemoglobin is > 10 gm/dl, transfusion is rarely necessary.
- If the hemoglobin is < 7 gm/dl, transfusion is usually indicated.
- If the hemoglobin is > 7 gm/dl, but < 10 gm/dl, use clinical status, mixed venous oxygen tension, and extraction ratio to determine transfusion need.

Although these recommendations probably can be extrapolated to veterinary patients, the criteria described in questions 4–8 are recommended for dogs and cats.

10. Assuming that whole blood transfusion is needed, how do I calculate how much blood to give?

How much do you want to raise the hematocrit? (See questions 5–8.) Once the answer is known, several formulas are available to help decide what volume to administer:

- A quick and reliable method is the "rule of 1's: 1 ml of transfused blood per 1 pound of body weight (BW) should raise the PCV by 1%. This is about the same as 2.2 ml blood/kg BW raises the PCV 1%. Another quick estimation is that a transfusion of 20 ml/kg BW of whole blood or 10 ml/kg of packed red cells should raise the hematocrit 10%.
- Volume of blood to transfuse (ml) = $\frac{\text{BW (kg)} \times \text{desired increase in Hb} \times 70}{\text{donor Hb}}$
- BW (kg) × 90 ml/kg × $\frac{\text{Desired PCV} - \text{Patient PCV}}{\text{Donor PCV}}$

The disadvantage of the second and third formulas is that the donor PCV and/or hemoglobin (Hb) concentration must be known.

11. How fast can I give blood?

The rate depends on the need for speed. Patients in profound hemorrhagic shock with ongoing losses unresponsive to crystalloid and synthetic colloid fluids need blood *now!* Blood administration

should be as fast as possible, using pressure infusors and multiple catheters if necessary. The risks of rapid administration are certainly outweighed by the life-saving benefits. Autotransfusion is an option in addition to blood replacement therapy.

In more routine situations in which blood transfusion is to replace losses that occurred over a longer period, the recommended rate of infusion for whole blood or blood products is 10-22 ml/kg/hr.

12. How is acute hemorrhage managed during surgery?

The first step is to quantify the amount of blood lost (use suction canisters, or estimate that one 4 × 4 gauze sponge contains about 5–10 ml of blood when soaked). Then decide if it is necessary to replace the lost blood. Many healthy animals can safely lose 10% of blood volume acutely, and some authors suggest they may be able to lose 40–50%. Sick animals, however, certainly cannot tolerate such a loss. Initially, treat blood loss with crystalloid volume replacement, recognizing that it takes 3 times as much crystalloid to replace 1 unit of blood. Monitor for hemodilution. If the hematocrit remains above 20%, total protein (albumin) remains above 3.5 gm/dl (1.5 gm/dl), and blood pressure is adequate, blood transfusion usually is not indicated. If these parameters fall below the above levels, or if cardiovascular function deteriorates and is unresponsive to conventional therapy, transfuse with whole blood.

13. What is autotransfusion? How is it done?

Autotransfusion, or autologous transfusion, is the collection and reinfusion of a patient's own blood. Its use in the emergent patient is as a life-or-limb-saving measure to replace severe acute blood loss into a major body cavity (chest or abdominal cavities) when blood products are not available immediately. Such use may gain time and save life while more appropriate measures are instituted. The usual methods of collection include centrifuge-based cell salvage, passive canister collection, and direct aspiration and reinfusion. Three components are essential: appropriate suction that does not damage red cells, filtration of blood to minimize contamination, and anticoagulation. Complications include coagulopathies, sepsis, microembolism, air embolism, and dissemination of malignancy. These risks must be weighed against the potential benefits (i.e., life) in each patient.

14. What are the risks of blood transfusions?

Risks of blood transfusions include acute and delayed hemolytic reactions, localized or systemic anaphylaxis, transmission of infectious agents, citrate toxicity (hypocalcemia), and circulatory overload.

15. What hemolytic transfusion reactions may occur? How do I recognize and treat them?

Acute hemolytic reactions (intravascular hemolysis) to donated blood occur within minutes to hours from the start of the transfusion. Signs include fever, tachycardia, restlessness, vomiting, salivation, tremors, weakness, respiratory distress, acute collapse, hypotension, and seizures. Stop the transfusion immediately, and begin aggressive fluid therapy to maintain blood pressure and renal perfusion.

Delayed hemolytic reactions (extravascular hemolysis) occur from 3 days to 3 weeks after transfusion. Signs include fever, anorexia, and icterus. Laboratory abnormalities include hyperbilirubinemia, hyperbilirubinuria, and anemia. Most delayed reactions are mild, and specific therapy is not required. The anemia that led to the initial transfusion obviously has redeveloped.

16. What immune-mediated (nonhemolytic) reactions may occur? How do I recognize and treat them?

Acute hypersensitivity reactions (anaphylaxis) usually occur almost immediately, up to 45 minutes after a transfusion is started. Signs may include urticaria, pruritus, erythema, emesis, respiratory distress, hypotension, bronchoconstriction, and severe shock, increasing in severity as anaphylaxis develops. Usually, in mild reactions, stopping the transfusion is all that is necessary to alleviate signs. Administration of diphenhydramine or glucocorticoids may help to prevent further complications.

17. Can transfusion reactions be prevented?

The risk can be reduced greatly by following these recommendations:

1. Use universal donors whenever possible.
2. Cross-match all donors with recipients, even universal donors.
3. Store and administer blood and blood products properly.

Some authors advise prophylactic treatment of high-risk patients with diphenhydramine or glucocorticoids, 15–20 minutes before transfusion. No evidence supports the prophylactic nature of this therapy, but the risks are minimal.

18. What are the blood types of dogs? Which are the most immunogenic?

Canine blood types are as follows:

- DEA 1.1
- *DEA 1.2
- *DEA 3
- DEA 4
- DEA 5
- DEA 6
- *DEA 7
- DEA 8

Types with an asterisk are most immunogenic.

19. What type is the universal canine donor?

Canine universal donors are DEA 1.1 negative and preferably DEA 1.2 negative and DEA 7 negative. Blood that is DEA 1.1 positive should be given only to DEA 1.1 positive recipients.

20. What are the blood types in cats? Which is most common?

Feline blood types are A, B, and AB. A is the most common.

21. What new treatment modalities may help to manage patients with blood loss?

The most promising new development available for veterinary use is hemoglobin-based oxygen carrier (artificial blood). Most products under development are polymerized bovine hemoglobin solutions. These solutions have excellent oxygen-carrying capacity, provide excellent colloid osmotic pressure, and thus are effective plasma volume expanders. They also have long shelf lives and low viscosity and are minimally antigenic. The only product currently licensed for veterinary use is Oxyglobin (Biopure Corporation, Cambridge, MA). Although numerous case reports are published in the literature, only a few clinical trials by the manufacturer are available. Oxyglobin is licensed for use in treating acute hemolytic anemia and is undergoing clinical trials in numerous facilities. Hopefully, more definitive data concerning its use, ideal dose, and potential side effects will be published soon. Its high cost may limit clinical use.

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16. BRAIN INJURIES

Wayne E. *Wingfield*, M.S., D.V.M.

1. What are some of the common causes of brain injury in dogs and cats?

- Cardiopulmonary arrest
- Severe hypotension
- Status epilepticus
- Trauma
- Cerebral vascular injury (stroke)
- Thromboembolism

2. What are the intracranial components? Why are they important in discussing brain injuries?

The intracranial components are brain tissue (86%), cerebrospinal fluid (CSF) (10%), and blood (4%). An increase in any one component results in a decrease in cranial vault volume, an increase in intracranial pressure, or both.

3. What is the significance of primary vs. secondary head injury?

Primary injury is direct disruption of brain tissue at the moment of impact. Primary injury may result in contusion, hemorrhage, and/or laceration. In humans, primary injuries account for approximately 50% of deaths due to head injuries. There is no treatment for the sudden mechanical disruption of brain tissue.

Secondary injury refers to delayed insults, both systemic and intracranial. Delayed intracranial hematomas (subdural, epidural, and parenchymal) as well as generalized cerebral edema that results in elevated intracranial pressure. Secondary systemic complications generally result from hypoxemia, increased intracranial pressure, and hypotension leading to decreased perfusion and thus brain ischemia, brain swelling, and possible herniation.

4. What is cerebral perfusion pressure?

Cerebral blood flow is regulated by neuronal stimulation, $PaCO_2$, PaO_2, and pressure autoregulation. Through autoregulation, cerebral blood flow is maintained over a range of mean arterial pressures of 50–150 mmHg. Below and above this range, cerebral blood flow is linearly related to blood pressure. Cerebral perfusion pressure (CPP) is the difference between mean arterial pressure (MAP) and intracranial pressure (ICP).

$$CPP = MAP - ICP$$

An increase in ICP may result in significant changes in CPP. Even temporary occlusion of the jugular vein raises the intracranial pressure. Thus, you should probably avoid inserting a jugular catheter in such animals.

5. What are the mechanisms by which brain injury elevates intracranial pressure?

- Increased CSF volume secondary to obstruction to flow by edema or clot formation
- Increased brain tissue secondary to diffuse or localized edema
- Increased mass secondary to intracranial hematoma formation
- Increased blood volume secondary to loss of autoregulation

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- Increased mass secondary to intracranial hematoma formation
- Increased blood volume secondary to loss of autoregulation

6. How are levels of consciousness described in head injuries?

Levels of consciousness vary from awake to mental depression, delirium, stupor (unconsciousness that is responsive to noxious stimuli), and coma (unresponsive loss of consciousness).

7. How can respiratory patterns help to localize the brain lesion?

Cheyne-Stokes respiratory patterns are rhythmic waxing and waning in ventilatory depth and rate. Severe and diffuse cerebral and diencephalic lesions result in this pattern of respiration in dogs. Hyperventilation is seen with injuries of the midbrain or pons. Obviously, hyperventilation also may result when the animal is in pain, a state of excitement, metabolic acidosis, or respiratory alkalosis. Apneustic (irregular) breathing (often accompanied by bradycardia) is associated with injury to the brainstem.

8. Describe the motor response of a decerebrate animal.

Extensor rigidity is present in both fore- and rearlimbs. The head is thrown back in opisthotonus. The prognosis is extremely grave.

9. What does an animal with decerebellate motor posturing look like?

The forelimbs are extended, the rearlimbs are flexed, and the head is thrown back into opisthotonus.

10. In animals with opisthotonus, extensor rigidity of the forelimbs, and flaccid paralysis of the rearlimbs, where is the lesion?

Trick question! This animal probably has a spinal cord lesion between T3 and L3.

11. If seizures immediately follow trauma, what does it mean?

First, you need to get a good history from the animal's owner. It is possible that the animal has a history of seizures and may well have been treated for seizures. Ask about a history of seizures before you begin to relate the seizures with head injury. Epileptiform seizures associated with head injury usually develop weeks to months (even years) after the trauma. Epileptiform seizures occurring soon after trauma suggest the presence of intraparenchymal cerebral hemorrhage.

12. Describe pupil size, reactivity, and prognosis in head trauma.

SEVERITY	PUPIL SIZE	REACTIVITY	PROGNOSIS
Least severe	Normal (midrange)	Normal	Good
	Bilateral miosis	Poor to nonresponsive	Guarded (variable, depending on other signs)
	Unilateral mydriasis	Poor to nonresponsive (mydriatic side)	Guarded to poor
	Unilateral mydriasis with ventromedial strabismus	Nonresponsive	Guarded to poor
	Normal (midrange)	Nonresponsive	Poor to grave
Most severe	Bilateral mydriasis	Poor to nonresponsive	Poor to grave

13. What is the small animal coma score for evaluating head trauma victims?

The small animal coma score is a modification of the Glasgow coma scale used to monitor human head trauma victims. It is an attempt to standardize the assessment of the depth and duration of impaired consciousness and coma.

The Small Animal Coma Scale for Evaluating Head Trauma Victims

CATEGORY DESCRIPTION	SCORE
Motor activity	
Normal gait; normal spinal reflexes	6
Hemiparesis, tetraparesis, or decerebrate activity	5
Recumbent; intermittent extensor activity	4
Recumbent; constant extensor rigidity	3
Recumbent; constant extensor rigidity with opisthotonus	2
Recumbent; hypotonia of muscles; depressed or absent spinal reflexes	1
Brainstem reflexes	
Normal pupillary light response and oculocephalic reflexes	6
Slow pupillary light response; normal-to-reduced oculocephalic reflexes	5
Bilateral unresponsive miosis; normal-to-reduced oculocephalic reflexes	4
Pinpoint pupils; reduced-to-absent oculocephalic reflexes	3
Unilateral, unresponsive mydriasis; reduced-to-absent oculocephalic reflexes	2
Bilateral, unresponsive mydriasis; reduced-to-absent oculocephalic reflexes	1
Level of consciousness	
Occasional periods of alertness and responsive to environment	5
Depression or delirium; capable of responding to environment	4
Semicomatose; responsive to visual stimuli	3
Semicomatose; responsive to noxious stimuli	2
Comatose; unresponsive to repeated noxious stimuli	1

Total score	**Likely Prognosis**
3–8	Grave
9–14	Poor to guarded
15–18	Good

From Shores A: Treatment and prognosis of head trauma. Proceedings of 13th Kal Kan Symp 29–36, 1990, with permission.

14. How are leaks of the cerebrospinal fluid detected?

CSF leaks through tears in the dura. CSF leaks can be distinguished from blood by the presence of a double-ring sign when applied to filter paper. CSF migrates further than blood, forming a target shape with blood in the center and blood-tinged CSF forming a ring outside the clot. CSF rhinorrhea can be detected by checking the glucose content of the fluid with a Dextrostix or glucometer. CSF contains approximately 60% of serum levels of glucose; nasal mucus does not contain glucose. No data are available to assess the sensitivity or specificity of these tests in dogs or cats.

15. List the cranial nerves, how to test for each, and clinical signs of deficits and abnormal neurologic signs for each.

Examination of the Cranial Nerve Responses in Brain Trauma

CRANIAL NERVE	CLINICAL TEST	NORMAL RESPONSE	CLINCIAL SIGNS OF DEFICITS	ABNORMAL NEUROLOGIC SIGNS
I. Olfactory	Smell food or nonirritating volatile substance	Interest in food Recoil or lick nose in response to volatile substance	Decreased or no ability to smell	No reaction
II. Optic	Obstacle test	Avoidance of ob-obstacles	Visual impairment hesitancy in walking	Bumping into objects No reaction
	Visual placing	Visual placing of limbs		
	Menace reaction	Eye blink		No reaction

Table continued on next page.

Examination of the Cranial Nerve Responses in Brain Trauma (Continued)

CRANIAL NERVE	CLINICAL TEST	NORMAL RESPONSE	CLINCIAL SIGNS OF DEFICITS	ABNORMAL NEUROLOGIC SIGNS
II. Optic *(cont.)*	Point source of light in each eye	Direct and consensual pupillary light reflexes	Dilated pupil (mydriasis)	On affected side, direct pupillary reflex is absent, consensual reflex is present; on normal side, direct pupillary reflex is is present, consensual reflex is absent
III. Oculomotor	Ocular movements in horizontal and vertical planes	Normal ocular excursion	Ventrolateral strabismus Paralysis of upper eyelid (ptsosis)	Impaired movements ments of affected eye
	Point source of light in each eye	Direct and consensual pupillary light reflexes	Mydriasis	On affected side, direct pupillary reflex is absent, consensual reflex is present; on normal side, direct pupillary reflex is present, consensual reflex is absent
IV. Trochlear			Usually not noted	
V. Trigeminal (motor and sensory)	Jaw tone—palpate and observe masticatory muscles	Resistance to opening the jaws; normal muscle contour to skull	Atrophy of masticatory muscles Inability to close jaws with impaired prehension	Lack of resistance; atrophy of muscles
	Palpebral reflex	Eye blink		No reaction
	Corneal reflex	Eye blink		No reaction
	Probe nasal mucosa	Globe retraction Recoil from nasal probe		No reaction No reaction
	Touch face	No reaction to touching face		Intense discomfort to touching face
VI. Abducent	Ocular movements in horizontal plane	Normal ocular excursion	Medial strabismus	Impaired lateral movement of affected eye
VII. Facial	Palpebral reflex	Eye blink	Asymmetry of facial expression	No reaction
	Corneal reflex	Eye blink	Inability to close eyelids	No reaction
	Menace reaction	Eye blink		No reaction
	Tickle ear	Ear flick	Lip commissure paralysis Ear paralysis	No reaction

Table continued on next page.

Examination of the Cranial Nerve Responses in Brain Trauma (Continued)

CRANIAL NERVE	CLINICAL TEST	NORMAL RESPONSE	CLINCIAL SIGNS OF DEFICITS	ABNORMAL NEUROLOGIC SIGNS
VIII. Vestibulocochlear				
Vestibular	Ocular movements in horizontal or vertical plane	Physiologically induced nystagmus (post-rotatory nystagmus)	Nystagmus, head tilt	No reaction, spontaneous positional nystagmus, strabismus (ventrolateral with dorsal head extension)
	Caloric or rotatory test	Same as above	Circling	Same as above
	Righting reactions	Normal righting	Righting reflexes	Same as above
Cochlear	Handclap over ear	Startle reaction; blink; ear contraction	Deafness	No reaction
IX. Glossopharyngeal	Gag reflex	Swallow	Dysphagia	No reaction
X. Vagus	Gag reflex	Swallow	Dysphagia	No reaction
	Laryngeal reflex	Cough	Abnormal vocalizing	No reaction
	Oculocardiac reflex	Bradycardia	Inspiratory distress	No reaction
XI. Spinal accessory	Palpation of cervical musculature	Normal cervical contour and muscle tone	Usually not noted but may see dorsolateral cervical muscle atrophy; torticollis	Muscle atrophy or hypotonia
XII. Hypoglossal	Tongue stretch	Retraction	Deviation of tongue	No reaction
	Rub nose	Lip response		No reaction

16. Do skull radiographs help in the evaluation and treatment of animals with head trauma?

Unfortunately, radiographs provide no evaluation of soft tissue structures within the cranial vault, but they do indicate the presence and severity of skull fractures. Computed tomography (CT) is considered the best means to assess skull fractures and magnetic resonance tomography (MRI) is the best method for visualizing detail of brain parenchymal injury.

17. Describe the essentials of management of head-injured animals.

- Management and protection of the airway
- Controlled ventilation to maintain normal or low $PaCO_2$
- Maintenance of cerebral blood flow
- Treatment of elevated intracranial pressure
- Evaluation and treatment of secondary systemic complications:

Gastrointestinal bleeding	Neurogenic pulmonary edema
Disseminated intravascular coagulopathy	Hypotension secondary to blood loss or spinal shock
	Hypoxemia secondary to thoracic trauma or aspiration

18. What is involved in the initial emergency management of a dog or cat with head trauma?

Follow the system-based priorities. Arterial bleeding, respiratory compromise, cardiovascular function, and hemorrhage and transfusion should be managed before definitive treatment for brain injury. Because hypoxemia and hypovolemia are extremely detrimental to an already compromised brain, oxygen delivery and cardiovascular support are immediate therapeutic requirements.

19. What is known about emergency fluid therapy in animals with brain injury?

The goal of fluid therapy is to administer the minimal amount of fluid necessary to maintain hydration and autoregulatory blood pressure values (50–150 mmHg). The decision to use crystalloid, hypertonic saline, or synthetic colloidal fluids remains extremely controversial. If large volumes of crystalloids (i.e., 90 ml/kg/hr in dogs) are administered, brain edema worsens and results in further increases in intracranial pressure. Hypertonic saline administration in hypotensive small animals increases myocardial contractility and cardiac output, improves peripheral perfusion, increases urine output, and improves mesenteric and coronary blood flow. These effects are transient (15–60 min). Obviously, hypertonic saline is not used in dehydrated animals, animals with uncontrolled hemorrhage or hypernatremia, hyperosmolar animals, or animals with hypothermia, congestive heart failure, or oliguric renal failure. Evidence of ongoing intracranial hemorrhage should raise concern. Concerns over the use of synthetic colloids are directed mainly to leakage from the vessels of the brain. Although hypertonic saline and Hetastarch reduce or prevent brain edema and elevations in intracranial pressure, they fail to increase oxygen delivery and perfusion to damaged brain tissue.

20. So what is the answer? Which and how much fluid should you use in brain trauma?

Intravenous crystalloid fluids are administered at an initial volume not to exceed 20 ml/kg/hr. After this initial bolus of fluids, fluid rates are given using the following formula to provide basal water requirements:

$$\text{ml crystalloid fluids/day} = (\text{body weight [kg]} \times 30) + 70$$

Monitor blood pressure, if possible, and monitor for negative changes in neurologic status during intravenous fluid administration.

21. How do you hyperoxygenate an animal with head trauma?

Methods for supplemental oxygen administration include oxygen cages, nasal oxygen insufflation catheters, and tracheal intubation. Although often mistrusted, the oxygen cage provides a constant concentration of oxygen, the least amount of stress, and the least invasive means of delivery. Nasal insufflation catheters provide oxygen levels of approximately 40% oxygen with flow rates of 50 ml/kg/min. The disadvantages are that the animal often will not tolerate the cannula, patient movement is restricted, and nasal drying and hemorrhage are common.

22. When is ventilator therapy used to reduce intracranial pressure?

Tough decision, with little information in the veterinary literature. Generally speaking, positive pressure ventilation is used whenever an animal cannot ventilate or oxygenate or works excessively to maintain ventilation and oxygenation. Reliable guidelines can be gained only from arterial blood gas values. Hypoventilation is defined as a $PaCO_2 > 60$ mmHg. Inadequate oxygenation is defined as a $PaO_2 < 60$ mmHg. Hyperventilation reduces cerebral blood volume as much as 36%, whereas hypoventilation increases cerebral blood volume as much as 170%. The goal is to maintain the $PaCO_2$ near 25 mmHg, which has been determined to be the optimal $PaCO_2$ for producing cerebrovascular vasoconstriction while still maintaining adequate perfusion to the brain. This effect is mediated through acute alterations in cerebral interstitial fluid pH; therefore, it generally becomes less effective after 48–72 hours. Humidify all oxygen when ventilating an animal. While the animal is ventilated, the head should be at approximately 30° to ensure adequate venous return of blood from the head.

23. How does mannitol decrease the intracranial pressure?

Brain tissue has a slightly greater osmolarity than blood. A gradient of approximately 3 mOsm/L is maintained by the blood–brain barrier. Mannitol is an osmotically active drug that reverses this osmotic gradient and shifts water from the brain to the blood. An increase of osmolarity by 10 mOsm/L removes 100–150 ml of water from the brain. In humans, it is reported that hyperosmolar treatment of elevated intracranial pressure increases the normal serum osmolarity of 290 to a value of 300–315 mOsm/L. An osmolarity < 300 is ineffective; an osmolarity > 315 results in renal and neurologic dysfunction. Such data are not available for dogs or cats.

24. Should mannitol be administered to head-injured dogs and cats?

Administration of mannitol is controversial and may pose inherent risks. The controversy centers largely on the safety of administration of mannitol when intracranial hemorrhage may be undetectable. There are several pitfalls in this scenario:

- Extravascular hemorrhage may increase.
- Increased blood flow may exacerbate hemorrhage.
- More room may be available for extravasation of epidural or subdural hemorrhage.

Of interest, these theoretical contraindications have not been confirmed through experimentation. Focal neurologic deficits may suggest hemorrhage, and mannitol is usually not administered. More commonly, diffuse deficits are noted, suggesting edema; thus, mannitol is given at a dosage of 0.25 gm/kg by slow intravenous injection.

25. Should furosemide be given in head trauma?

In humans with head trauma, furosemide reduces intracranial pressure and improves neurologic outcome. Presumably it exerts its effects by causing diuresis, decreasing cerebrospinal fluid production, and reducing astroglial swelling. Some suggest that mannitol and furosemide have a synergistic effect in reducing intracranial pressure.

26. Should corticosteroids be used in head trauma?

Old habits are hard to break. The primary rationale for glucocorticoid administration is to reduce brain swelling. Unfortunately, glucocorticoids have consistently failed to show any significant beneficial (clinical or experimental) effects on the outcome of animals with brain trauma. In humans, glucocorticoid therapy does not reduce intracranial pressure or cerebral edema or improve overall outcome. Will it do harm? Probably not. If you need an excuse for administering glucocorticoids in head trauma, remember the old adage, "No animal should die without the benefit of corticosteroids."

27. What is the role of barbiturates in the treatment of increased intracranial pressure?

Barbiturates decrease cerebral metabolic rate and cerebral blood flow. Theoretically, they should lower intracranial pressure. To date, their use is controversial.

28. Is dimethyl sulfoxide (DMSO) useful in treating head trauma?

DMSO has been effective in reducing intracranial pressure and improving the outcome of brain injury, both experimentally and clinically. It reportedly exerts a neuroprotective effect by reducing oxygen and glucose requirements of brain tissue, scavenges oxygen free radical species, stabilizes lysosomal membranes, directly decreases brain edema by stabilizing capillary endothelial cells, and indirectly reduces brain edema through antiinflammatory and diuretic properties. DMSO is given at a dosage of 0.5–1.0 gm/kg by slow (30–45 min) intravenous injection every 8–12 hours. Detrimental effects from DMSO include intravascular hemolysis and prolonged bleeding times. If you use DMSO, use it soon after injury and be prepared for its obnoxious smell.

29. How is a patient with a severe brain injury monitored?

Because hypoxemia and hypotension are the main determinants of brain injury, continuous monitoring of arterial and central venous blood pressure, electrocardiography, pulse oximetry, end-tidal capnography, and body temperature are essential.

30. What laboratory parameters should be monitored daily in severe brain injury patients?

Electrolytes, acid–base balance, and glucose should be monitored at least once daily.

31. What factors are useful in establishing a prognosis for brain-injured animals?

Factors such as level of consciousness, brainstem reflexes, motor ability, respiratory patterns, and presence of other injuries help the veterinarian to establish a prognosis. Such signs as coma persisting more than 48 hours despite therapy, decerebrate rigidity, and ataxic or apneustic respiratory patterns in comatose patients usually culminate in permanent dysfunction or death.

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17. ACUTE SPINAL CORD INJURIES

Wayne E. *Wingfield*, M.S., D.V.M.

1. List the common causes of spinal cord trauma in small animals.

- Exogenous causes
  - Automobile trauma
  - Falls
  - Falling objects
  - Projectile wounds
- Endogenous causes
  - Intervertebral disc extrusion
  - Fibrocartilaginous infarct

2. Explain the mechanism of spinal cord trauma.

The spinal cord is encircled by a rigid, inelastic bony encasement (vertebrae). If the spinal canal diameter decreases due to displacement of vertebrae, hemorrhage, or edema, the spinal cord is easily displaced and intraspinal pressure increases. Pressure changes lead to ischemia, further hemorrhage, or edema, all of which lead to a self-perpetuating process of spinal cord damage that often was present with the initial mechanical injury (second injury theory).

3. What are some of the endogenous mediators of the second injury theory in spinal cord trauma?

- Excitatory amino acid neurotransmitters
- Endorphins
- Catecholamines
- Eicosanoids
- Unstable oxygen free radicals

4. Why are endogenous mediators important?

Most current therapeutic efforts are directed at counterbalancing or neutralizing endogenous mediators of cell injury.

5. What are the four major regions of the spinal cord?

1. Cervical (C1–C5)
2. Brachial enlargement (C6–T2)
3. Thoracolumbar (T3–L3)
4. Lumbar enlargement (L4–C5)

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3. Thoracolumbar (T3–L3)
4. Lumbar enlargement (L4–C5)

6. What is Schiff-Sherrington syndrome?

Schiff-Sherrington syndrome is characterized by thoracic limb hyperextension and paraplegia of the rear limbs due to injury to the thoracolumbar spinal cord (T3–L3). The mechanism is based on neurons located in the lumbar spinal cord that are responsible for tonic inhibition of extensor muscle alpha motorneurons in the cervical intumescence. These inhibitory neurons are called border cells, and their cell bodies are located on the dorsolateral border of the ventral grey column from L1 through L7 with a maximal population from L2 through L4. Their axons cross to the contralateral fasciculus proprius of the lateral funiculus, where they ascend to the cervical intumescence. Acute spinal injuries cranial to border cell neurons and caudal to the cervical intumescence result in sudden deprivation of tonic inhibition of cervical intumescence neurons and cause their release. This release results in the extensor hypertonia observed in the thoracic limbs; there are no abnormalities cranial to C5. This posture is usually seen with severe spinal cord injuries.

7. If an animal presents with an inability to use a forelimb and evidence of a Horner's syndrome, what neurologic abnormality is most likely present?

Brachial plexus avulsion.

8. How do you know if you are dealing with a Schiff-Sherrington lesion or a lesion to the cervical spine?

Provide minimal manipulation to the paw of the forelimbs with a pin or mild pressure with forceps to determine whether pain and voluntary motion are present. In the Schiff-Sherrington syndrome, pain and voluntary motion are present in the thoracic limbs and absent in the pelvic limbs. With cervical cord injuries, tone and deficit in pain and voluntary movement are more nearly equal in all four limbs.

9. What is spinal shock?

Spinal shock is a temporary concussive-like condition in which cord-mediated reflexes are absent. It results in complete suppression of all spinal segmental reflexes below the level of a lesion affecting the upper motor neuron (UMN) because of separation from higher centers and from functional disturbances caused by sudden disorganization in the dendritic zone and cell body of the general somatic efferent motor neuron. Spinal shock in domestic animals is of little clinical significance because spinal reflexes are present caudal to the lesion by the time the animal is presented to the veterinarian. Spinal shock appears to last only about 30–60 minutes. This fact is important when the animal presents shortly after the injury. Be sure to reexamine the animal 1–2 hours later to determine the location and extent of the lesion.

10. What parameters should be assessed on physical examination?

The key parameters are the spine itself and the neurologic examination. The spine is carefully palpated to assess tenderness, deformity, and muscle spasm. Because the veterinarian is palpating only one side of the vertebrae, a fracture may still be present even in the absence of tenderness or displacement. During the neurologic evaluation allowances must be made for the fact that the animal may have an unstable vertebral fracture and normal manipulations may be detrimental. Begin the examination in whichever position the animal arrives at the hospital (usually lateral recumbency). First note motor responses that may suggest the presence of decerebrate, decerebellate, or Schiff-Sherrington syndrome. The cranial nerves usually can be assessed accurately but the head must be manipulated with caution because cervical injury is possible. Reflex function of the thoracic and pelvic upside is assessed in the recumbent animal. Check for a panniculus response (cutaneous trunci reflex) and evidence of hyperesthesia. Check for superficial and deep pain responses last. If a spinal cord trauma is suspected at this point, the animal should be stabilized (taped) to a rigid surface (sheet of plexiglass) before further manipulation. Radiographs should be taken as soon as possible to assess for instability, compression, or other injuries to the vertebrae.

11. What neurologic findings suggest complete spinal cord compression along the various vertebral segments?

Neurologic Findings Suggesting Complete Spinal Cord Compression

SEGMENT OF SPINAL CORD	MOTOR	SENSORY	AUTONOMIC
C1–C4	UMN tetraplegia	Anesthesia	Apnea, no micturition
C5–C6	UMN tetraplegia. LMN suprascapular nerve	Anesthesia, hyperesthesia-midcervical	Apnea-phrenic nerve, LMN, no micturition
C7–T2	Tetraplegia or UMN paraplegia, LMN brachial plexus	Anesthesia, hyperesthesia-brachial plexus	Diaphragmatic breathing only, no micturition
T3–L3	UMN paraplegia, Schiff-Sherrington syndrome	Anesthesia	Diaphragmatic breathing, some intercostal and abdominal respiration (depending on level of lesion), no micturition
L4–S1	Paraplegia with LMN lumbosacral plexus	Anesthesia, segmental hyperesthesia	No micturition; with S1 lesion, anal sphincter tone may be atonic
S1–S3	Knuckling of hind foot, paralysis of tail	Anesthesia, segmental hyperesthesia	No micturition, atonic sphincters
Cy1–Cy5	Paralysis of tail	Anesthesia, segmental hyperesthesia	None

C = cervical, T = thoracic, L = lumbar, S = sacral, Cy = coccygeal, UMN = upper motor neuron, LMN = lower motor neuron.

12. What radiographs should be taken of a suspected spinal cord injury?

Two views are mandatory. With the animal taped to a solid surface, such as a sheet of plexiglass, the lateral radiograph is easily obtained without manipulating the animal. If at all possible, the ventrodorsal view should be taken using a horizontal beam from the radiographic machine.

13. Does the radiographic appearance of the vertebral column help with prognosis?

No. The radiograph is a static record of the lesion at the time of the study. It does not assess the degree of displacement of the vertebrae at the time of the injury or before the radiograph was taken. The paraspinal musculature is extremely strong and often can pull displaced vertebrae back to near-normal position before the radiograph is taken.

14. What are the ABCS of interpreting the lateral radiograph of the vertebrae?

A = **A**lignment
B = **B**ones
C = **C**artilage (intervertebral joint spaces and facet joints)
S = **S**oft tissue

15. What initial resuscitative efforts do you administer to an animal with a spinal cord injury?

Spinal immobilization is important to prevent worsening the injury. Airway management is important but is usually not faced by most veterinarians. The animal with a cervical fracture sufficient to paralyze the phrenic nerve often does not arrive at the hospital. Undoubtedly airway management is the most immediate threat to patients with injury to the spinal cord. This threat comes from hypoxemia (hypoventilation) and aspiration pneumonitis. Animals that are mildly hypoxemic may respond to supplemental, nasally administered oxygen. If the lesion is above C5, the animal requires early intubation and assisted ventilation. Fortunately, emergency tracheostomy is

rarely required. Pulse oximetry should be used for continuous assessment of the adequacy of arterial oxygen saturation, and arterial blood gases are used to monitor the partial pressure of oxygen and carbon dioxide.

16. What are the cardiovascular consequences of a cervical spinal cord injury?

Loss of systemic sympathetic vasomotor tone after a cervical injury may result in vasodilation, increased venous capacity, and hypotension. The associated bradycardia should distinguish this reaction from shock due to hemorrhage. Careful administration of crystalloids is usually adequate to correct this relative hypovolemia.

17. How do you decide whether to administer medical or surgical therapy?

Tough question. First it depends on the surgical skills of the veterinarian or the availability of a surgical specialist. Second, there is little objective guidance in the available literature to help make this decision. Most of the veterinary data is derived from anecdotal experiences or extrapolated from research animals or human medicine. The table below summarizes the 1996 guidelines devised by Bagley.

Scoring of Severity of Spinal Cord Injury

SCORE	CLINICAL STATUS	SEVERITY	THERAPY
10	Normal	Least severe	
8	Pain only		Candidate for medical
6	Paresis (walking)		therapy
5	Paresis (not walking)		Candidate for combina-
4	Plegia (micturition, pain intact)		tion of medical and
3	Plegia (no micturition, deep pain intact)		surgical therapies
2	Plegia (deep pain absent < 48 hr)		
1	Plegia (deep pain absent > 48 hr)		Extremely poor prog-
0	Myelomalacia	Most severe	nosis

18. Are corticosteroids indicated in spinal cord injury?

No clinical data are available for veterinary patients. Most recommendations follow published results of the Second National Acute Spinal Cord Injury Study (in humans), which indicate improved neurologic outcome when methylprednisolone is given in a bolus dosage of 30 mg/kg, followed by 5.4 mg/kg/hr for 23 hours. Patients were not cured but demonstrated greater preservation of neurologic function. Veterinarians have modified this approach and give 2 additional dosages of methylprednisolone instead of the constant-rate infusion at a rate of 15 mg/kg IV at 2 and 6 hours. No data are available to note the effectiveness.

19. What are the absolute indications for surgery?

Spinal instability and spinal cord compression.

20. What is tirilazad mesylate?

Tirilazad mesylate is a 21-aminosteroid that is a potent inhibitor of lipid peroxidation. Research in humans has shown some promise for return of motor function when this drug is used. In a clinical trial, tirilazad (2.5 mg/kg every 6 hr for 48 hours), following an initial 30-mg/kg bolus of methylprednisolone, resulted in motor recovery rates equivalent to those in patients who received methylprednisolone for 24 hours. Thus, it appears that spinal injury involves more than lipid peroxidation—or the dosage may be inappropriate. Further trials are ongoing.

21. What is the rationale for using calcium channel blockers in acute spinal cord injury?

The accumulation of intracellular calcium in injured neurons and neuronal death are closely related to the rise in intracellular calcium. Thus far, the use of calcium channel blockers has had mixed results.

22. What other therapies may be tried?

Many drugs, including dimethyl sulfoxide, thyrotropin-releasing hormone (TRH), naloxone, GM-1 ganglioside, GK11, and other corticosteroids have been tried. No results have proved to be effective in reversing the second injury of spinal cord trauma.

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18. PERIPHERAL NERVE TRAUMA

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is the most common cause of neuropathies in animals?

Trauma is the most common cause of neuropathy to peripheral, cranial, and spinal nerves in animals.

2. What are some of the causes of nerve injury?

- Projectiles
- Fractures
- Pressure
- Stretching (see brachial plexus below)
- Mechanical blows
- Iatrogenic causes
  - Surgery
  - Casts and splints
  - Injections

3. Numerous terms are associated with injuries to nerves. For each of the following, provide a working definition in terms of structural damage:

- **Neurapraxia**
  - An interruption in the function and conduction of a nerve, without structural damage.
- **Wallerian degeneration**
  - Axonal necrosis and myelin fragmentation.

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- **Neurotmesis**
  Complete severing of all nerve structures with Wallerian degeneration of the distal nerve stump.
- **Axonotmesis**
  Damage to the nerve fibers results in degeneration, but the endoneurial and Schwann cell sheaths remain intact and provide a framework for axonal regeneration.

4. What two fractures are most commonly associated with neuropathy in small animals?
- Humerus: radial nerve
- Acetabulum: ischiatic (sciatic) nerve

5. Identify the nerves, spinal cord origin, muscles innervated, and clinical signs of injury for each of the thoracic limbs.

Thoracic Limb Nerves and Associated Origin, Muscles Innervated, and Clinical Signs of Injury

NERVE	SPINAL CORD ORIGIN	MUSCLES INNERVATED	CLINICAL SIGNS OF INJURY
Suprascapular	C6–C7	Supraspinatus Infraspinatus	Loss of shoulder extension Muscle atrophy with prominent scapular spine
Axillary	C7–C8	Deltoideus Teres minor Teres major	Reduced shoulder flexion Deltoid atrophy Reduced sensation over lateral shoulder surface
Musculocutaneous	C6–C8	Biceps brachii Brachialis Coracobrachialis	Reduced elbow flexion Loss of bicipital reflex Reduced sensation over medial forearm muscle
Radial	C7–T2	Triceps brachii Extensor carpi radialis Lateral digital extensor Common digital extensor	Reduced extension of elbow, carpus, and digits Loss of extensor postural thrust and limb support Loss of triceps reflex Reduced sensation over dorsal paw and craniolateral forearm surface
Median	C8–T2	Flexor carpi radialis Superficial digital extensor	Reduced flexion of carpus and digits Reduced sensation over palmar paw surface
Ulnar	C8–T2	Flexor carpis ulnaris Deep digital flexor	Reduced flexion of carpus and digits Reduced sensation over caudal forearm surface

6. Which nerves make up the brachial plexus of the thoracic limb?
The brachial plexus is made up of the ventral branches of the sixth, seventh, and eighth cervical and first two thoracic spinal nerves.

7. What is the proposed mechanism of injury leading to brachial plexus root avulsion?
It is speculated that the thoracic limb is abducted severely from the body or the entire shoulder mechanism is driven away from its normal position. This force puts a tremendous tension on the nerve roots, and injury is due to stretching and tearing of the roots within the spinal canal. Nerve roots lack a perineurium and thus are susceptible to stretch injuries. The avulsion is usually intradural, and degenerative changes are characterized by axonal necrosis, myelin fragmentation,

and loss of myelinated fibers. Many fibers are damaged where they penetrate the leptomeninges, resulting in neuroma formation.

8. What clinical signs are associated with a brachial nerve root avulsion?

Clinical signs of brachial nerve root avulsion include various gait abnormalities, depending on the site and extent of damage, and Horner's syndrome due to damage to the sympathetic nerves at their exit point from the spinal canal at the cranial thoracic vertebrae.

9. How do you differentiate brachial nerve root avulsion from radial nerve paralysis?

	BRACHIAL NERVE ROOT AVULSION	RADIAL NERVE PARALYSIS
Location of lesion	Sixth, seventh, eighth cervical and first two thoracic nerves	Seventh, eighth cervical and first two thoracic nerves
Loss of sensation	Any sensory dermatome on thoracic limb	Craniolateral forearm and dorsum of paw
Panniculus reflex	May be absent ipsilaterally	Present
Horner's syndrome	May be present (often only partial)	Absent
Presence of muscle atrophy	Any thoracic limb muscle	Triceps brachii, carpal extensors

10. What is the likelihood of return of function in a thoracic limb with brachial plexus avulsion?

The prognosis should be considered guarded to poor. In one study, 28% (8 of 29 dogs) regained reasonable return of function of the affected limb 4 or more months after injury.

11. What is the treatment for brachial nerve root avulsion?

There is no practical means to affect return of function. Assuming no evidence of infection, self-mutilation, or limb trauma, it is reasonable to wait 4–6 months before considering amputation. Some may choose transposition of the bicipital tendon and carpal fusion as alternatives to amputation, but long-term studies are unavailable to review expected results.

12. Identify the nerves, spinal cord origin, muscles innervated, and clinical signs of injury for each of the pelvic limbs.

Pelvic Limb Nerves and Associated Origin, Muscles Innervated, and Clinical Signs of Injury

NERVE	SPINAL CORD ORIGIN	MUSCLES INNERVATED	CLINICAL SIGNS OF INJURY
Femoral	L4–L6	Iliopsoas Quadriceps Sartorius	Inability to extend the stifle or bear weight Loss of patellar reflex Reduced sensation over medial paw, hock, stifle, and thigh surface
Obturator	L5–L6	External obdurator Pectineus Gracilis	Inability to abduct hip or thigh (animal does splits on smooth surfaces)
Sciatic	L4–S1	Biceps femoris Semimembranosus Semitendinosus	Inability to flex the stifle Loss of reflexor reflex
Tibial	L6 or 7–S1	Gastrocnemius Popliteus Deep digital flexor Superficial digital flexor	Inability to extend hock or flex digits Reduced sensation over plantar paw surface Loss of gastrocnemius reflex
Common peroneal	L6-7–S1	Peroneus longus Lateral digital extensor Cranial tibial	Inability to flex hock or extend digits Knuckling of dorsal paw Reduced sensation over craniodorsal paw, hock, and stifle surface

Table continued on next page.

Pelvic Limb Nerves and Associated Origin, Muscles Innervated, and Clinical Signs of Injury (Continued)

NERVE	SPINAL CORD ORIGIN	MUSCLES INNERVATED	CLINICAL SIGNS OF INJURY
Pudendal	S1–S3	External anal sphincter Striated urethral muscle	Loss of anal reflex and bulbocavernosus reflex (males) Reduced sensation to perineum
Pelvic plexus (parasympathetic)	S1–S3	Smooth muscle of rectum and bladder	Urinary incontinence

13. What determines a nerve's regenerative ability? If it occurs, at what rate does the nerve grow?

The ability of a nerve to regenerate is directly proportional to the continuity of its connective-tissue structures. In neurapraxic and axonotmestic lesions, in which the endoneurial connective tissue and Schwann cells remain intact, the potential for axonal regeneration is good. In neurotmesis, axonal regeneration is thwarted by lack of connective-tissue tubes and scar tissue. Once the axon has grown past the point of injury and penetrates a Schwann tube in the distal nerve stump, remyelination occurs. Axonal regeneration occurs at a rate of 1–4 mm/day.

14. How can a diagnosis of neuropathy be confirmed? When should this diagnostic test be run?

Electrodiagnostic testing is most helpful in evaluating the integrity and severity of nerve injury. Increased insertional activity, positive sharp waves, and fibrillation potentials are detected at 5–7 days after injury.

15. What is the treatment for peripheral nerve injury?

Realistically, little can be done by most veterinarians. Surgical anastomosis of a severed nerve is an extremely difficult procedure, and few veterinary surgeons have the necessary skill. Most animals with peripheral nerve injuries are monitored for infection, self-mutilation, and complications of injury. Ultimately, amputation is often the treatment provided.

16. What immunosuppressive drug shows promise in accelerating nerve regeneration?

Cyclosporin A.

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19. EXTREMITY TRAUMA

Wayne E. *Wingfield*, M.S., D.V.M.

1. What are the immediate treatment priorities in an open fracture?

Open fractures are considered orthopedic emergencies. If you find a break in the skin, it should be assumed to communicate with the fracture until proved otherwise. Immediate care includes the following:

- Application of a sterile pressure dressing to control hemorrhage, if necessary
- Assessment for neurovascular damage
- Management of pain
- Careful removal of hair surrounding the open fracture
- Debridement of foreign debris and dead tissue at the fracture site
- Thorough irrigation of the site with copious volumes of sterile saline
- Culture of the wound site
- Application of Betadine dressing to cover the wound
- Application of splint, if possible
- Institution of intravenous antibiotics (cephalosporins)
- Consultation with a surgical specialist

2. How are open fractures classified?

TYPE	MECHANISM	SOFT TISSUE OR BONE DAMAGE	COMMON APPEARANCE OF FRACTURE	RELATIVE RISK OF INFECTION
I	Bone fragment protrudes outward from within	Minimal	Transverse, oblique	1
II	Penetrating external wound contacts bone	Moderate	Comminution	2
III	Several external forces cause wound	Severe	Severe comminution	4

3. What rule should be applied in splinting a fracture?

Immobilize the joint above and the joint below the fracture.

4. Which fractures are more likely to be open fractures in dogs and cats?

The radius/ulna and tibia/fibula are the long bones most likely to have an open fracture. Because of their proximity to the skin, you should treat the fracture as if it were open to the air with any break in the overlying skin.

5. What neurologic deficit is most likely to be seen with a humeral shaft fracture?

The radial nerve may be stretched (neurapraxia) or lacerated. If so, the patient cannot extend the carpus and forefoot. The dorsum of the paw is anesthetic, and self-mutilation often ensues. In checking for superficial pain via the superficial radial nerve, it is imperative to avoid dermatomes innervated by the ulnar and median nerves.

6. What is a Monteggia fracture?

A fracture of the proximal one-third of the ulna with radial head dislocation, usually anterior, constitutes a Monteggia fracture.

7. What are the major complications in pelvic fracture?

- Urologic injuries
- Hemorrhage
- Narrowing of pelvic canal
- Osteoarthritis when fractures involve the acetabulum
- Urinary incontinence with sacroiliac fractures

8. What is a greenstick fracture?

A greenstick fracture is caused by an angular force applied to a long bone with bowing of one side of the cortex and fracture of the other. They are sometimes called incomplete fractures and are more likely in younger animals because of their more elastic bones.

9. What is the Salter-Harris classification of fractures?

The Salter-Harris (SH) classification is a method of classifying epiphyseal injuries. Any epiphyseal injury may result in growth disturbances, and the animal's owner should be so informed. The following descriptions are used in the SH classification:

Salter-Harris Classification of Epiphyseal Injuries

TYPE	DESCRIPTION
I	Fracture extends through the epiphyseal plate, resulting in displacement of the epiphysis.
II	As in type I, with the additional fracture of a triangular segment of metaphysis.
III	Fracture line runs from the joint surface through the epiphyseal plate and epiphysis.
IV	Fracture, as seen in type III, passes through the adjacent metaphysis.
V	Crush injury of the epiphysis; may be difficult to determine with radiographic examination. Look for significantly narrowed epiphyseal space, using opposite leg for comparison.

10. How do you initially manage fractures of the metacarpal/metatarsal or phalangeal bones?

All have the potential of being open fractures. Pain relief and splinting are important initial treatments, followed by careful assessment for evidence of tendon injuries.

11. How do you initially manage carpal or tarsal fractures?

Open fractures are managed as described above. With closed fractures, splinting and consultation with an orthopedic specialist are the best strategies.

12. With coxofemoral luxation, in which direction do the femoral head and neck normally move?

In a cranial and dorsal direction.

13. When do you attempt closed reduction of coxofemoral luxation?

If you expect to have success in replacing a coxofemoral luxation via closed reduction, the procedure should be done within the first 24 hours after trauma. The animal also should be stable enough to withstand general anesthesia.

14. What is an Ehmer sling?

The Ehmer sling is used to hold a coxofemoral luxation in place after reduction.

15. Why take postreduction radiographs in luxations of the coxofemoral or elbow?

You need confirmation that the reduction was successful. Reduced joints may luxate again.

16. Why do you usually replace an elbow luxation earlier than a coxofemoral luxation?

Pain seems to be a bigger problem with elbow luxations. Unless you can reduce the fracture, it is sometimes difficult to resolve the clinical signs of shock.

17. Are shoulder luxations common? How are they usually managed?

Luxations of the scapulohumeral joint are not common in dogs and cats. Management includes a thorough neurologic assessment followed by surgical repair.

18. When is a Velpeau sling useful?

A Velpeau sling is useful in the immobilization of a scapular fracture.

19. Do pelvic fractures require surgical repair?

Surgery is indicated for the following reasons in pelvic fractures:

- Fractures of the acetabulum involving weight-bearing surfaces of the acetabulum
- Instability of the sacroiliac joint(s)
- Narrowing of the pelvic canal, as seen with multiple pelvic fractures
- Fractures of the ischium resulting in loss of hamstring muscle function

20. How do you manage a patient with a fractured head or neck of the femur?

Controversial issue. Ideally one would surgically repair the fracture to restore the functional coxofemoral joint. Unfortunately, most animals also lose the blood supply to the capital epiphysis; thus, avascular necrosis results. If surgical reduction is not successful, one can always resort to a femoral neck osteotomy or, more rarely, consider insertion of a prosthetic device.

21. How would one manage a gunshot wound to a joint?

Generally treatment of all open joint injuries should include broad-spectrum antibiotics before, during, and after arthrotomy, surgical debridement and irrigation, and primary closure of the wound, whenever possible. All retained intrasynovial shot or fragments should be removed. Not only do they cause mechanical dysfunction, but the lead is dissolved by the synovial fluid and becomes deposited in subsynovial tissues, causing subsequent periarticular fibrosis. The toxic action of lead on joint cartilage may also cause chondrolysis and, eventually, severe arthritis.

22. What are the complications of flail chest? How is it treated?

Rib fractures are reported in 25% of trauma patients. When rib fractures are found, internal thoracic damage should be assumed. Isolated rib fractures are rarely of concern. Flail chest occurs when multiple adjacent ribs are fractured in two places, creating a free-floating section of chest wall. Severe respiratory signs result from paradoxical motion of the unstable segment, underlying thoracic trauma, and marked hypoventilation due to pain. Treatment should be directed at resolving the underlying pulmonary contusions and draining air or fluid. Conservative treatment of the flail segment consists of local intercostal nerve blocks and pain management. Fixation is rarely used to stabilize the flail segment.

23. In birds, is immediate surgical repair of a fracture necessary?

Many birds that present with fractures have been ill and in a catabolic state for some time. Presurgical conditioning tremendously increases surgical success rates. Temporary splinting of fractures followed by cage rest, fluid therapy, and possibly tube feeding for 24 hours before fracture repair may be indicated. The goals of presurgical treatment are to maintain or improve cardiovascular and renal output, to revitalize diseased or damaged organs, to treat microbial infections, to ensure proper oxygen transport throughout the body, and to minimize the risk of any problems during surgery.

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20. ABDOMINAL INJURIES

Wayne E. *Wingfield*, M.S., D.V.M.

1. What are the two major traumatic abdominal injuries?

- Blunt trauma
- Penetrating trauma

2. What is the pathophysiology of blunt abdominal injuries?

Blunt trauma involves a combination of crushing, stretching, and shearing forces. The magnitude of these forces is proportional to the mass of the objects, rate of change of velocity (deceleration vs. acceleration), direction of impact, and elasticity of the tissues. Blunt trauma results when the sum of the forces exceeds the cohesive strength and mobility of the tissues and organs in the abdomen. When high energy is transferred to the abdomen, a pronounced rise in intraabdominal pressure may result in rupture of hollow organs or produce solid-organ burst injuries. In addition, organs may be trapped between the thoracic cage or vertebral column, thus resulting in crush injuries. Some organs may be avulsed from their vascular pedicles with abrupt shearing forces.

3. Describe the pathophysiology of penetrating abdominal injuries.

When the abdomen is penetrated, energy is dissipated along the path of the penetrating object. Firearm injuries are especially prone to energy transmission because the kinetic energy is proportional to the mass (m) and velocity (v):

$$KE = MV^2/2$$

An increase in mass of a given missile by a factor of 2 doubles the kinetic energy, whereas doubling the velocity of the bullet quadruples the kinetic energy. In addition, the physical characteristics of the bullet determine the efficiency of energy dissipation. Soft lead or hollow-point bullets mushroom, fragment, and tumble, whereas jacketed bullets tend only to spiral. Low-velocity projectiles directly crush and tear, whereas high-velocity bullets induce variable tissue cavitation as well. The extent of cavitation is governed by the rate of energy dissipation and the physical characteristics of the tissues. Solid, inelastic organs such as the liver, spleen, and kidney are more susceptible to cavitation than more pliant tissues such as the lung or skeletal muscle. Shotgun wounds involve a group of pellets of varying sizes and number. The pellets disperse as a function of distance and length of taper of the gun barrel. Because of their spherical shape, pellets rapidly disperse their velocity over distance. Unless the shotgun is fired at close range, most pellets do minimal injury.

4. Should abdominal and thoracic injuries be considered separately?

No. The diaphragm permits significant transmission of force between the abdomen and thorax. Multiple organ system injury is most likely with blunt abdominal trauma.

5. What are the most common physical findings associated with blunt abdominal injury?

Abdominal tenderness and guarding, abdominal bruising, hemodynamic instability, and increasing girth dimensions are characteristic of abdominal injuries. In human adults, each inch of increase in girth may represent 500–1000 ml of blood. Other reports in humans suggest that abdominal distention is not a sensitive indicator of hemoperitoneum. No information is available for veterinary patients. Of interest, 20–40% of human patients with abdominal injury are said to be asymptomatic. This is true in veterinary patients as well. Considering the forces of injury in proportion to body size, the occurrence of abdominal injuries may be even higher.

6. Which abdominal organs are most commonly injured in blunt abdominal trauma?

No information is currently available in veterinary patients. In humans, the spleen is reported to be most commonly injured. However, because CT scans are more commonly used for evaluation of humans, the liver appears to be more frequently injured but requires operative intervention less often.

7. Which diagnostic tools are most useful for the initial evaluation of blunt trauma?

Abdominocentesis is one means for confirming abdominal injury. A four-quadrant tap is performed, and, from the fluid obtained, packed-cell volume, total solids, cytology, blood urea nitrogen (or creatinine), and perhaps total bilirubin should be requested.

Diagnostic peritoneal irrigation is useful when the abdominocentesis has been unfruitful and the index of suspicion for blunt abdominal injury is high.

Abdominal radiography is rarely fruitful in blunt abdominal injuries. If fluid is present, you still need abdominocentesis for a diagnosis. In addition, radiography should always precede abdominocentesis or irrigation. These invasive procedures may introduce atmospheric air and thus complicate diagnosis of a ruptured hollow organ.

Ultrasonography is becoming more popular for initial evaluation of blunt abdominal trauma. In humans, ultrasonography is about 95% sensitive to significant hemoperitoneum. The procedure is safe, noninvasive, and nonionizing. Unfortunately, ultrasonography cannot reliably stage solid-organ injuries or reliably assess hollow-organ perforations. Ultrasonography will probably supplant diagnostic lavage in certain instances.

Computed tomography (CT) in humans currently is an important diagnostic adjunct in early evaluation of abdominal injuries. CT has unquestioned specificity for organ injuries. The obvious limitation to use of CT in veterinary medicine is lack of available instruments. As CT instruments become more widely available, especially in large metropolitan areas, CT will assume a larger role in the diagnosis of abdominal trauma.

8. What is the "boy scout test"? How did it get its name?

The boy scout test involves placing a drop of abdominocentesis fluid on a glass slide, carefully heating the slide with a flame, and smelling for ammonia released with heating. The name comes from an age-old tradition of boy scouts putting out their campfire by urinating on the coals!

9. What constitutes a positive test for blood during abdominocentesis or irrigation?

When the packed cell volume (PCV) of the blood from centesis exceeds the packed cell volume from a peripheral vascular sample, the injury usually involves the liver, spleen, and, rarely, kidney. Centesis PCV is higher than peripheral vascular samples because of the higher PCV in splenic tissue and the fact that when whole blood is spilled into the abdomen, the peritoneal surface resorbs water and electrolytes immediately, whereas the red blood cells may require up to 2 weeks to be absorbed.

In observing for blood from irrigation procedures, one subjective criterion has been the ability to read newsprint through intravenous (IV) tubing containing the fluid. Others believe that a quantitative red blood cell count of 100,000/mm^3 or a white blood cell count of 500/mm^3 is positive for significant abdominal hemorrhage. In humans, lavage levels of amylase and alkaline phosphatase are reported to have a 95% specificity for small bowel perforation.

Criteria in Humans for a Positive Diagnostic Peritoneal Lavage

SAMPLE	POSITIVE	EQUIVOCAL
Abdominocentesis		
Blood	> 10 ml	—
Fluid	Enteric contents	—
Abdominal irrigation		
Red blood cells	> 100,000/mm^3	> 20,000/mm^3
White blood cells	—	> 500/mm^3
Enzyme	Amylase > 20 U and alkaline phosphatase > 3 IU	Alkaline phosphatase < 3 IU
Bile	Confirmed biochemically	

10. How do you diagnose urologic trauma with abdominocentesis or irrigation?

The traditional confirmation of urine in the abdominal cavity is an elevated creatinine level. Urea nitrogen is as accurate as creatinine for diagnosis of acute urologic injury.

11. Which other diagnostic tests are useful in urologic injury?

Contrast studies of the urologic system are required before surgical exploration. A complete evaluation includes the following radiographic assessment:

- Excretory urograms assess the kidneys and ureter, and contrast material empties into the bladder as well.
- Positive contrast urethragrams in male dogs or cats are advised if a ruptured urethra is suspected. One needs to consider mixing the contrast agent with an agent such as K-Y jelly to increase adherence of the material to the urethral mucosa.
- Positive and/or negative cystograms are used to assess the urinary bladder.

12. Does passing a urinary catheter rule out a ruptured urethra?

No. In fact, passing a urinary catheter in a ruptured urethra may lead to either complete separation of the torn urethra or passage of the catheter into cavernosum tissue and the possibility of air embolism if air is injected.

13. Does passing a urinary catheter and retrieving urine rule out a ruptured bladder?

No. Most ruptures are on the cranial-dorsal portion of the bladder. A catheter can easily be inserted into the bladder where urine may still reside. Aspiration of urine tells nothing about whether the bladder is intact.

14. How do you manage a patient with a positive centesis and penetrating abdominal injury?

Surgical laparotomy.

15. Describe the management of an animal with a penetrating wound when abdominocentesis and lavage are negative.

If abdominal radiographs taken before centesis show free air within the peritoneal cavity, surgical laparotomy is indicated. If the abdominal fluid collected via centesis has few white blood cells, repeat the abdominocentesis about 4 hours later. If the white count is still elevated or has risen, surgical exploration is indicated. Penetrating wounds into the peritoneal cavity have the potential of significant organ injury. Such animals should be hospitalized for observation.

16. How are urologic injuries managed?

During the first 12–24 hours, if the abdominal cavity is drained of urine, the animal may be a more respectable anesthetic risk. Ultimately, surgery is the treatment of choice.

17. Which abdominal injury may escape diagnosis until several weeks after the insult?

We probably miss many abdominal injuries. The one that is often overlooked is injury to the common or major bile duct. In such cases, bile continues to effuse into the peritoneal space, and it may be 3–4 weeks before icterus is identified clinically. To avoid the embarrassment of missing this diagnosis, run a bilirubin test on any blood from abdominocentesis or lavage. If the total bilirubin of the centesis fluid is greater than the peripheral blood bilirubin, suspect an injury to the biliary tree. Surgery is not considered an emergency but should be done soon after diagnosis. It is often technically difficult, and one should consider referring this animal to a surgical specialist.

CONTROVERSY

18. Should you use a surgical or conservative approach in animals with hemoabdomen secondary to trauma?

Surgeons, of course, want to explore any animal with hemoabdomen. Unfortunately, once the surgeon takes the animal, which is at high risk for anesthetic complications, to the operating table

and opens the abdomen, often the only result is confirmation of hemoabdomen. Some surgeons remove a damaged spleen, but most traumatized spleens have already clotted by the time of surgery. Suturing of the liver is an inexact, frustrating experience. Again, the bleeding is generally well controlled before surgery. Without doubt, if a kidney is avulsed from the aorta, surgery may be life-saving.

Conservative management of the hemoabdomen appears anecdotally to be more successful than surgery. Crystalloids, occasionally colloids, and whole blood transfusions are administered to stabilize the animal hemodynamically. In addition, if there is no evidence of severe thoracic injury or diaphragmatic hernia, a circumferential compression bandage is applied to the abdomen. The idea behind this approach is simply to compress the abdominal organs and thus control hemorrhage. Currently, abdominal compression bandaging and intensive fluid therapy are the only techniques used for hemoabdomen secondary to trauma.

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21. PAIN MANAGEMENT IN EMERGENCIES

Peter W. Hellyer, D.V.M., M.S., and Ann E. Wagner, D.V.M., M.S.

1. What are the benefits of effective pain management in emergency patients?

Improving patient comfort after trauma or surgery has important benefits. Unrelieved pain may induce a state of distress in which the animal diverts an excessive amount of energy away from healing simply to cope with the pain. Effective pain management reduces anxiety, decreases the stress response with its associated hormonal and metabolic derangements, and allows the patient to get the rest needed for more rapid recovery. The benefits of effective pain management on recovery after trauma or surgery have been well documented in human medicine, and anecdotal observations support a similar beneficial effect in veterinary patients. Shortened stays in the intensive care unit and a more rapid return to normal function provide evidence that effective pain management may have economic as well as medical benefits in people. Although not documented, similar benefits may occur with animals.

2. What are some of the most painful injuries or procedures that require analgesic treatment?

Trauma (particularly with extensive musculoskeletal injuries), pancreatitis, peritonitis, and intervertebral disc disease are a few of the conditions that often result in distressing levels of pain in animals. Numerous surgical procedures also induce severe pain, particularly amputations,

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Trauma (particularly with extensive musculoskeletal injuries), pancreatitis, peritonitis, and intervertebral disc disease are a few of the conditions that often result in distressing levels of pain in animals. Numerous surgical procedures also induce severe pain, particularly amputations,

proximal limb and pelvic orthopedic procedures, thoracotomies, surgeries of the cervical spine, and auricular and perianal surgeries.

3. Should pain management be considered of secondary importance to treating the primary emergency problem(s)?

There is no question that pain management must be considered in the context of overall patient management. In many emergency situations, stabilizing the cardiopulmonary systems to ensure adequate oxygen delivery and to prevent organ failure or cardiovascular collapse is the highest priority. Similarly, careful physical examination and a minimal database are essential to formulating an initial differential diagnosis. Nevertheless, the judicious use of analgesics should be incorporated into the initial care plan for animals in pain. All too often pain relief is not considered until long (hours or days) after the animal may have benefited most from alleviation of pain.

4. Under what circumstances are analgesics contraindicated in emergency patients?

Analgesic therapy is contraindicated during the initial phases of resuscitation in an animal with cardiovascular collapse. Once the animal is stabilized, appropriate analgesic therapy can be instituted. There may be contraindications to the use of specific drugs, depending on the animal's underlying condition and health status. For example, most of the currently available nonsteroidal antiinflammatory drugs are contraindicated in animals with concurrent renal disease, gastrointestinal bleeding, or coagulopathy. Similarly, opioid use may be contraindicated in patients at risk of brainstem herniation secondary to increased intracranial pressure unless ventilation can be supported.

5. What are the reasons for withholding analgesia from an animal in pain?

In many cases, concern for patient health is the main reason for withholding analgesia, particularly in emergency situations in which the animal has not been stabilized. All of the analgesic drugs have potential adverse effects that must be taken into account before administration to compromised animals. Inexperience with analgesic use and an overstated incidence of adverse side effects (particularly with the opioids) often lead to excessive caution. Traditional beliefs that relieving pain leads to excessive activity in an animal are also cited as a reason to withhold analgesia. Unfortunately, the inability of caregivers to recognize the clinical signs of pain and to appreciate the importance of pain to the patient are also primary reasons why analgesic therapy may be withheld in both human and veterinary medicine. The actual or perceived increase in drug costs is another reason.

6. Do veterinarians routinely provide aggressive analgesic therapy to traumatized and suffering animals?

To date, no comprehensive studies have evaluated the prevalence of use of analgesics in private veterinary practice. Over the past decade veterinarians have increasingly recognized that alleviation of pain is an important therapeutic goal. Still there remains an entire spectrum of views among veterinarians and veterinary staff about the necessity of alleviating pain. Considering the well-documented and widespread practice of either withholding or grossly underdosing analgesic therapy in humans, it is not surprising that veterinarians do not have a uniform appreciation for the importance of pain management.

7. Providing emergency therapy for animals is already expensive. Does analgesic therapy greatly increase the cost?

Selection of the specific analgesic drug and/or technique largely influences the costs of analgesic therapy. For example, oxymorphone is more expensive than morphine even though both drugs provide equivalent analgesia with similar durations of action. The increased costs associated with morphine or fentanyl administration are often insignificant compared to the overall costs of treating a patient with intensive supportive care over a 24- or 48-hour period. Furthermore, anecdotal reports indicate that many clients are willing to pay extra to ensure that their pet receives adequate pain relief during hospitalization.

8. What are the clinical signs of acute pain in dogs?

The clinical signs of acute pain in dogs are often not specific and may be obtunded in a critically ill or traumatized patient. Accordingly, it may be necessary to treat for pain regardless of clinical presentation, provided the patient's vital signs are stable. Vocalization may indicate pain in dogs; however, it is an insensitive and nonspecific indicator. Pain is frequently associated with abnormal activity, which may appear as either an increase or a decrease in activity. Dogs may appear restless, agitated, or even delirious; or they may be lethargic, withdrawn, dull, or depressed. Such dogs may not pay attention to environmental stimuli. The normal sleep/wake cycle may be disrupted, so that less sleep than normal is obtained. Normal activity such as grooming or eating may decrease or stop. Dogs may bite, lick, chew, or shake painful areas.

Dogs may adopt abnormal body postures in an attempt to relieve or cope with pain in a given area. For example, dogs with abdominal pain may assume a posture with a rigid torso and arched back. Dogs with thoracic pain may be reluctant to lie down despite obvious exhaustion. Disuse or guarding of a painful area is a fairly reliable indicator of pain. The dog's gait may be abnormal, or the dog may appear much more rigid than normal.

Interactive behaviors are frequently changed in painful animals. Dogs may become more aggressive and resist handling or palpation. In contrast, they may become more timid and seek increased contact with caregivers. Although dogs do not have the same degree of motor control over their facial muscles as primates, changes in facial expression can be used in some dogs to detect pain. The dog may hold its ears back or in a downward position. The eyes may be wide open with dilated pupils or partially closed with a dull appearance. Many dogs display a fixed stare into space, apparently oblivious to their surroundings. Some dogs may display an uncharacteristic grimace.

Tachypnea, tachycardia, hypertension, dilated pupils, and salivation are physiologic signs suggestive of pain. Tachypnea, tachycardia, and hypertension are less likely to be observed in conscious patients than in patients under inadequate general anesthesia.

9. If a dog is not vocalizing, does it mean that the dog is not in pain?

No. Vocalization is neither a specific nor sensitive indicator of pain. Stoic dogs that do not routinely vocalize may have severe pain without making any sound. Vocalization has been shown to be the number one clinical sign in dogs that prompts administration of analgesic drugs in the postoperative period. Thus, animals that do not vocalize are much more likely to receive inadequate or no pain relief, regardless of degree of pain. In contrast, some dogs will vocalize continuously even though there is no reason why they should be in pain. Individual breed differences may complicate the interpretation of vocalization. For example, "Northern Breeds" (i.e., Huskies, Malamutes) frequently vocalize and the vocalization often becomes worse after the administration of opioid analgesics. Dogs that respond to analgesic therapy with increased vocalization are often administered acepromazine concurrently.

10. Other than pain, what might tachycardia and tachypnea indicate in the postsurgical or traumatized patient?

Cardiopulmonary abnormalities, such as hypotension, anemia, thromboembolism, pneumo- or hemo- thorax, pulmonary edema, any cause of hypoxemia, or sepsis should be ruled out before assuming that the physiological alterations are solely due to pain.

11. Are the clinical signs of acute pain different in cats and dogs?

Although dogs and cats may express similar clinical signs, it is often more difficult to evaluate the degree of pain in cats. Vocalization is much less common in cats than dogs. The clinical signs of pain in cats are frequently subtle and may be characterized as a lack of activity. The cat may sit in the back of the cage and avoid interaction with caregivers. At the other end of the behavioral spectrum, some cats in pain thrash around the cage violently. This response to pain probably occurs more commonly in young healthy cats that have undergone a painful procedure (e.g., declawing).

12. Are the outwardly recognizable clinical signs of pain ever obtunded by the underlying disease process?

Yes. Trauma, major surgery, and metabolic derangements may blunt an animal's behavioral response to pain. Lack of overt signs of pain (e.g., vocalizing, thrashing) does not confirm that the animal is not in pain. On the contrary, some animals with severe pain that are obtunded become much more alert and interactive once effective analgesia has been administered.

13. Does the routine use of analgesics mask clinical signs that may indicate deterioration in the animal's health?

The likelihood that analgesic therapy will mask deterioration of health status in dogs and cats is probably small, particularly if the animals are closely monitored. However, it is certainly possible that analgesics may mask some clinical signs that signal the need to alter the current course of therapy. For example, the administration of potent analgesics to animals with abdominal pain may make it more difficult to determine if the animal requires an exploratory laparotomy. Similarly, neurologic examination of animals with CNS disease (brain tumor, head trauma) may be more difficult if the animal becomes more obtunded after opioid administration. Dogs and cats that sleep after administration of an analgesic may be easier for a busy nursing staff to overlook. Caregivers may assume that the animal is comfortable and stable, whereas in fact the animal's medical condition is deteriorating.

14. What classes of drugs are available to treat acute pain in emergency patients?

Opioids (morphine, oxymorphone, fentanyl, butorphanol), local anesthetics (lidocaine, bupivacaine), nonsteroidal antiinflammatory drugs (flunixin meglumine, ketoprofen, carprofen), and alpha-2 agonists (xylazine, medetomidine) may be used to treat acute pain in dogs and cats.

15. Describe the potential adverse effects of alpha-2 agonists in emergency patients.

The alpha-2 agonists may elicit marked cardiopulmonary effects in compromised animals, particularly when administered intravenously. Bradycardia, atrioventricular blocks, and decreases in myocardial contractility contribute to significant decreases in cardiac output. Correcting alpha-2 agonist-induced bradycardia with an anticholinergic does not ensure a return of cardiac output. The IV administration of alpha-2 agonists may cause arterial constriction, transiently increasing arterial pressure at the expense of forward flow (perfusion). This initial increase in arterial pressure may be followed by a sustained period of hypotension. Alpha-2 agonists predispose the myocardium to ventricular dysrhythmias in small animals, particularly in the presence of hypoxemia, acid-base disturbance, and electrolyte abnormalities. Depression of CNS respiratory centers may lead to hypoventilation, hypercapnia, and hypoxemia. Because of the marked cardiopulmonary effects of these drugs, alpha-2 agonists are generally reserved for animals in which all other analgesic therapies have failed.

16. Should nonsteroidal antiinflammatory drugs (NSAIDs) be routinely used in traumatized or emergency patients in pain?

The currently available NSAIDs are only effective in the treatment of mild-to-moderate pain; therefore they have limited utility in animals with severe trauma or pain. The well-established side effects of gastrointestinal ulceration, decreases in renal blood flow, and coagulopathies are due to inhibition of prostaglandin synthesis. Newer NSAIDs (e.g., carprofen) are weak inhibitors of cyclooxygenase; however, their safety and utility in emergency patients have yet to be established. The effects of NSAIDs on renal blood flow may be particularly detrimental in hypovolemic emergency patients. Accordingly, NSAIDs should be used only after the animal is stabilized and the possibility of renal impairment, GI ulceration, and coagulopathies has been ruled out.

17. Why should I consider using opioids in my clinic?

Opioids have been shown to be the most effective and useful analgesics available for the management of acute severe pain in people and small animals and generally cause minimal cardiovascular depression.

18. Considering all the record-keeping hassles mandated by the Drug Enforcement Agency (DEA), how can I afford to keep controlled substances in my clinic?

Without a doubt, the record-keeping requirements mandated by the DEA for administering scheduled drugs (e.g., opioids) increase the amount of paperwork. The myth in veterinary medicine is that these requirements are so onerous that they preclude the use of opioids. In fact, the amount of additional work is minimal in comparison with the benefits in terms of patient comfort.

19. Are any good analgesics not controlled substances?

No opioid analgesics known to be efficacious for the treatment of moderate-to-severe pain are uncontrolled. Local anesthetics, alpha-2 agonists, and NSAIDs are not controlled drugs and may be helpful in controlling pain if used cautiously in emergency patients.

20. What specific opioids are clinically used to control pain in dogs and cats?

Morphine, oxymorphone, fentanyl, butorphanol, and buprenorphine.

21. How should I choose an appropriate opioid analgesic?

The choice of opioid is usually based on availability, cost, efficacy, and duration of action. Mu opioid agonists (e.g., morphine, oxymorphone, fentanyl) are much more effective in the treatment of moderate-to-severe pain than the partial agonists (e.g., buprenorphine) or agonist-antagonists (e.g., butorphanol, nalbuphine). The duration of action varies markedly and depends on the specific drug, route of administration, species treated, and individual variability (dose and frequency depend on the amount of pain).

22. Is a more potent opioid a better choice for the treatment of severe pain than a less potent opioid?

A more potent opioid is not necessarily more effective than an opioid of lesser potency. Opioids are compared according to analgesic potency, with morphine arbitrarily assigned a potency of 1. In practical terms, analgesic potency determines the dose that must be administered to achieve the desired effect. For example, both morphine and oxymorphone are opioid agonists at the mu receptor, but oxymorphone is approximately 10–15 times more potent than morphine. As a result of these differences in potency, an equianalgesic dose of morphine (0.5–1.0 mg/kg) is 10 times the dose of oxymorphone (0.05–0.1 mg/kg). Although fentanyl is approximately 100 times more potent than morphine, it is not administered as a bolus for sustained analgesia because of its short duration of action (approximately 15–30 minutes). Fentanyl can be highly effective, however, if it is delivered as a constant-rate IV infusion or in the form of a transdermal patch. In contrast to the opioid agonists, butorphanol (agonist-antagonist) and buprenorphine (partial agonist) are approximately 5 and 30 times more potent than morphine, respectively. Although these drugs are more potent than morphine, neither is as efficacious at controlling severe pain (agonist-antagonists and partial agonists have a ceiling effect on analgesia).

23. What are effective doses and approximate duration of effect of the commonly used opioids?

Opioid Analgesics

DRUG	ANALGESIC POTENCY	DOSE (mg/kg)	SPECIES	ROUTE	DURATION (HR)	INDICATIONS (TYPES OF PAIN)
Opioid agonists						
Morphine	1	0.05–1.0	Dog	IV*	1–2	Mild to severe
		0.2–2.0	Dog	IM, SQ	2–6	
		0.05–0.2	Cat	IV*	1–2	
		0.1–0.5	Cat	IM, SQ	2–6	
Oxymorphone	5–10	0.02–0.1	Dog	IV	1–2	Mild to severe
		0.05–0.2	Dog	IM, SQ	2–4	
		0.02–0.05	Cat	IV	1–2	
		0.05–0.1	Cat	IM, SQ	2–4	

Table continued on next page.

Opioid Analgesics (Continued)

DRUG	ANALGESIC POTENCY	DOSE (mg/kg)	SPECIES	ROUTE	DURATION (HR)	INDICATIONS (TYPES OF PAIN)
Opioid agonists *(cont.)*						
Fentanyl	75–125	0.001-0.005† (mg/kg/hr CRI)	Dog	IV	CRI	Moderate to severe
		0.001–0.004 (mg/kg/hr CRI)	Cat	IV	CRI	
Agonist-antagonist						
Butorphanol	5	0.2–0.5	Dog	IV	1–2‡	Mild to moderate
		0.2–0.8	Dog	IM, SQ	1–2‡	
		0.1–0.2	Cat	IV	1–2	
		0.1–0.4	Cat	IM, SQ	2–4	
Partial agonist						
Buprenorphine	30	0.005–0.02	Dog	IV, IM	4–12	Mild
		0.005–0.01	Cat	IV, IM	4–12	

IV = intravenous, IM = intramuscular, SQ = subcutaneous, CRI = constant-rate infusion.
* IV morphine must be administered slowly to avoid side-effects such as hypotension and excitement.
† Fentanyl infusion may be incrementally increased to 0.01 mg/kg/hr in dogs as needed.
‡ Butorphanol's duration of analgesic effect in dogs is controversial; it may be < 1 hr.

24. Is morphine a dated drug that is not as effective as oxymorphone?

No. Both morphine and oxymorphone are opioid agonists that may induce the same degree of analgesia if the appropriate dose is administered. The primary disadvantage of morphine compared with oxymorphone is that morphine may cause histamine release in dogs and presumably in cats. Histamine release may cause peripheral vasodilation and hypotension, which may be particularly problematic in anesthetized or compromised animals. IM, SQ, or slow IV administration of morphine minimizes the incidence of histamine release. Vomiting may be more frequent in ambulatory animals who receive morphine rather than oxymorphone. On the other hand, morphine is much less expensive than oxymorphone.

25. Are opioid analgesics contraindicated in cats?

No. The opioids are excellent analgesics for cats. Cats are more sensitive to the excitatory effects of opioids, but administering lower doses (¼ to ½ of the dog dose) often prevents opioid-induced excitement. As in dogs, the concurrent administration of low doses of acepromazine usually eliminates unwanted excitation. Anecdotal reports suggest that oxymorphone may provide more sedation in cats than morphine, however, either drug can be used safely in this species.

26. Is respiratory depression a potentially life-threatening side effect of opioids in compromised animals?

Opioids are clearly respiratory depressants; however, the importance of opioid-induced respiratory depression is often overstated in veterinary medicine. Opioids act centrally to decrease the responsiveness of the ventilatory centers to carbon dioxide and interfere with regulation of respiratory rhythm by the pontine and medullary ventilatory centers. The clinical significance of opioid-induced respiratory depression appears to be much more important in people than in animals. Administering opioids in small incremental doses, to effect, greatly decreases the likelihood of depressing ventilation. Greater care, coupled with vigilant monitoring, should be used for administering opioids to animals with preexisting respiratory disease or increased intracranial pressure (e.g., head trauma, intracranial tumor). Opioids should be administered in reduced doses to brachycephalic breeds that have clinically significant upper airway obstruction. Opioid agonist-antagonists, such as butorphanol, cause less respiratory depression and are often tolerated better in brachycephalic dogs than opioid agonists.

27. What should I do if the animal sleeps for long periods after administration of an opioid analgesic?

Effective analgesic doses of opioids frequently cause animals to sleep. The animal should be monitored periodically, with particular attention to pulse (rate and strength), color of mucous membranes, capillary refill time, respiratory rate, and temperature. As long as vital signs are stable, the animal is probably benefiting from the rest. If the amount of sleep appears excessive or if the vital signs are in question, the dose and frequency of opioid administration may be reduced. Alternatively, the opioid agonists (morphine, oxymorphone, fentanyl) may be partially antagonized with an agonist-antagonist (butorphanol, nalbuphine) or a low dose of an opioid antagonist (naloxone, 0.001–0.002 mg/kg, IV) to decrease sedation without completely removing analgesia.

28. What should I do if an animal becomes agitated or disoriented after receiving an opioid?

Administering either a low dose of acepromazine (0.01–0.05 mg/kg, IV) or a benzodiazepine (diazepam or midazolam, 0.1–0.2 mg/kg, IV) sedates most animals that are agitated or disoriented. Low doses of an alpha-2 agonist (xylazine 0.1–0.2 mg/kg, IV; medetomidine 0.001-0.002 mg/kg, IV) may be added as a last resort, however, close monitoring of vital signs will be necessary. Alternatively, the opioids can be either partially reversed with an opioid agonist-antagonist or completely reversed with naloxone. Naloxone is only rarely administered because the acute awareness of pain, and subsequent autonomic effects, may increase myocardial oxygen consumption and/or induce ventricular dysrhythmias in compromised animals.

29. What if I have given what I think is an appropriate dose of an opioid and the animal remains agitated? How can I tell if the animal is still in pain, anxious, or dysphoric?

Differentiating pain from anxiety and/or opioid-induced dysphoria is difficult and represents a significant challenge clinically. Careful observation of the dog's clinical signs may shed some light on the root problem. Determining whether the dog responds to attention and interaction with caregivers may help to determine if anxiety has a significant role. Assessing the level of consciousness is important in differentiating pain from dysphoria. Some dogs receiving opioids vocalize continually, although otherwise they appear sedate and comfortable. Administering a test dose of additional analgesic may help to determine if the dog is still in pain. Alternatively, partial or complete reversal of the opioid with either an opioid agonist-antagonist or antagonist, respectively, can be used to rule out dysphoria. Unfortunately, if the dog is truly in pain, administering an antagonist only worsens the situation. Of importance, the clinician needs to consider the extent of the animal's injuries and to determine how likely it is to be still in pain. Many animals require relatively high doses of opioids initially to control pain. Beginning therapy with low doses of opioids and adding additional doses at preset intervals is a safe and effective method to control pain while minimizing adverse effects. Acute tolerance to opioids may develop during the normal course of opioid therapy. In addition, it has been hypothesized that individuals with severe injuries may experience an increased sensitivity of the pain pathways (wind-up) resulting in opioid tolerance before they ever receive their first dose of an opioid. Thus, inadequate dosing of opioid analgesics is a very real clinical problem that may explain why some patients need "larger than normal" doses of opioids to be comfortable.

30. How should opioid therapy be discontinued?

Analgesic therapy should be slowly tapered off while observing the animal for signs of discomfort. The longer the animal has received opioid therapy, the more likely that some degree of dependence has developed. Depending on the opioid used, doses may be tapered over a number of hours or days.

31. Are there any advantages to administering drugs in the epidural space rather than systemically?

Epidural administration of drugs allows a greater response (analgesia) with a much lower dose than systemic administration. The lower doses used in the epidural space are associated with a reduced incidence of side effects. The epidural administration of drugs also may provide longer

duration of analgesia. For example, epidural morphine may provide analgesia for 12 hours or more in comparison with 4 hours when administered systemically. Opioids and local anesthetics are most commonly administered in the epidural space in dogs and cats. Epidural injections are typically made in the lumbosacral intervertebral space (L7–S1). The cranial extent of analgesia is dependent upon several factors, however, epidurals are generally indicated for analgesia of caudal areas of the body.

32. How do I know if I overdosed an animal with opioids, alpha-2 agonists, or NSAIDs?

Overdosages of opioids and alpha-2 agonists result in excessive cardiopulmonary depression as evidenced by bradycardia, decrease in pulse quality, slowed capillary refill time, and pale or cyanotic mucous membranes. Overdosage with NSAIDs may not be immediately apparent but may manifest as gastrointestinal bleeding, azotemia, or prolonged bleeding times.

33. What are some means to provide analgesia besides systemic analgesics?

Ensuring that the animal is in a comfortable position, appropriate use of splints or bandages, cold or hot packs, attention to the needs of the animal (e.g., does the animal need to urinate, defecate), and interacting with the animal frequently to decrease stress and anxiety may increase comfort and tolerance of pain.

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22. DISASTER PREPAREDNESS AND THE VETERINARIAN

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is the role of a veterinarian in disaster medicine?

The role of the veterinarian in disaster preparedness is increasing; veterinary medicine is considered a first-responder profession.

2. What is the definition of a disaster?

There is no standard definition of disaster. Traditionally, the term is used to describe large-scale incidents that overwhelm the resources of the affected community. Because disaster medicine is multidisciplinary and depends on the integration of multiple levels of responders, the use of more concise definitions is essential. More frequently in the U.S., the term "emergency" should be used to describe incidents that can be handled with existing community resources. It is certainly possible for an emergency to overwhelm resources quickly, especially in small rural communities. This is less likely in larger metropolitan areas if there is an organizational structure for veterinary professionals responding to the incident. Thus, the functional impact on a specific area is the key to determining whether a disaster exists.

3. Who often finds lost pets during a disaster?

Most often it is volunteers and rescuers who find dogs and cats after a large-scale disaster.

4. Which domestic small animal is less likely to be rescued in a disaster?

Cats are apparently less likely to be evacuated than dogs, probably because of their solitary nature as opposed to the more family-oriented behavior of dogs.

5. Why is it important to have a disaster "hotline" dedicated to household pets during and after a disaster?

Individuals searching for their lost pet experience a trauma similar to other victims. Experience in the Oakland fire shows the importance of a disaster "hotline" dedicated to lost or found animals. This hotline should be locally based and staffed and have an organized, computerized, database ready when called upon to react. Consistency in the database is of paramount importance.

6. List some of the important items to be included in a disaster hotline for pets.

- Date and time of the call
- Is this a lost pet or a found animal?
- Date the animal was lost
- Person initiating this call
- Address and phone number of the caller
- Association of caller with the pet (veterinarian, shelter volunteer, rescuer, other)
- Were other locations searched for the pet? (e.g., shelters, neighbors, veterinary hospitals)
- Pet's profile (species, age [< 1 year, adult, > 10 years], breed, sex, color and markings, photograph)
- Known injuries to the pet
- Date and resolution (reunited with owner, returned to owner's address, adopted, euthanized)

7. What is known about the probability of reuniting with a pet following a disaster?

The longer an owner waits to search for their pet, the lower the chance of being reunited. Of interest, animals wearing a collar with the owner's name and address have a 10-fold increased likelihood of being reunited. Few pets are reunited with their owners 4 weeks after a disaster.

8. Who can the local veterinary community depend on to provide the most support early in a disaster?

Veterinary disaster medicine should concentrate expertise on building local emergency-response capacity through research, training, and preparedness.

9. How does one provide immediate veterinary care in a disaster?

Providing immediate veterinary care in disasters can be modeled after its human counterpart. The operations plan of the medical [veterinary] disaster-response model organizes surviving veterinarians into teams capable of delivering immediate care after a disaster. The goal of these teams is to recognize the seriousness of injuries, stabilize the patient, and arrange for transport to intact shelters, kennels, or veterinary hospitals. The plan is divided into three phases according to the time elapsed since the initial disaster: hour 0 to 1, solo-treatment areas; 1 to 12, disaster-veterinary medical aid centers; and hours 12 to 72, casualty-collection points.

10. List the items that would be useful in a mobile crash cart for veterinary use.

Contents of a Mobile Crash Module.

MAINTENANCE OF CIRCULATION	AIRWAY MANAGEMENT	ORTHOPEDIC MANAGEMENT	MISCELLANEOUS
Atropine sulfate	Endotracheal tubes	Emergency surgery pack*	Sodium bicarbonate
Epinephrine (1:1000)	Laryngoscope	Roll cotton	Dextrose (50%)
Furosemide	Ambu bag and nose cones	Kling gauze	Diazepam
Intravenous catheters	Thoracic drains	1" and 2" adhesive tape	Diphenydramine
Heparinized saline	Heimlich valves	Vetwrap	Foley catheters
Intraosseous needles	Dexamethasone SP		Insulin (regular)
0.9% sodium chloride	Ketamine		Methylprednisolone
Hetastarch	Bupivacaine		Nasogastric tube
Oxyglobin	Lidocaine		Normosol
Intravenous needles			Orogastric tube
			Mineral oil

* Knife handle, blades, hemostats, needle holder, carmalt forcep, thumb forceps, sterile 4 × 4 gauze sponges, towel clamps.

11. What is a simple, rapid method to perform triage at the scene of a disaster?

Early in the management of disasters, rescue personnel often use a **START** technique: simple triage and rapid treatment. (See figure on next page.)

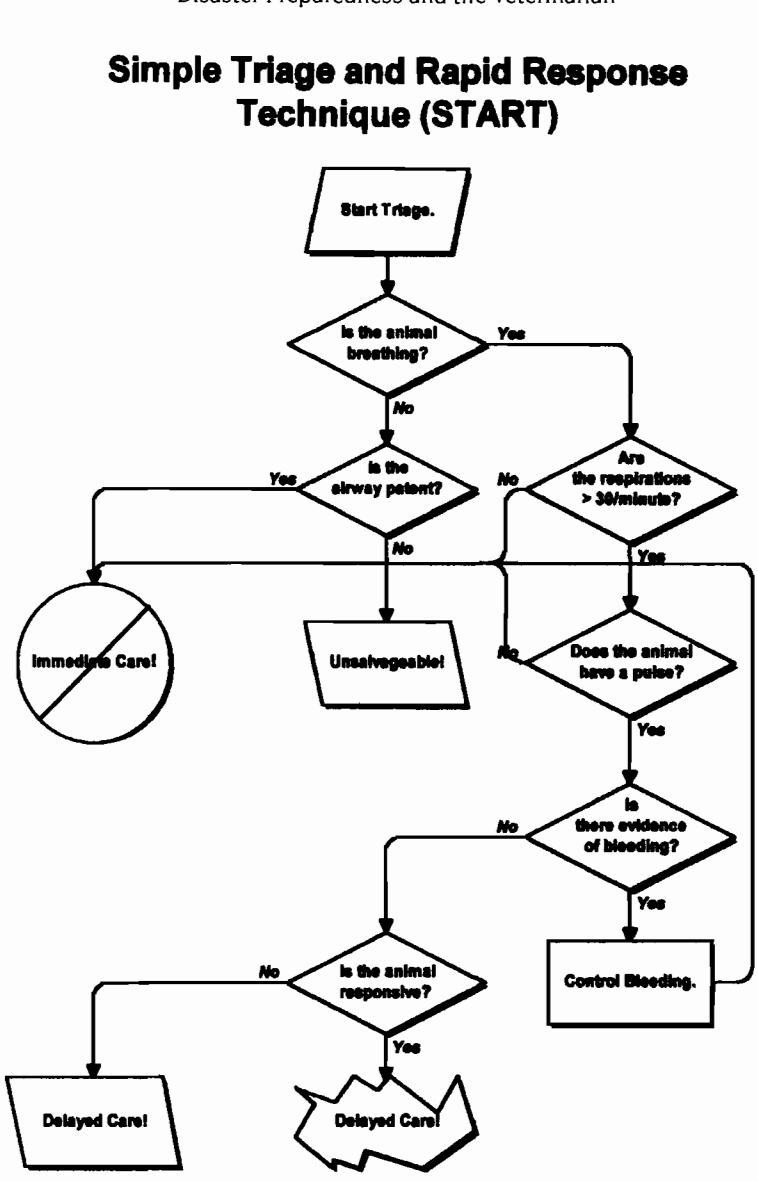
12. What is the purpose of triage in a disaster setting?

In disaster situations triage must be conducted with the purpose of doing the greatest good for the largest number of patients.

13. Describe the triage categories and color coding associated with each.

Categories and Identification in Triage

GROUP	COLOR	TYPE OF INJURIES
Priority 1/immediate	Red	Critical; may survive if simple lifesaving measures are applied
Priority 2/delayed	Yellow	Likely to survive if simple care is given within hours
Priority 3/nonurgent	Green	Minor injuries; care may be delayed while other patients receive treatment
Priority 2 or 3	Blue	Catastrophic: patients unlikely to survive or those who need extensive care within minutes
None (dead or dying)	Black	Dead or severely injured and not expected to survive



14. What challenges face veterinarians in a disaster?

In veterinary medicine we often are faced with catastrophic casualty management (e.g., poultry, swine, and fish) with large numbers of victims, severely limited medical resources, and poorly trained local rescue personnel.

15. When disaster strikes a veterinary hospital, what are some of the expected effects on hospitalized animals?

When disaster affects a veterinary hospital and requires triage decisions, an injury to the hospitalized animal confounds the seriousness of the previous illness or injury. These multiple injuries should be considered synergistic, and the prognosis is worse for an individual patient than the simple sum of the likelihood of survival for each injury. With preexisting illness, multiple

injury, and advancing age, prognosis worsens; these factors should be taken into consideration when triage decisions are made.

16. Which special resource people may assist in the event of a disaster?

Occasionally an animal owner is recruited to assist with treatment of disaster victims. The poultry or swine producer, the owner/manager of a dog kennel or cattery, and animal attendants from the zoo know their species and are used to handling these animals. Moving such people to a treatment area and seeking their assistance can enhance outcomes. Undoubtedly, the addition of skilled hands to a disaster treatment team not only improves outcome but also increases effectiveness. Again, the guiding principle in disaster triage is to maximize the benefit to the most animals.

17. How can a veterinarian begin to prepare for a disaster?

To triage and initiate life-saving treatment quickly and efficiently, it is imperative to develop a team approach. All veterinary clinical personnel should have a working knowledge of basic life-saving procedures and equipment. Staff meetings should set aside a portion of time for review and updates on trauma priorities, basic cardiopulmonary resuscitation (CPR), emergency procedures, and individual duties and responsibilities. "Dry-runs" or practice drills can improve the team's speed and efficiency.

18. What is meant by a "systems approach" to triage in disasters?

A systematic, standardized approach to every emergency is essential. Such an approach minimizes oversight during assessment of organ systems and anatomic areas. By having a standardized emergency response protocol, life-threatening problems can be identified and immediate therapy initiated. The recommended systems priorities in trauma are as follows:

1. Arterial bleeding
2. Respiratory system
3. Cardiovascular system
4. Transfusion and hemorrhage control
5. Neurologic system
6. Musculoskeletal system
7. Abdominal injuries

19. What advice can you offer to a colleague or treatment team member when dealing with emergencies during a disaster?

Stay calm, work quickly, and minimize patient stress.

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III. Common Primary Complaints

Section Editor: Tim Hackett, D.V.M., M.S.

23. VOMITING

Tim Hackett, D.V.M., M.S.

1. What is the difference between vomiting and regurgitation?

Vomiting is the forceful ejection of gastric and occasionally proximal small intestinal contents through the mouth. Sustained contraction of abdominal muscles, elevation and opening of the cardia, and contraction of the pylorus result in the movement of gastric contents out of the stomach. Regurgitation is the passive, retrograde movement of ingested material, usually before it has reached the stomach. Regurgitation may occur immediately after ingestion of food or water or be delayed for hours.

2. How can vomiting and regurgitation be differentiated?

Question witnesses carefully about the timing and nature of the event. Tubular, mucus-covered, undigested food passed without effort is most likely regurgitation. Retching, nausea, ptyalism, and forceful contractions usually accompany vomiting. By measuring the pH of the material recovered, vomitus may be differentiated from regurgitated ingesta. Vomitus usually contains hydrochloric acid and has a pH less than 4.

3. Describe the neural pathways involved in vomiting.

Two functionally and anatomically separate regions are responsible for emesis: the chemoreceptor trigger zone (CTZ) in the floor of the fourth ventricle and the vomiting center in the reticular formation of the medulla oblongata. All stimuli pass through the vomiting center, which integrates afferent information and coordinates the patterned response of nausea, retching, and vomiting. Afferent input includes stimuli from other neural centers (psychogenic, vestibular, CTZ) and the gastrointestinal (GI) tract. The CTZ acts in response to chemical substances in the blood. Examples of chemical stimuli include anesthetic agents, cardiac glycosides, chemotherapeutic agents, and emetic agents such as apomorphine.

4. What are the common causes of regurgitation?

Causes of Regurgitation

Cleft palate	Esophageal disorders
	Esophagitis
Pharyngeal disorders	Esophageal diverticula
Foreign bodies	Esophageal stricture
Neoplasia	Foreign bodies
Retropharyngeal lymphadenopathy	Hiatal hernia
Rabies	Neoplasia: esophageal, mediastinal
Botulism	Vascular ring anomalies
Cricopharyngeal achalasia	Periesophageal masses
Myathenia gravis	Granulomas
	Congenital and acquired megaesophagus
	Hypomotility

5. What electrolyte and acid–base changes may be seen with vomiting?

Vomiting may result in profound dehydration. Loss of sodium, chloride, and potassium varies with the cause. Serum sodium is often low. Hypokalemia is often due to lack of intake, loss in vomitus, and increased loss due to alkalemia. Serum chloride levels depend on the source of fluid loss. Loss of gastric secretions in patients with pyloric or duodenal obstruction may result in loss of hydrochloric acid, profound hypochloremia, and metabolic alkalosis. Total plasma bicarbonate (TCO_2) may be increased, normal, or decreased depending on the type of fluid lost and underlying systemic disease. Metabolic alkalosis may progress to a mixed acid–base disorder if volume loss and hypovolemia lead to decreased oxygen delivery to the tissues.

6. What is the initial management of intractable vomiting?

Careful assessment of vital functions includes evaluation of airway patency, adequacy of respirations, and cardiovascular status. Vomiting and especially regurgitation may predispose an animal to aspiration pneumonia. Respiratory distress, tracheal sensitivity, or harsh airway sounds may indicate respiratory complications. Supplemental oxygen, thoracic radiographs, and arterial blood gas analysis may be indicated. Protracted vomiting may cause significant dehydration and signs of hypovolemic shock. Intravenous fluid replacement is indicated in any clinically dehydrated, vomiting animal. Enteral fluid replacement should be withheld until vomiting has ceased. The estimated fluid deficit should be replaced along with maintenance fluid volumes and any further losses. Approximately 80% of the deficit is replaced in the first 24 hours along with maintenance fluids. Ongoing volume losses are estimated and replaced in a 6–8 hour period.

7. Besides aspiration pneumonia, hypovolemia and electrolyte disorders, what other problems are associated with protracted vomiting?

Vomiting associated with a variety of primary and secondary GI disorders can compromise gastric and esophageal mucosal barriers, increasing the risk of gastric ulceration. Decreasing gastric acid secretion and providing a diffusion barrier against gastric acid are the main ways of maintaining the gastric mucosal barrier. Esophagitis has been associated with persistent vomiting and can lead to esophageal stricture.

8. What is the diagnostic approach to the vomiting patient?

Thorough history and physical examination help to identify the likelihood of an ingested foreign body or other dietary indiscretion. Young animals without obvious signs of distress may be treated conservatively by withholding food and water for 24 hours. Animals still vomiting or animals presenting in obvious distress should have a blood chemistry panel, complete blood count, and abdominal radiographs. Young animals should be screened for viral enteritis. Electrolyte changes may suggest hypoadrenocorticism, whereas pancreatic enzymes and white blood cell count are often elevated in cases of pancreatitis. Metabolic diseases causing vomiting secondarily should be identified through screening blood tests. If plain radiographs are not diagnostic, contrast radiographs may be performed to evaluate GI motility and patency. Endoscopic examination may be used to visualize the esophagus, stomach, and proximal bowel, to obtain diagnostic samples, and to remove gastric foreign bodies.

9. What common gastrointestinal diseases cause vomiting in dogs and cats?

Common primary GI complaints include gastroenteritis, pancreatitis, gastric and intestinal foreign bodies, and enteric viral diseases such as canine parvovirus.

Causes of Vomiting

PRIMARY GI DISORDERS	SECONDARY CAUSES
Adverse reactions to food	**Other primary organ disorders**
Dietary indiscretions	Pancreatitis
Food hypersensitivity or allergies	Peritonitis
Obstructions	Pyometra
Delayed gastric emptying	Renal failure
Ileus	

Table continued on next page.

Causes of Vomiting (Continued)

PRIMARY GI DISORDERS	SECONDARY CAUSES
Obstructions *(cont.)*	**Other primary organ disorders** *(cont.)*
Foreign bodies	Hepatic failure
Intussusception	Congestive heart failure
Torsions	**Neurologic diseases**
Pyloric hypertrophy	Central nervous system diseases (neoplasia, trauma, meningitis)
Neoplasia	Central or peripheral vestibular disease
Granuloma	Dysautonomia
Strictures	**Systemic disorders**
Inflammatory diseases	Uremia
Primary gastritis	Metastatic neoplasia
Inflammatory bowel disease	Acid–base or electrolyte imbalance
Diffuse neoplasia	**Endocrine diseases**
Hemorrhagic gastroenteritis	Hypoadrenocorticism
Ulcerative gastroenteritis	Diabetic ketoacidosis
Lymphangiectasia	Gastrinoma
Infectious enteritis	Hyperthyroidism
Viral	Hyperparathyroidism
Bacterial	**Drugs, chemicals, poisons**
Fungal	Apomorphine, narcotics
GI parasites	Chemotherapeutic agents
	Anesthetics
	Digitalis
	Thiacetarsamide
	Lead

10. How is the timing of vomiting in relation to eating important?

Vomiting shortly after eating suggests dietary indiscretion, food intolerance, overeating, stress, gastritis, or a hiatal hernia. Because the stomach is normally emptied of food in 7–10 hours, vomiting of partially digested food more than 7 hours after a meal suggests a motility disorder or an upper GI obstruction.

11. What radiographic signs suggest small bowel obstruction?

Some foreign objects are visualized directly either because they are radiopaque or because they are surrounded by a gas interface. Obstruction of the stomach or bowel may be seen as gas or fluid distention, delayed transit of contrast material, fixation or displacement of loops of bowel, and luminal filling defects.

12. Discuss the common antiemetic drugs, including their mechanism of action and contraindications to their use.

D_2-dopaminergic antagonists such as metoclopramide act centrally at the chemoreceptor trigger zone. Metoclopramide is also a 5-HT_3 serotonergic antagonist. Because metoclopramide enhances gastric emptying and intestinal motility, it should not be used when intestinal obstruction is suspected. **M_1-cholinergic antagonists** such as chlorpromazine and scopolamine also act on the chemoreceptor trigger zone, emetic center, and vestibular apparatus. Because chlorpromazine is a potent α-adrenergic antagonist, it should not be used in hypotensive patients. **Newer, more potent centrally acting antiemetics** include ondansetron and dolasetron, 5-HT_3 serotonergic antagonists that work at the emetic center, chemoreceptor trigger zone, and afferent nerves from the gut.

13. What about vomiting due to vestibular stimulation?

Stimuli from the vestibular system can result in motion sickness. This response can be normal, as in car sickness, or the result of pathologic stimulation of the vestibular center and

idiopathic vestibular disease in older dogs. Regardless of cause, treatment with receptor antagonists of H_1 histaminergic (meclizine, diphenhydramine) or M_1 cholinergic (scopolamine) receptors helps to alleviate nausea.

14. How can nutrition be addressed in a vomiting patient?

Enteral nutrition can be given to a vomiting patient only through a jejunostomy feeding tube. Nasogastric, pharyngostomy, esophagostomy, and gastrostomy feeding tubes aggravate vomiting by stimulating gastric secretions and motility. Although jejunostomy feeding stimulates some pancreatic activity, there is no risk of tube aspiration or direct gastric stimulation as with other feeding tubes. Radiographic confirmation of tube position is mandatory after emesis to prevent iatrogenic aspiration pneumonia. Parenteral nutrition is another means of providing calories while bypassing the GI tract.

15. What is the significance of nonproductive vomiting?

Nonproductive vomiting is a symptom of gastric dilatation-volvulus (GDV). GDV primarily affects large-breed dogs and results in abdominal distention and circulatory shock.

16. A client telephones about her vomiting dog. What is your first concern?

In talking to clients over the telephone, it is imperative to rule out possible GDV before suggesting conservative management of the vomiting dog. When the stomach twists on its axis, it may cut off blood supply to the gastric walls and spleen. The sooner the animal is treated for shock and the GDV surgically corrected, the better the prognosis for recovery.

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24. DIARRHEA

Tim Hackett, D.V.M., M.S.

1. What life-threatening problems are associated with diarrhea?

Diarrhea may result in dramatic loss of fluids. Patients often present with severe dehydration. Primary gastrointestinal (GI) disease may result in loss of electrolytes and inability to absorb nutrients, especially proteins. Many causes of diarrhea damage the mucosal integrity of the bowel, allowing normal intestinal flora to cross into the bloodstream. Animals with diarrhea may present in shock from blood loss, fluid loss, and sepsis.

2. What is the most important treatment for patients with severe diarrhea?

Patients with diarrhea may be unable to maintain hydration. Common causes of diarrhea leave the patient weak and anorectic. Even if an animal drinks, intestinal pathology may prevent adequate absorption of water. Parenteral fluid therapy is necessary to prevent dehydration and to support the patient until normal intestinal function is restored. Hospitalized patients receiving intravenous fluids may become dehydrated if GI losses of fluid are not quantified and returned to the patient. Fluid volumes should be based on maintenance volumes plus dehydration plus

idiopathic vestibular disease in older dogs. Regardless of cause, treatment with receptor antagonists of H_1 histaminergic (meclizine, diphenhydramine) or M_1 cholinergic (scopolamine) receptors helps to alleviate nausea.

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ongoing losses. Daily body weight can be used to determine precisely whether fluid therapy is adequate.

3. What are the common causes of acute diarrhea?

Acute diarrhea may result from a change in diet, dietary indiscretion, or intolerance to a type of food or medicine. Dietary indiscretions include overeating and ingestion of spoiled garbage, decomposing carrion, and abrasive or other nondigestible foreign material. Intestinal parasites, viruses, bacteria, and rickettsia are potential causes of infectious diarrhea. New sources of stress or metabolic disturbances also may cause acute diarrhea.

4. How should an animal presenting with diarrhea be managed?

All diarrhea, acute or chronic, should be considered infectious until proved otherwise. Young animals, debilitated animals, and animals from shelters or kennels are most likely to have infectious diarrhea. Hospital staff should plan to isolate such animals immediately. If possible, they should be treated as outpatients. Systemically ill and dehydrated patients should be hospitalized away from other animals. Feces should be removed and kept away from other animals. Personnel should wear protective clothing and wash hands, stethoscopes, and thermometers before handling other patients.

5. How is diarrhea classified?

Diarrhea is often classified as either small bowel or large bowel. A large volume of stool usually without increased frequency or urgency characterizes small-bowel diarrhea. Small-bowel diarrhea results from small intestine dysfunction due either to primary GI disease or diseases of other digestive organs such as the liver and pancreas. Large-bowel diarrhea refers to cecal, colonic, or rectal etiologies. Large-bowel diarrhea is characteristically small in volume, is associated with blood and mucus, and usually presents with signs of tenesmus.

6. What steps should be taken to identify the cause of acute diarrhea?

The diarrhea should be classified as either small bowel or large bowel. Clients should be questioned about duration of signs, possible exposure to other animals, travel history, vaccination status, and new stress in the animal's life. A complete physical exam should be followed by fecal examination to look for parasites and, when indicated, to test for canine parvovirus. Animals with signs of systemic illness should be checked for other primary problems. A minimal database includes complete blood count, electrolytes, and serum chemistries. Fecal cultures for *Salmonella* spp., *Campylobacter jejuni, Yersinia enterocolitica,* and *Shigella* spp. are indicated when an infectious cause is strongly suggested.

7. Describe the various pathophysiologic mechanisms of diarrhea.

Intestinal disease may cause diarrhea through decreased absorption, hypersecretion, increased permeability, and abnormal motility. Poor absorption (osmotic diarrhea) results in accumulation of nonabsorbable solutes in the gut. These solutes draw water into the lumen of the gut and result in bulky, fluid diarrhea. Secretory diarrhea occurs when the mucosal lining of the bowel is stimulated to secrete fluid and electrolytes without compensatory changes in absorption, permeability, or osmotic gradients. Increased permeability (exudative diarrhea) is usually accompanied by increased transmural hydrostastic pressure. The result is loss of protein-rich fluid into the intestinal lumen.

8. What are the common infectious causes of diarrhea?

When confronted with a young animal with diarrhea, viral enteritis is usually a top differential diagnosis. Coronavirus, parvovirus, rotavirus, and astrovirus are among the agents identified in the stools of diarrhetic dogs and cats. Bacterial pathogens include enteropathogenic *Escherichia coli, Clostridium* spp., *Salmonella* spp., *Yersinia enterocolitica, Campylobacter jejuni*, and *Bacillus piliformis* (Tyzzer's disease). Systemic mycoses such as *Histoplasma capsulatum, Aspergillus* spp., and *Candida albicans* may affect GI function and result in diarrhea.

9. What are the potential zoonotic causes of diarrhea in small animals?

Several important bacterial and parasitic zoonoses are seen in small animals with diarrhea. The enteric bacteria of zoonotic significance include *Salmonella* spp., *Campylobacter jejuni*, *Shigella* spp., and *Yersinia enterocolitica*. *Giardia* spp., *Toxoplasma gondii*, *Cryptosporidium parvum*, *Toxocara canis*, *Toxascaris leonina*, *Uncinaria stenocephala*, *Ancylostoma caninum*, *Strongyloides stercoralis*, *Echinococcus multilocularis*, and *Echinococcus granulosa* are the most significant enteric parasite zoonoses in small animals and often cause clinical disease.

10. Is it common to find zoonotic agents in dog feces?

Identifying infectious and potentially zoonotic agents requires appropriate testing. In a survey of 131 fecal samples from diarrhetic and normal dogs, subjected to fecal analysis, bacterial culture, viral screening, and immune fluorescent testing for *Giardia* spp. and *C. jejuni*, potentially zoonotic agents were detected in 16%.

11. What are the common iatrogenic causes of diarrhea?

Sudden changes in an animal's diet may cause diarrhea. A gradual transition in diet is recommended to prevent this problem. Osmotic diarrhea is a common complication of enteral feeding in critically ill patients with esophagostomy, gastrostomy, or jejunostomy feeding tubes. Many drugs may cause acute intestinal upset resulting in diarrhea.

12. How does the presence of blood in the stool affect medical management?

With any injury to intestinal mucosa, hemorrhage and melena are often noted. The presence of blood, either fresh or digested, implies damage to the lining of the bowel. Normal enteric bacteria may become pathogenic if allowed to cross the mucosal barrier and enter the circulation. Antibiotic therapy is indicated.

13. Discuss symptomatic treatments for diarrhea.

Acute diarrhea may be managed conservatively by withholding food for 12–24 hours to allow the GI tract time to heal. Small, bland, low-fat meals are then started. Fluid and electrolyte homeostasis should be monitored closely. Parenteral fluid replacement and oral supplementation with glucose-electrolyte solutions may be used to maintain hydration.

14. What are some nonspecific drug therapies for diarrhea? How do they work?

Opiate agonists (diphenoxylate, loperamide, and paregoric) work by stimulating circular smooth muscle contraction and absorption while inhibiting secretion of fluid and electrolytes. Ondansetron and dolasetron are 5-HT_3 serotonin antagonists that inhibit chloride and water secretion. Sulfasalazine, prednisone, and 5-aminosalicylate are prostaglandin synthetase inhibitors. Examples of intraluminal absorbents and protectants include kaolin-pectin, bismuth, and barium sulfate. Bismuth subsalicylate is a protectant and also has antisecretory and antiendotoxin effects. It should be used with caution in patients sensitive to salicylates. Antibiotics are indicated only for bacterial diarrhea and animals with significant disruption of intestinal mucosa.

15. When should a detailed diagnostic work-up be recommended?

Any animal that does not respond to routine supportive care and whose condition is deteriorating should be evaluated more completely. Intestinal biopsy is usually required for diagnosis in animals with chronic, unresponsive diarrhea. Increasing clinical signs and owner frustration may result from prolonged symptomatic care. Infiltrative and inflammatory diseases of the bowel should be pursued when a patient continues to have diarrhea despite dietary and medical intervention.

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25. SYNCOPE VS. SEIZURES

Andrew J. Triolo, D.V.M., M.S.

1. Syncope or seizure—which is it?

At times it is difficult to tell the difference. A systematic diagnostic approach is vital in distinguishing between the two.

2. What is syncope?

Syncope is loss of consciousness caused by inadequate glucose or oxygen to the brain. The causes tend to be neurogenic or cardiovascular.

Common Causes of Syncope

Brain	Metabolic disorders
Thromboembolic disease	Causes of hypoglycemia
Neoplasia	Insulin-secreting tumors
Trauma	Glycogen storage diseases
Cardiovascular system	Starvation (especially in small breeds)
Arrhythmias	Iatrogenic causes
Thromboembolic disease	Insulin overdose
Blood loss	Digitalis intoxication
Congenital or acquired heart disease	
Low blood pressure	

3. What is a seizure?

Seizure is one of the clinical signs of abnormal brain function. Although the causes of seizure are many, the underlying process causes a similar outcome—a favorable balance toward neuron excitation.

4. Describe the clinical approach to a patient with syncope or seizures.

The basics are the same. Evaluate the patient for immediate life-threatening diseases such as arterial blood loss and hyperthermia. Once the most immediate concerns are evaluated and addressed, one can resume solving the mystery of the cause.

5. What diagnostic tests are recommended to distinguish among the many causes of syncope and seizures?

Always start with a minimum database (complete blood count, biochemistries, urinalysis), which should help to rule in or out major causes of both. Additional diagnostics may be needed, including an electrocardiogram, radiographs, computed tomography or magnetic resonance imaging (MRI), and cerebrospinal fluid tap.

6. What should you do when the client cannot afford a full work-up?

You have to make choices about which diagnostic tests to pursue. Start with tests for readily treatable conditions. Performing an MRI on a patient whose owner cannot afford follow-up care (e.g., chemotherapy or radiation) is probably not the wisest way to begin.

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7. How do you treat a patient with syncope?

Treating the underlying cause will most likely suppress the syncopal episode. At times the cause cannot be found, and you must treat symptomatically. Many animals do not have another episode (especially while boarded in your hospital!).

8. How is a seizuring patient treated?

A patient in status epilepticus is a medical emergency. The drug of choice is intravenous diazepam. At times patients may be refractory to diazepam, and you may need to administer phenobarbital or pentobarbital intravenously.

DRUG	DOSE
Diazepam	0.5–1 mg/kg IV, repeated as needed up to 3 doses
Phenobarbital	2–4 mg/kg IM, IV, or constant-rate infusion at 3–16 mg/hr
Pentobarbital	3–15 mg/kg IV to effect

9. What else do you monitor in a seizuring patient?

Seizuring patients may become hyperthermic and need immediate cooling. If the seizure has been prolonged, central nervous system edema may have developed and may require treatment with osmotic or antiinflammatory agents such as mannitol or Solu-Medrol.

10. What medications are used for controlling seizures in an epileptic patient?

Phenobarbital is probably the drug of choice. Begin treatment with a dose of 2 mg/kg twice daily. A loading dose of phenobarbital can be given at 6–10 mg/kg. If a dose of 8 mg/kg is required to control seizures, add potassium bromide at 30 mg/kg/day to start, and try to reduce the dose of phenobarbital. Starting the patient with potassium bromide instead of phenobarbital is also acceptable. Other drugs include primadone or phenytoin, which, in the author's opinion, should not be used in small animals except as a last resort.

11. What are the side effects of phenobarbital?

Initial side effects may include sedation or polyphagia. These effects tend to resolve in 5–7 days in normal animals. Chronic therapy may lead to hepatic toxicosis and clinical signs similar to liver disease.

12. What are the side effects of potassium bromide?

The primary side effect is gastroenteritis, although central nervous system depression or behavioral changes also may be seen with overdosage. Potassium bromide is eliminated by the kidneys and therefore may be used in patients suspected to have liver disease due to phenobarbital.

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26. ATAXIA

Tim Hackett, D.V.M., M.S.

1. What is ataxia?

Ataxia is failure of muscular coordination or irregularity of muscle action associated with various anatomic lesions within the nervous system. Ataxia simply is a failure of muscle coordination and is seen without paresis or spastic, involuntary movements. Disorders of the cerebellum, vestibular system, and spinal cord sensory pathways are the most common causes of ataxia.

2. What systems are involved in ataxia?

Proprioceptive pathways (both conscious and unconscious)
Cerebellum
Vestibular system

3. Discuss specific causes of ataxia.

Proprioceptive ataxia (also called sensory or truncal ataxia) is caused by spinal cord disease. Examples include intervertebral disk disease, neoplasia, degenerative myelopathy, vascular accidents, and trauma. Vestibular ataxia may be idiopathic or due to otitis media and interna, vascular accidents, granulomatous meningioencephalitis, ototoxins, neoplasia, and trauma. Cerebellar ataxia may result from cerebellar atrophy, globoid leukodystrophy, congenital hypoplasia, canine distemper, rabies, toxoplasmosis, trauma, toxins, or neoplasia.

4. How can the common causes of ataxia be distinguished?

Patients with central or peripheral vestibular ataxia usually present with a head tilt. Postural deficits are seen with central vestibular diseases, not peripheral vestibular diseases. Proprioceptive ataxia and cerebellar ataxia do not occur with head tilt and are distinguished from each other by the presence of intention tremors and dysmetria (seen only with cerebellar ataxia).

5. Describe the diagnostic plan for patients with ataxia.

Signalment and a thorough history help to differentiate congenital, infectious, and traumatic causes of ataxia. Physical examination should include a complete neurologic examination and close attention to the external ear canal and tympanic membrane. In addition to a complete blood count and serum chemistry profiles, a coagulation profile should also be performed. Skull radiographs may be useful to evaluate the tympanic bullae. Analysis of cerebrospinal fluid and advanced imaging with computerized tomography (CT) or magnetic resonance imaging (MRI) scans may be necessary to identify intracranial disease.

6. What is the most serious common toxin causing ataxia in small animals?

Ethylene glycol intoxication may cause a drunken presentation. Because of the urgency of treatment, patients presenting with ataxia of unknown cause should be evaluated carefully for possible ethylene glycol ingestion. Commercial serum test kits are available. If they are unavailable, a high anion gap metabolic acidosis and calcium oxalate crystalluria are highly suggestive. Treatment with either 4-methylpyrazole or 20% ethanol and intravenous fluids should be initiated immediately.

7. What antibiotic and antiparasitic drugs may cause ataxia?

The most common antibiotic causing ataxia is metronidazole. Patients usually have received metronidazole for weeks or longer and quickly recover after discontinuation of the drug.

Aminoglycosides, polymyxin B, erythromycin, and vancomycin may cause ototoxicity and ataxia; unfortunately, they also may cause permanent damage. Ivermectin toxicity often causes severe neurologic disease, including ataxia. Treatment is supportive, and it may take days to weeks to see improvement. Amitraz also has been implicated in ataxia after overdosage. Treatment includes yohimbine and supportive care.

8. What are the most common causes of otitis interna and media?

The most common causes of otitis interna and media are bacterial infections, foreign bodies, and parasites. The common bacteria involved are *Staphylococcus* spp., *Proteus* spp., *Pseudomonas* spp., *Escherichia coli, Streptococcus* spp., and *Enterococcus* spp. The most common aural parasite is the Otodectes mite. The grass-awn remains one of the most common foreign bodies found in animals' ears.

9. Describe the diagnosis and treatment of otitis interna and media.

Clinical signs of otitis externa include head tilt, head shaking, aural pain, inflammatory discharge, torticollis, circling, ataxia, positional ventral strabismus, and nystagmus. The patient may have unilateral facial nerve paralysis. If the middle ear is involved, the patient may have Horner's syndrome. Diagnosis is based on clinical signs and otoscopic exam. If the tympanic membrane cannot be visualized, debris should be removed from the ear canal with a gentle lavage of warm saline. Cytology and culture of the debris should reveal causes of otitis externa. Radiographs of the tympanic bullae show fluid density with otitis interna. Myringotomy or bulla osteotomy may provide drainage and an etiologic diagnosis. Bacterial infections are treated over the long term with an antibiotic selected on the basis of culture and sensitivity testing. Empirical treatment may begin with cephalosporins or chloramphenicol.

10. What if there does not appear to be an underlying cause for the ataxia?

Both dogs and cats may develop idiopathic vestibular disease. Clinically, such patients usually show multiple vestibular signs, including ataxia, circling, head tilt, and nystagmus. The onset is usually acute and unilateral. Although they are usually older animals, they are generally in good health. Spontaneous recovery usually begins within 72 hours, and most are normal in several weeks. Symptomatic treatment may provide some relief. H_1 receptor antagonists such as meclizine, diphenhydramine or dramamine may provide symptomatic relief from the motion sickness associated with idiopathic vestibular disease.

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27. ANOREXIA

Tim Hackett, D.V.M., M.S.

1. How is food intake regulated in normal animals?

Food intake is regulated by neurologic, metabolic, humoral, nutritional, and alimentary mechanisms. Gastric distention, enteric hormones such as insulin and cholecystokinin, and oxidation of energy-rich metabolites by the liver combine to effect the change from hunger to satiety. Control of hunger and satiety in the brain includes nuclei located in the lateral hypothalamus. Stimulation of these nuclei initiates a psychic drive to search for and ingest food. The ventromedial nuclei of the hypothalamus contain a satiety center that, when stimulated, inhibits feeding behavior. Higher centers in the amygdala closely coupled with the olfactory nervous system can stimulate and inhibit feeding and may serve in food discrimination.

Increased blood levels of glucose and amino acids reduce feeding, whereas reduced levels stimulate feeding. Adipose stores within the body inversely affect feeding through concentration of free fatty acids and fat metabolites in the blood. As the amount of adipose tissue in the body decreases, the concentration of fat metabolites in the blood increases.

Alimentary mechanisms are important in the short-term control of feeding behavior. Mechanoreceptors in the walls of the stomach and intestines stimulate the ventromedial nuclei of the hypothalamus, inhibiting feeding. Related activities, such as salivation, mastication, tasting, and swallowing, are collectively termed cephalic regulation and inhibit the feeding center after a meal.

2. What is anorexia?

Anorexia is the lack of hunger. It is a disinterest in ingestion of food, generally associated with illness. Anorexia may be complete or partial, sometimes reflecting the severity of disease. Anorexia is associated with many pathologic processes that may directly inhibit appetite by suppressing the hunger center or stimulating the satiety center.

3. How is anorexia classified?

Anorexia is categorized as primary, secondary, or pseudoanorexia. **Primary anorexia** results from diseases affecting the appetite centers of the hypothalamus or other psychological disorders that directly affect neural regulation of feeding behavior. Diseases outside the brain that affect the neural and endocrine control of hunger can cause secondary anorexia. **Secondary anorexia** is the most common cause of anorexia in animals. **Pseudoanorexia** encompasses diseases of oral cavity, pharynx, and esophagus that affect the animal's ability to prehend, masticate, or swallow food. Such patients often are very hungry but physically unable to eat.

4. If an animal is not eating enough, what steps should be taken to determine the cause?

Pseudoanorexia should be ruled out by observing the animal when presented with a meal. Is the animal interested in food? Can it prehend and masticate food? Is the animal acting as if in pain? A thorough oral examination should then be conducted. Many causes of primary and secondary anorexia can be identified by a complete physical examination, evaluation of serum chemistries, complete blood count, urinalysis, and chest and abdominal radiographs.

5. What are the metabolic consequences of anorexia?

Tissues prefer carbohydrates for energy to fat and protein. Carbohydrates, stored as glycogen, are limited, and less than 1 day after the last meal the body begins depleting fat and protein reserves. Fat depletion occurs steadily but cannot supply the brain with needed glucose. Protein is rapidly depleted early in starvation. Through hepatic gluconeogenesis, protein is converted to glucose, supplying the brain with most of its energy. When the quickly mobilized protein is depleted, gluconeogenesis slows. With decreased availability of glucose, alternative energy sources

are exploited. Ketone bodies formed by hepatic conversion of fatty acids readily cross the blood–brain barrier for energy. When all fat stores have been depleted, the body returns to the remaining protein for energy. These proteins are essential for maintenance of cellular functions, and death occurs shortly after their depletion.

6. Describe methods of supplementing nutrition.

Animals can be force-fed or supplemented through various tube-feeding strategies. Force-feeding meatballs or a liquid diet may be effective in the short term but difficult for long-term management. Nasoesophageal, nasojejunal, pharyngostomy, esophagostomy, gastrostomy, and jejunostomy tubes are used in veterinary medicine. Jejunostomy tubes traditionally have required abdominal surgery for placement and, like nasoesophageal tubes, are limited to a liquid diet. New techniques and tubes are available that allow the placement of a feeding tube beyond the stomach into the small intestine. Using long, weighted jejunal feeding tubes, patients can receive the benefit of jejunal feeding without additional surgery. Laparoscopic and endoscopic alternatives are also being explored. Passing a small jejunal feeding tube through a gastrostomy tube, then taking it into the small intestine with an endoscope, has provided another novel way to initiate jejunal feeding. Because it enters beyond the stomach, the jejunostomy tube can be used in vomiting patients. Gastrostomy tubes can be placed surgically, endoscopically, or blindly. Because of their larger size, various gruel diets can be prepared from canned foods and water. Incorporated into a bandage, gastrostomy tubes can easily be maintained for months by the owner. Esophagostomy and pharyngostomy tubes can be placed with minimal equipment and provide large-bore feeding for short periods. Nasogastric tubes are uncomfortable and require a liquid diet but may provide short-term nutritional support.

7. What risks are associated with tube feeding?

Endotracheal placement of any feeding tube results in serious iatrogenic aspiration pneumonia. Feeding tubes that pass near the larynx should be checked radiographically before feeding. Nasogastric, pharyngostomy, and esophagostomy tubes may become dislodged and inhaled. If an animal vomits, the placement of the tube should again be confirmed before feeding is resumed. It is also a good idea to inject a small amount of water before each feeding while listening for a cough or sounds suggesting intratracheal placement.

8. Define TPN and PPN.

TPN or total parenteral nutrition is the delivery of essential nutrients directly into the bloodstream. The nutrients bypass intestinal absorption and the portal venous system and are available to the intermediary metabolic pathways. The standard TPN formula includes dextrose, an amino acid source, and a lipid. Additional B vitamins and potassium are also added. TPN is hyperosmolar and must be given through a central venous catheter.

PPN or partial parenteral nutrition also has been called protein-sparing fluid therapy and uses a 3% amino acid solution with electrolytes. Because the amino acid solutions are not as hyperosmolar as TPN, PPN may be given through peripheral veins. Theoretically the amino acids are used for gluconeogenesis instead of the patient's protein stores.

9. What are the risks and complications associated with TPN?

Complications of TPN include sepsis, metabolic acidosis, hyperphosphatemia, hyperglycemia, and hyperammonemia. Patients with hyperlipidemia or pancreatitis should not receive lipid-containing solutions. TPN requires the placement of a sterile, central catheter and close attention to aseptic technique during handling of related equipment. Recent clinical and experimental evidence suggest that TPN may impair host immune defenses and intestinal barrier function. Experiments comparing enterally fed animals with parenterally fed animals documented better antibacterial host defenses and improved survival against an infectious challenge in the enterally fed group. Randomized clinical trials of TPN in humans have documented an increased incidence of infectious complications in patients receiving TPN.

10. Should anorexia be anticipated in any specific group of patients?

Yes. Any debilitated, stressed patient may develop anorexia. It is most common after painful surgical procedures or abdominal surgery and with some medications. Critically ill surgical patients anticipating days of hospitalization should receive some sort of enteral feeding tube at the time of surgery. Animals with cancer or renal disease commonly develop anorexia. Strategies to treat the primary disease should be coupled with supportive measures to improve appetite and encourage caloric intake.

11. What diseases or conditions result in anorexia?

Causes of Anorexia

PRIMARY ANOREXIA	SECONDARY ANOREXIA	PSEUDOANOREXIA
Neurologic disease	Pain	Disorders of oral cavity
Increased intracranial pressure	Abdominal	Gingivitis, stomatitis
Cerebral edema	Thoracic	Pharyngitis, tonsillitis
Hydrocephalus	Musculoskeletal	Tooth root abscess
Intracranial pain	Urogenital	Broken teeth
Hypothalamic disorders	Organomegaly	Foreign bodies
Neoplasia	Inflammation	Neurologic disease
Infection	Toxic agents	Hypoglossal paralysis
Trauma	Exogenous	Mandibular paralysis
Psychologic disorders	Drugs	Tetanus
Unpalatable diet	Poisons	Blindness
Stress	Endogenous	Trauma
Sudden changes in environment	Metabolic wastes	Maxillary or mandibular fractures
	Inflammatory mediators	Temporomandibular dislocation
	Neoplasia	Retrobulbar abscess or neoplasia
	Infectious disease	Esophagitis
	Miscellaneous	
	Cardiac failure	
	Ketosis	
	Motion sickness	
	High ambient temperature	
	Autoimmune disease	

12. Describe the diagnostic plan for an anorectic patient.

Anorexia is a common sign of many different primary diseases. Pseudoanorexia may be eliminated by thorough physical examination and careful observation of the animal when presented with food. The animal may reveal pain when the jaws are open. Oral examination for dental disease, foreign bodies, or inflammatory lesions within the mouth may explain lack of appetite. If nothing abnormal is discovered, a complete polysystemic evaluation should be performed to uncover causes of secondary anorexia.

13. Are there any symptomatic treatments for anorectic patients?

The definitive treatment of decreased appetite is to find and correct the underlying problem. Environmental stimuli may affect appetite. Timid animals may not eat in a noisy room or around strangers. Palatability of food may be enhanced by experimenting with new diets, textures, and odors. Food can be heated to enhance olfaction. Flavoring agents such as animal fat, garlic, cheese, bouillon, clam juice, and butter also may increase palatability. Pharmacological agents reported to stimulate appetite include anabolic steroids, corticosteroids, benzodiazepine derivatives, and cyproheptadine hydrochloride.

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28. FEVER

Derek P. Burney, D.V.M.

1. What is fever?

Fever is an increased core body temperature due to resetting of the hypothalamic thermoregulatory center to a higher temperature. The thermoregulatory center is located in the preoptic region of the rostral hypothalamus.

2. How is body heat regulated?

The thermoregulatory center is composed of two parts. The rostral part is a heat loss center that is parasympathetic. The caudal part is a heat production center that is sympathetic. Peripheral thermoreceptors in the skin and internal receptors in the abdomen and central nervous system (CNS) along with the thermoregulatory centers help to maintain a delicate balance between heat loss and production.

3. How is fever defined in companion animals?

A core body temperature > 102.5°F (39.1°C) is elevated in dogs and cats. The elevated temperature may be due to fever or hyperthermia.

4. What is the physiologic basis of fever?

Endogenous pyrogens are released after circulating monocytes and fixed mononuclear phagocytes are activated. Endogenous pyrogens, including interleukin 1, tumor necrosis factor, and platelet activating factor, cause the thermoregulatory center in the hypothalamus to be reset to a higher temperature. Many chemical mediators, such as prostaglandins, prostaglandin precursors, cyclic adenosine monophosphate, 5-hydroxytryptamine, and norepinephrine, also may contribute to fever. Endogenous pyrogens raise the thermoregulatory set point by unknown means. The set point also may be altered by intracranial diseases such as trauma or neoplasia or drugs such as tetracycline.

Leukocytes are activated after exposure to antigens, called exogenous pyrogens. Antigens associated with bacteria, viruses, fungal infections, parasites, neoplasia, tissue necrosis, and immune-mediated disorders are considered to be exogenous pyrogens. Exogenous pyrogens have a large molecular mass and cannot cross the blood–brain barrier; therefore, they do not stimulate the hypothalamus directly.

5. Where is most body heat produced?

Most of the heat generated internally by the body is due to oxidative reactions in the liver. Of course, muscle activity can rapidly generate a tremendous quantity of heat.

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5. Where is most body heat produced?

Most of the heat generated internally by the body is due to oxidative reactions in the liver. Of course, muscle activity can rapidly generate a tremendous quantity of heat.

6. What is the difference between hyperthermia and fever?

In hyperthermia, the hypothalamic thermoregulatory set point is not changed. Hyperthermia may result from high environmental temperature, increased metabolic rate, or increased muscle activity. Hyperthermia occurs because heat loss mechanisms are overwhelmed or poorly functioning. Hyperthermia does not result from pyrogens. Fever is due to resetting of the thermoregulatory set point in the hypothalamus by endogenous pyrogens.

7. How can you determine the difference between fever and hyperthermia?

A good history and physical examination are the most important skills to differentiate fever from hyperthermia. Examples of causes of hyperthermia from increased muscle activity include exercise, seizures, or nervousness. Heat stroke may result when a patient is left in a car on a warm day, even if only for a few minutes. Heat stroke also may result when an animal is confined to an area with no shelter or water on a hot day. Clients are often surprised when a dog gets heat stroke after a day at the beach with no water or shelter. Animals recovering from anesthesia and left on a heating pad unsupervised may become hyperthermic.

8. What major disease categories should be considered in evaluating a patient with elevated body temperature?

First, fever must be differentiated from hyperthermia. Fever may be drug-induced or caused by immune-mediated disease, neoplasia, infection, or inflammatory disorders.

9. At what body temperature is therapy necessary?

Fevers above 106°F (41.1°C) are potentially harmful to cellular metabolism and should be treated. A fever > 106°F (41.1°C) is considered a medical emergency. Prolonged exposure to body temperatures > 106.5°F (41.4°C) may result in brain damage or heat stroke.

10. How is fever treated?

Although it is controversial, fevers > 106°F (41.1 C) should be treated. Antiprostaglandin antipyretics are the first choice of therapy, beginning with aspirin (acetylsalicylic acid). Cats do have metabolism problems with salicylates. Phenothiazines are also effective because they use central and peripheral vasodilatory effects to decrease body temperature. Whole body cooling (e.g., ice water baths and enemas, fans) should not be used; physical removal of heat increases metabolic stress because the body tries to meet the temperature set by the hypothalamus.

Nonsteroidal Antiinflammatory Drugs for Treatment of Fevers > 106°F (41.1°C)

DRUG	DOSE FOR DOGS	DOSE FOR CATS
Acetylsalicylic acid (aspirin)	25–35 mg/kg orally every 8 hr	12.5–25 mg/kg orally every 24 hr*
Sodium salicylate	10 mg/kg IV every 8 hr	10 mg/kg IV every 24 hr
Dipyrone†	25 mg/kg SQ, IM, IV, or orally every 8 hr	25 mg/kg SQ, IM, IV, or orally every 8 hr

IV = intravenously, SQ = subcutaneously, IM = intramuscularly.
* Do not exceed this dose.
† Should be limited to short-term use because of potential agranulocytosis and leukopenia.

11. How should hyperthermia be treated?

Hyperthermia should be treated aggressively by eliminating the cause of heat stress. The body should be cooled by use of ice water baths and enemas, alcohol baths, and fans. To avoid hypothermia, cooling procedures should be stopped when the temperature has been decreased to 103°F (39.4°C). Patients with hyperthermia should be observed closely for signs of cerebral edema and disseminated intravascular coagulation.

12. Does fever have beneficial effects?

There is no conclusive evidence that fever is beneficial. It has been suggested that fever may inhibit bacterial and viral proliferation. Proteolytic enzymes, which are easily released from lysosomes

during fever, can be destructive to viruses. Fever reduces the ability of bacteria to trap and chelate iron, and exogenous pyrogens probably cause iron sequestration in hosts, making iron stores less available to bacteria. Fever may enhance interferon production, which adversely affects viral growth. Leukocyte mobility, phagocytic activity, and bactericidal effects may be enhanced by fever. Fever also has been suggested to enhance lymphocyte transformation. Monitoring fever in an infectious disease may provide evidence of therapeutic efficacy.

13. What are the detrimental effects of fever?

Fever > 106°F interferes with cellular processes, and prolonged high fevers may result in brain damage, heat stroke, or dissemianted intravascular dissemination. Fever also causes anorexia, which can be metabolically detrimental to an animal suffering from disease. The detriments to fever outweigh the benefits unless a diagnosis is still being pursued.

14. What is FUO?

FUO is a commonly used abbreviation for fever of unknown origin. FUO is a fever of unknown etiology that has persisted for 10–14 days in the face of aggressive diagnostic tests, including complete blood count, biochemical profile, urinalysis, and chest and abdominal radiographs. In humans, FUO must be a fever of 3 weeks or more with vague, nonspecific signs of infection in the face of aggressive diagnostic tests.

15. What effect does fever have on metabolism?

Data from humans and rats have estimated that metabolism increases 13.6% for each degree Celsius that the body temperature is above normal. Based on these data, an animal with fever may need to have caloric intake increased by 7 kcal/kg body weight for each degree Celsius that the temperature is above normal.

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29. STRANGURIA

Stephanie J. *Lifton*, D.V.M.

1. What is the first thing to do for an animal with a primary complaint of stranguria?

The first thing to do is to determine whether the animal has a urinary obstruction. Palpate the abdomen for a hard, distended bladder, and do a quick but thorough physical examination. If the animal has been obstructed for some time, hyperkalemia may be a life-threatening complication, necessitating immediate supportive therapy as well as alleviation of the obstruction before further diagnostics are collected. Because of the smaller diameter and longer urethra of male dogs and cats, obstruction is more common in males than females.

2. What are the primary differential diagnoses of an animal with stranguria?

In general, stranguria is associated with lower urinary tract disease. Possible diagnoses include the following:

during fever, can be destructive to viruses. Fever reduces the ability of bacteria to trap and chelate iron, and exogenous pyrogens probably cause iron sequestration in hosts, making iron stores less available to bacteria. Fever may enhance interferon production, which adversely affects viral growth. Leukocyte mobility, phagocytic activity, and bactericidal effects may be enhanced by fever. Fever also has been suggested to enhance lymphocyte transformation. Monitoring fever in an infectious disease may provide evidence of therapeutic efficacy.

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2. What are the primary differential diagnoses of an animal with stranguria?

In general, stranguria is associated with lower urinary tract disease. Possible diagnoses include the following:

- Urinary tract infection (UTI)
- Prostatic disease
- Cystic and/or urethral calculi
- Granulomatous urethritis
- Bladder or urethral neoplasia
- Neurologic disease
- Idiopathic sterile hemorrhagic cystitis (idiopathic feline lower urinary tract disease [FLUTD])
- Urethral stricture
- Congenital anomaly

3. What other historical questions should you ask the client?

Ask clients about the presence of pigmenturia, pollakiuria, polyuria, and polydipsia and whether they have noticed the animal urinating at all.

4. How should you relieve an obstruction?

There are many techniques for relieving an obstruction. In male cats with FLUTD, the obstruction is sometimes close to the tip of the penis, and simply massaging the end of the penis relieves the obstruction. More often, grit and calculi in the urethra need to be gently flushed back into the bladder before a catheter can be passed. This process is sometimes facilitated by using a small amount of lidocaine in the lubricant to decrease urethral spasms. In addition, using a syringeful of K-Y jelly, diluted with some saline, may relieve the obstruction when saline alone has been unsuccessful.

If these techniques are ineffective, cystocentesis should be performed. Cystocentesis temporarily alleviates the adverse effects of the obstruction and provides a sample for urinalysis and culture. In addition, decompression of an overdistended bladder may relax the urethral sphincter and allow retrograde flushing of the plug back into the bladder.

It is imperative not to forget the importance of intravenous fluids and treatment for hyperkalemia while attempting to relieve the obstruction.

5. What electrocardiographic (ECG) changes typically accompany hyperkalemia?

Changes include tall and tented T waves, shortened Q-T intervals, wide QRS, decreased amplitude or disappearance of P waves, prolonged P-R interval, and eventual asystole.

6. List two treatments that can be used in the emergency treatment of hyperkalemia, and explain how they work.

1. Glucose and insulin: 4–10 ml/kg of a 10% dextrose solution and 0.06–0.2 U/kg of regular insulin IV.
2. Bicarbonate: 1–2 mEq/kg

Both treatments result in a shift of potassium into the intracellular space. Although bicarbonate can treat the metabolic acidosis that is often present, it may have several deleterious effects, including a shift of the oxygen/hemoglobin saturation curve to the left, increasing serum osmolality, and lowering the serum concentration of ionized calcium. The last effect is particularly noteworthy because it has been shown that cats with urethral obstruction can have a low serum ionized calcium concentration. Calcium gluconate may be given to counteract the hypocalcemia and to mitigate the effects of hyperkalemia on the myocardium.

7. What are the important parameters to monitor once the obstruction has been relieved?

Postobstructive diuresis may result in higher than expected fluid requirements. In addition, levels of potassium and other electrolytes often drop precipitously as a result of diuresis. It is also important to monitor blood urea nitrogen (BUN) and serum creatinine for evidence of permanent renal compromise. One study found that cats with urethral obstruction have low serum concentrations of ionized calcium. This change was negatively correlated with the degree of hyperkalemia and may exacerbate the cardiac abnormalities associated with the hyperkalemia.

8. List the diagnostic tests that may be appropriate for an animal with stranguria.

- Urinalysis with urine culture
- Rectal exam: for assessment of prostate and masses in the urethra or neck of the bladder
- Complete blood count and serum biochemistries
- Abdominal radiographs
- Contrast radiographs
- Abdominal ultrasound
- Cystoscopy
- Bladder biopsy
- Prostatic wash (in dogs)
- Urethral pressure profile: may be helpful in documenting inappropriate urethral resistance

9. If you find ammonium biurate crystals or calculi, what other tests should you consider?

In animals other than Dalmatians, ammonium biurate crystals may be associated with hepatic disease, especially portosystemic shunts. Therefore, further investigation of potential liver disease (e.g., serum bile acids, ammonia levels) is warranted.

10. Which types of calculi are radiodense, and which are radiolucent?

Radiodense uroliths: magnesium ammonium phosphate, calcium oxalate, calcium phosphate, silica, and cystine.

Radiolucent uroliths: urate salts.

11. What are the most common types of uroliths?

Magnesium ammonium phosphate uroliths are the most common uroliths in dogs. These calculi are often secondary to chronic bacterial cystitis. In cats, the incidence of calcium oxalate uroliths appears to be increasing, and the number of struvite uroliths is decreasing. Consumption of a diet designed to prevent formation of struvite crystals is one of the risk factors associated with development of calcium oxalate uroliths.

12. Which bacteria are most commonly cultured from the urine of dogs?

Gram-negative coliforms are the most common pathogens found in the urine of dogs and cats, with *Escherichia coli, Proteus mirabilis,* and *Klebsiella pneumoniae* accounting for most cases. Other common bacteria include *Pseudomonas* and *Enterobacter* spp., *Staphylococcus intermedius, Streptococcus* and *Enterococcus* spp., and *Pasteurella* spp. In approximately 15–20% of cases, infections are due to multiple bacteria. Less than 5% of cats with signs of lower urinary tract disease have bacterial infections.

13. Which antibiotic is best to start before culture results are available?

Many antibiotics are concentrated in urine and therefore reach levels effective against pathogens that otherwise they may not be able to treat. Almost 80% of *E. coli* infections respond to trimethoprim-sulfonamide; 80% of *Proteus* infections respond to ampicillin; 80% of *Pseudomonas* infections respond to tetracycline; 90% of *Klebsiella* infections respond to cephalexin; and almost 100% of staphylococcal and streptococcal infections respond to penicillins. Many urinary pathogens, especially *E. coli*, are most likely sensitive to the combination of amoxicillin and clavulinic acid. The fluoroquinolones also are concentrated in the urine and have a broad spectrum of activity, especially against gram-negative bacteria. The fluoroquinolones also reach good levels in the prostate; however, they probably should be reserved for more resistant infections to prevent emergence of resistant strains. A simple UTI should be treated for 10–14 days, whereas recurrent or chronic infections may need 4–6 weeks of antibiotic therapy.

14. What type of neoplasm is most common in the lower urinary tract of dogs? Of cats?

Tumors of the bladder account for less than 1% of all cancers in dogs and are even less common in cats. In cats, mesenchymal tumors are almost as common as epithelial tumors, whereas epithelial tumors are much more common in dogs. The most common tumor in both dogs

and cats is transitional cell carcinoma (87% of bladder tumors in dogs, 30% in cats). Other tumors include adenocarcinoma, squamous cell carcinoma, undifferentiated carcinomas, rhabdomyosarcoma, benign mesenchymal tumors (cats), leiomyosarcoma/leiomyoma, and lymphosarcoma.

15. What treatments are available for urinary tract neoplasia?

The best treatment is surgical excision. Unfortunately, many bladder neoplasms are not discovered until surgical resection is impossible. Response of transitional cell carcinoma to traditional chemotherapy with cisplatin or carboplatin has been disappointing. Recently, treatment with piroxicam, a nonsteroidal antiinflammatory drug, has shown promise. The mechanism of action of the antitumor activity of piroxicam is still unknown, but it appears to alleviate the clinical signs of stranguria, dysuria, and hematuria in many dogs and even induces remission in some patients. The most severe side effect of piroxicam is gastric irritation and ulceration.

Placement of a permanent cystostomy catheter can temporarily relieve signs of urinary obstruction while awaiting response to other treatments or be used as palliative therapy when definitive treatment is unsuccessful or declined by the client.

In addition, animals with bladder neoplasms often have concurrent UTIs, which need to be treated with appropriate antibiotic therapy.

16. What types of prostatic disease may cause stranguria?

- Abscess
- Cyst
- Neoplasia
- Acute or chronic prostatitis
- Benign prostatic hyperplasia

17. How can you differentiate the between these prostatic conditions?

Palpation of the prostate for symmetry, size, and pain is extremely important. Other diagnostic tools include radiographs (in addition to prostate size, evaluate sublumbar lymph nodes and the caudal spine for evidence of metastases), ultrasonography, and evaluation of prostatic fluid (obtained by prostatic massage or ejaculate). Ultimately, a biopsy may be necessary to distinguish among chronic prostatitis, benign prostatic hyperplasia, and neoplasm. Acute bacterial prostatitis and prostatic abscesses are contraindications to percutaneous biopsy.

18. What are the treatment options for the various prostatic diseases?

The best treatment for benign prostatic hyperplasia is castration. Medical treatments (synthetic estrogens, dihydrotestosterone receptor blockers, and synthetic progestins) also have been used. Large paraprostatic cysts often require resection and marsupialization. Bacterial prostatitis requires antibiotic therapy based on culture and sensitivity testing of urine or prostatic fluid. In patients with acute prostatitis, the blood–prostate barrier is often disrupted so that most antimicrobial drugs reach the site of infection. Treatment should be continued for 3–4 weeks. In cases of chronic prostatitis, the blood–prostate barrier is often intact, necessitating the use of antibiotics with high lipid solubility. In addition, antimicrobials with a higher pKa cross the prostatic epithelium and become ionized in the more acidic environment; thus they are "trapped" within the prostate, ensuring adequate antimicrobial concentrations. In chronic cases, treatment should continue for at least 4–6 weeks. Prostatic abscesses may require surgical marsupialization, drain placement, or even partial prostatectomy. The most common prostatic neoplasms in dogs are adenocarcinoma and transitional cell carcinoma. In general, treatment of neoplasms has been unrewarding. Possible therapeutic options include prostatectomy, intraoperative radiation therapy, chemotherapy, and piroxicam.

19. What is feline lower urinary tract disease?

FLUTD is an umbrella term referring to a cluster of signs of lower urinary tract disease due to any number of causes. Once infection, urolithiasis, crystalluria, and neoplasms have been ruled out, the disease is diagnosed as idiopathic FLUTD. Some evidence suggests that FLUTD may be similar to interstitial cystitis in humans. Interstitial cystitis is characterized by difficult, painful, and frequent urination in the absence of an obvious etiology. On cystoscopy, some cats with idiopathic

FLUTD have lesions identical to those seen in humans with interstitial cystitis. At this time, there is no effective treatment for interstitial cystitis in humans.

20. What treatments may be used for idiopathic FLUTD in cats that are not obstructed?

The signs associated with idiopathic FLUTD in cats are often self-limiting and may recur intermittently. Therefore, treatment may not be necessary in all cases. Most medications used in the treatment of FLUTD have not been proved effective in controlled clinical trials.

Diet. If struvite crystals are seen in the urine, together with an alkaline pH, a diet designed to dissolve and/or prevent struvite uroliths may be recommended. Although dietary manipulations are effective at preventing signs of FLUTD in some cats, some evidence suggests that such diets may predispose cats to calcium oxalate uroliths. In addition, the prevalence of struvite crystals in cats with FLUTD appears to be decreasing and signs of FLUTD commonly occur in the absence of crystalluria. One study found that cats consuming dry food were more likely to exhibit signs of FLUTD than cats eating canned food.

Antispasmodics. Propantheline, an anticholinergic agent, decreases the force and frequency of detrusor muscle contractions. Phenoxybenzamine and prazosin are alpha-1 antagonists that act on urethral smooth muscle, whereas diazepam and dantrolene act on skeletal muscle. The efficacy of any of the above drugs has not been well established.

Antiinflammatory agents. Studies have shown no benefit to treatment with glucocorticoids or dimethyl sulfide compared with placebo. Glucocorticoids are contraindicated in cats with UTIs or urethral obstruction, especially those requiring urethral catheterization.

Amitriptyline. This tricyclic antidepressant and anxiolytic was successful in decreasing the clinical signs in a small number of cats with severe, recurrent FLUTD, although its exact mechanism of action in patients with idiopathic cystitis is unknown. Studies involving a larger number of cats are needed to document safety and efficacy.

Glycosaminoglycans. Pentosan polysulfate sodium, a synthetic low-molecular-weight heparin GAG analog, was helpful in ameliorating clinical signs in human patients with idiopathic cystitis. Studies investigating the use of this drug in cats are warranted.

Urohydrodistention. This therapy provides temporary relief from clinical signs in some humans with interstitial cystitis. Controlled studies in cats are needed for further evaluation.

Ongoing studies may further elucidate the cause of this syndrome and lead to more successful therapeutic options. Until that time, FLUTD will continue to be a frustrating disease for both pet owners and veterinarians.

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30. OBSTIPATION AND CONSTIPATION

Andrew I. Triolo, D.V.M., M.S.

1. Are constipation and obstipation common problems in small animals?

Absolutely. Although occasionally seen in dogs, they are more common in cats.

2. Define constipation and obstipation.

Constipation is the difficult passage of feces. Obstipation is more severe constipation with fecal impaction. Obstipated animals usually cannot eliminate feces on their own.

3. How are constipation and obstipation diagnosed?

Most cases can be diagnosed with a complete history and physical examination. In extremely large or obese animals, radiographs also may be helpful.

4. What causes constipation and obstipation?

Although there are many causes, any disease state that encourages fecal stasis and/or colonic water absorption may lead to constipation or obstipation.

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Common Causes of Constipation and Obstipation

Diet	Environment
Bones	Decreased exercise
Grass	Dirty litter box
Rocks	Neurologic disease
Low fiber	Idiopathic megacolon
Drugs	L4–S3 spinal disease
Anticholinergics	Obstructions
Antihistamines	Foreign bodies
Anticonvulsants	Neoplasia and strictures
Barium sulfate	Pelvic fractures
Endocrine or metabolic disease	Perianal hernias
Hypothyroidism	Perirectal disease
Hyperparathyroidism	Anal gland disease
Renal failure	Perianal fistulas
	Anal strictures

5. How serious are constipation and obstipation?

Extreme cases may lead to bowel/colon perforation, which results in septic peritonitis. Immediate exploratory surgery is required in such patients.

6. What are the typical clinical signs of constipation and obstipation?

Tenesmus and dyschezia are the more common clinical signs of constipation and obstipation. Anorexia and vomiting are often seen in chronic cases, especially in cats. In animals with urinary obstructions, clinical signs may be similar.

7. What is the typical work-up for constipation and obstipation?

A minimal database, which includes complete blood count, serum biochemical analysis, urinalysis, and abdominal radiographs, helps to rule out major medical causes of constipation, including renal disease. At times, further diagnostic tests may include an abdominal ultrasound, pneumocolonogram, or barium contrast studies.

8. What may result from repeated episodes of constipation or obstipation?

Chronic megacolon is a serious complication, most often seen in cats. Chronic megacolon also may result in cases that are refractory to pharmacologic manipulation.

9. How do you treat constipation and obstipation?

Simple constipation is often treated with mild soapy or mineral oil enemas. Avoid phosphate enemas, especially in cats. Hexachlorophene products also should be avoided. Obstipated animals often need to be sedated and the fecal material digitally removed, along with administration of enemas. Small sponge forceps are useful for removal of fecal matter and do not create major trauma to the colon. Obstipation rarely needs to be surgically addressed.

10. How are chronic cases of obstipation and constipation medically managed?

Drugs most often used are Lactulose and Propulcid. Fiber agents such as bran, Metamucil, or canned pumpkin are also helpful in managing chronic cases.

Drugs Used for Chronic Constipation or Obstipation

DRUG		DOSE	COMMON SIDE EFFECTS
Lactulose	Dog	5–30 ml 3 times/day orally	Diarrhea, vomiting, cramping
	Cat	1–10 ml 3 times/day orally	
Propulcid	Dog	0.5 mg/kg 3 times/day orally	Diarrhea, abdominal cramping
	Cat	2.5–5 mg 2 or 3 times/day orally	

Table continued on next page.

Drugs Used for Chronic Constipation or Obstipation (Continued)

DRUG	DOSE	COMMON SIDE EFFECTS
Fiber products		
Canned pumpkin	1–5 tbsp daily with food	Flatulence
Psyllium	1–5 tsp daily with food	Flatulence

11. How does Lactulose work?

Lactulose is an osmotic laxative that helps to retain water in the colon. The end result is softer feces.

12. What is the mechanism of action of Propulcid?

Propulcid increases physiologic release of acetylcholine from postganglionic nerve endings. This is believed to increase motor activity in the esophagus, stomach, and small and large intestines. The company that makes Propulcid is withdrawing the drug from the market, but it should be available if you petition the company directly.

13. Fiber is used for patients with diarrhea. Why is it recommended for patients with obstipation or constipation?

Fiber may be used for patients with either diarrhea or constipation, depending on the type of fiber. Insoluble high fiber leads to softer fecal consistency, decreased transit time, increased fecal weight, and increased frequency of defecation.

14. Can properly managed cases still be refractory?

Yes. In the author's experience, 10–20% of cases are refractory to proper medical management. Subtotal colectomy, which must be performed by a skilled surgeon, is recommended as a last resort. Even then, postoperative dehiscence and peritoneal sepsis are possible complications. Clients also must be informed that some patients still need some medical management.

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31. FRACTURED TOOTH

Tim Hackett, D.V.M., M.S.

1. Review the normal anatomy of the tooth, including enamel, the dentinal layer, and the pulp.

The exterior of the tooth is covered with a layer of **enamel** that is mostly inorganic, the hardest substance in the body. The enamel protects the interior of the tooth from oral flora. The white color of enamel develops from a translucent gray when the tooth first erupts. As the dentine layer develops, the tooth turns to its normal white. Damage to the enamel layer can cause problems to the deeper, more sensitive structures because enamel cannot regenerate and heal.

The **dentinal layer** separates the pulp from the enamel. The dentine is porous; if it is exposed, bacterial invasion of the pulp may result.

The **pulp cavity** is the vital, living core of the tooth. If the pulp dies, the tooth will be lost.

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2. How are dental lesions classified?

Type A Confined to the crown of the tooth with no involvement of the cemantoenamel junction (CEJ) and no exposed pulp.

Type B Confined to the crown with pulp exposure.

Type C Centered on or involving the CEJ enamel, cementum, and dentin, but with no exposed pulp.

Type D Centered on or involving the CEJ enamel, cementum, and dentin with exposed pulp.

Type E Confined to the root below the CEJ.

Type F Destructive and degenerative lesions involving the whole root.

3. What finding in a fractured tooth makes further treatment mandatory?

Exposure of the pulp cavity requires definitive care—either extraction or endodontic care with or without reconstruction. An open pulp cavity exposes nerves and the core of the tooth to contact and contamination. Without endodontic therapy the tooth remains painful and becomes infected. Exposed pulp may be treated temporarily by placement of calcium hydroxide paste over the fracture.

4. Do the roots of fractured deciduous teeth need to be removed, or do they simply resorb?

Often the retained primary tooth is in the process of resorption; however, the root may remain intact for a long time. The most important reason to extract the complete tooth is to prevent malocclusion. Orthodontic malocclusion occurs below the gumline; thus, it is in the patient's best interest to remove the roots of primary teeth.

5. Which teeth are most commonly fractured?

The canines, upper fourth premolar (upper carnaissal tooth), and incisors are most commonly fractured in small carnivores.

6. Define endodontics.

Endodontics means within the tooth and refers to diseases of the pulp. Pulp is the core of the tooth, consisting of nervous, vascular, and connective tissue. Any condition that exposes the pulp cavity is an indication for endodontic therapy.

7. What are the treatment goals of endodontic therapy?

The entire contents of the pulp cavity are removed with specialized endodontic files and irrigation. The files are used to clear and enlarge the pulp cavity, forming a slight funnel shape tapering toward the apex of the tooth. The apex of the tooth is sealed after the canal is packed with a special endodontic filling material.

8. What is pulpotomy? What are the contraindications to its use?

Pulpotomy is a conservative variation of standard endodontic therapy reserved for acute traumatic injuries of young permanent teeth with pulp exposure. Pulpotomy involves removal of pulp from the pulp chamber in the crown of the tooth while leaving vital pulp in the pulp canals (roots) to function in a healthy condition.

Contraindications to pulpotomy include fractures more than 25 hours old, evidence of sensitivity of the tooth to percussion, suppurative pulp, or radiographic evidence of periapical changes consistent with tooth root abscess. Exposed pulp from injuries less than 25 hours old is red and bleeds freely when probed. Frequent radiographic rechecks are indicated to assess the viability of the tooth.

9. What is the approach to a displaced or avulsed tooth?

If client reports an avulsed tooth, instruct the client to place the tooth in a glass of milk or, if available, a commercial conditioning solution for transport to the veterinary hospital. The periodontal ligament on the root of the tooth must be preserved for reattachment without root resorption. Handle the tooth by the crown, not the root. A human tooth kept in dry storage for 30 minutes undergoes root resorption when replanted. The same tooth is viable for 6 hours in milk

and up to 96 hours in Hank's Balanced Salt Solution. Once the patient is anesthetized, radiographs should be taken to assess the extent of injury to the surrounding alveolar bone. Tooth displacement may be accompanied by fracture of surrounding alveolar bone; this is almost always the case with tooth avulsion. The area should then be lavaged with sterile saline or 0.12% chlorhexidine. Lavage the socket, and remove any blood clots. Remove any bone fragments from the wound edges, and replace and reposition the tooth. The fractured alveolar bone can be pressed back into place. Hold the tooth firmly in place for a few minutes before suturing the soft tissue. The tooth should be splinted with either a self-cure composite or an acrylic. Acrylics are not as strong as composites and may cause thermal damage to the oral tissues when they cure. A figure-8 wire should be placed between the canines to act as a framework for the splint.

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32. ABSCESSES AND CELLULITIS

Tim Hackett, D.V.M., M.S.

1. Differentiate abscess and cellulitis.

An abscess is a localized collection of pus and debris in a distinct cavity surrounded by firm granulation tissue. Cellulitis is a diffuse inflammation of soft tissues characterized by infection spreading through the fascial planes of the skin and subcutaneous tissues.

2. Why do cats get more percutaneous abscesses than dogs?

The thin, sharp teeth and fighting behavior of cats provide a means of entry for resident oral microflora. Cat skin is tough and elastic, sealing over contaminated puncture wounds. Subcutaneous exudates quickly form pus-filled cavities, usually around the cat's legs, face, back, and base of the tail.

3. What are the common systemic consequences of localized infections?

Animals with systemic signs of infection are often febrile and lethargic and may develop septicemia and shock. Large inflammatory reactions recruit white blood cells, causing relative neutropenia. Mature neutrophilia is a common finding with mature, walled-off abscesses. Diffuse cellulitis is more likely to cause neutropenia and fever. Through hematogenous spread of bacteria, animals with local infections may develop pneumonia and other deep infections. Septic shock results from the systemic activation of a cascade of mediators that lead to vasodilation, hypotension, and circulatory failure.

4. What diseases should be ruled out in patients with recurrent bacterial infections?

Outdoor cats, especially adult males that fight with other cats, are at risk for infection with feline leukemia virus (FeLV) or feline immunodeficiency virus (FIV). Such cats often have severe leukopenia with or without anemia. Osteomyelitis, foreign body, neoplasia, infections with L-form bacteria, *Nocardia* and *Mycobacterium* spp., and fungi also should be considered when lesions fail to heal.

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5. How does management of cellulitis differ from management of an abscess?

Surgical drainage is the treatment of choice for an abscess. With good drainage, antibiotics may not be necessary in healthy animals. Because of the diffuse nature of cellulitis, immobilization, warm compresses, and antibiotics are the recommended treatment. Animals with cellulitis are often systemically ill and may benefit from intravenous fluids, antibiotics, and analgesics.

6. What direct complications of abscesses and cellulitis may require emergency care?

The location of the abscess may cause a mass effect that impinges on vital structures. Pharyngeal swelling may obstruct airflow. Abscess in the gastrointestinal tract or abdomen may obstruct the bowel. Localized infection may lead to systemic complications, including septicemia and fever. Septic shock may result directly from the effect of endotoxin or from systemic activation of inflammatory mediators. The result is maldistribution of blood flow and multiple organ failure.

7. What is the most important point in treating a localized infection?

Antibiotics do not penetrate well into enclosed infectious foci. Surgical drainage and debridement are necessary to resolve local infections. Antibiotic therapy guided by culture and susceptibility testing is important to prevent systemic complications, but drainage is necessary for resolution.

8. What zoonotic diseases cause abscesses in dogs and cats?

Yersinia pestis (plague) is a potentially lethal bacterial infection in small animals, especially cats. Although infection with *Y. pestis* may take bubonic, pneumonic, or septicemic forms, most cats with *Yersinia* infection have submandibular, cervical, and retropharyngeal lymphadenopathy. *Yersinia* infections may present like any other facial abscess—with lethargy, fever, and a draining wound from enlarged lymph nodes. Cats may develop septicemic plague or pneumonic plague if the lymph nodes do not drain. People may become infected by inhalation of respiratory droplets from animals with pneumonic plague, by handling infected tissues or fluids via broken skin, or through bites of plague-infected fleas. Giemsa-stained tissue aspirates are used to detect bipolar-staining coccobacilli. The diagnosis is confirmed by fluorescent antibody staining of lymph node aspirates or abscess fluid.

Sporothrix schenckii is a dimorphic fungus that favors soils rich in organic matter. Animals become infected via inoculation of the organism into the tissues. People may become infected by contact exposure with infected cats. The cutaneous and cutaneolymphatic forms of sportichosis present with multiple nodules. Nodules may be firm, ulcerated, or draining. In cats, the lesions usually occur on the distal limbs, head, or base of the tail. Animals are often lethargic and febrile. The lesions may appear similar to other draining fight wounds. The organism can be identified in exudates or biopsy specimens, using either periodic acid-Schiff (PAS) or Gomori's methenamine silver (GMS) stain. Organisms are usually easy to find in cats but more difficult in dogs.

9. What common bacterial pathogens are found in abscesses? What first-line antibiotics should be considered?

If the abscess is from a cat bite, common pathogens may include *Pasteurella* spp., *Streptococcus* spp., *Escherichia coli*, *Actinomyces* spp, and *Nocardia* spp. Anaerobes such as *Bacteroides*, *Fusobacterium*, *Peptostreptococcus*, and *Clostridium* spp. are also potential pathogens. *Actinomyces* and *Nocardia* infections are common causes of abscesses in dogs, especially intact, large-breed, male hunting dogs. Effective antibiotics include penicillin products because of their anaerobic spectrum and chloramphenicol because of its broad spectrum and ability to penetrate tissues. Most antibiotics do not penetrate to the center of a walled-off abscess. Surgical drainage and debridement reduce the infectious burden and allow antibiotic penetration into surrounding tissues.

10. What are some fungal causes of abscess and cellulitis?

Sporotrichosis, blastomycosis, coccidiomycosis, crytococcosis, histoplasmosis, and trichosporosis may result in draining skin wounds and systemic illness and usually can be identified on PAS-stained specimens. Specific fungal cultures should be submitted in cases without an obvious bacterial etiology.

11. What other differential diagnoses should be considered for recurrent abscesses?

Although cysts, granulomas, hematomas, and seromas are common mass lesions, neoplasia can result in a rapidly developing mass that may outgrow its blood supply. If this happens, the lesion may become necrotic and infected. Biopsy should be considered in any mass that fails to resolve quickly after surgical debridement and drainage.

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33. RATTLESNAKE ENVENOMATION

Tim Hackett, D.V.M., M.S., *and Wayne* E. *Wingfield*, D.V.M., M.S.

1. What groups of poisonous snakes cause the most problems for domestic animals in the United States?

There are three groups of poisonous snakes in the United States:

Pit vipers. Pit vipers are the largest group and include rattlesnakes, copperheads, and water moccasins. Pit vipers have thermoreceptor organs ("pits") between the eye and nostril, triangular-shaped heads, and retractable fangs.

Elapids. Elapids include coral snakes. They are brightly colored and have fixed fangs. The coloring of coral snakes differentiates them from the similar but harmless king snake:

- *Red on yellow, kill a fellow* (coral snake)
- *Red on black, venom lack* (king snake)

Colubrids. Colubrids include the Sonoran lyre snake, vine snake, and night snake. They have fixed fangs and are of minor importance.

2. What first aid should be rendered in the field after a rattlesnake bite?

Rescuers should be careful not to get bitten. The best treatment for rattlesnake envenomation is to take the animal to a veterinary hospital as soon as possible. Tourniquets, suction devices, and local application of electrical current have been reported for early management of rattlesnake envenomation. These interventions may delay transport, and none has proved efficacious.

3. What are the common clinical signs associated with pit viper attack?

"Snakebite" can be difficult to diagnose. In general, pit viper envenomation produces a local reaction. Look for fang marks, rapid swelling, edema, and pain at the site. Other symptoms may include erythema, petechia, ecchymosis, and tissue necrosis. Clinical signs of systemic illness include vomiting, respiratory distress, tachycardia or arrhythmia, hypotension, bleeding disorders, nystagmus, and fever.

4. Once the animal arrives at the hospital, how can you determine whether the animal was envenomated by a rattlesnake?

Owners may present their animals after coming in close contact with a rattlesnake, unsure whether the animal was bitten. If envenomation has occurred, the affected areas usually develop

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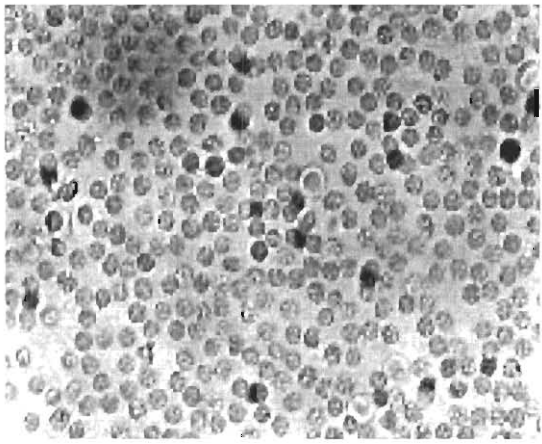
Owners may present their animals after coming in close contact with a rattlesnake, unsure whether the animal was bitten. If envenomation has occurred, the affected areas usually develop

marked edema and erythema within 1 hour of the strike. The face, neck, and forelimbs should be examined carefully for fang marks, swelling, and bleeding; the animal may be in extreme pain. Measurement of swollen areas should be repeated, because rapid swelling indicates probable snakebite. One useful test for envenomation is to examine a peripheral blood smear for echinocytes.

5. How do you examine for echinocytes? What do they look like?

A drop of the patient's blood is placed on a slide with a drop of saline and examined under the microscope for echinocytosis. Small, finely crenated echinocytes are present and affect most of the red blood cells (see figure below). Often this change is seen before swelling and systemic illness become apparent. As you monitor the peripheral blood smear, the number of echinocytes decreases each day; by day 3–5, it is nearly impossible to find these abnormal cells. The mechanism of echinocytosis is unknown in envenomation but probably involves uncoupling of oxidative metabolism. In addition, dogs bitten by rattlesnakes do not have increased levels of bilirubin, as one may expect if the echinocytes were destroyed by the spleen. For some reason, perhaps because of massive tissue injury by envenomation, dogs often show increased fractional excretion of potassium in the urine.



Echinocytosis affecting 100% of the red blood cells in a dog after rattlesnake envenomation.

6. What determines the severity of a snakebite?

Many factors influence the amount and type of venom received and the host's reaction. Host size and health are important, as are regional and species differences among snakes. Bites from copperheads and prairie rattlesnakes are usually minimally symptomatic. Conversely, in some southwestern desert areas the Mojave rattlesnake may cause respiratory paralysis and rapid death. The age and size of the snake, time of day, time since the snake's last meal, and season affect the amount of venom administered in a bite. Many bites are dry and nonpoisonous. They may be painful but usually show no signs of swelling. Wounds still should be considered contaminated, and appropriate cleaning and antibiotic therapy are indicated.

7. What is a dry snakebite?

A dry snakebite is present if no venom is released at the time of the bite. Clinically a dry snakebite is assumed if no pain or swelling occurs within 1 hour of envenomation.

8. What toxic components are found in pit viper venoms?

Rattlesnake venom contains various proteolytic enzymes. An early, direct effect of an enzyme called kininogenase is bradykinin activation. Bradykinin is a potent vasodilator on its own, but it also stimulates endogenous phospholipase A, which stimulates the arachidonic cascade to produce various inflammatory eicosanoids, including prostaglandins I_2, E_2, and $F_{2\alpha}$ and thromboxane A_2. The results are systemic inflammation, vasodilation, and severe hypotension.

Rattlesnake venom also disrupts the basal lamina and collagen of the capillaries, allowing leakage of blood cells and plasma into the surrounding tissues. Signs include edema and petechia. Venom may cause platelet aggregation and margination through damage to the endothelium. Activated platelets then produce thromboxane and prostaglandins, which attract more platelets and white blood cells. Activation of platelets and the coagulation cascade may lead to consumption of clotting factors. The snake's venom also has a thrombinlike enzyme that cleaves fibrin and adds to the mechanisms of disseminated intravascular coagulation (DIC).

9. What are the first steps to treat snake envenomation?

When an animal presents in distress after rattlesnake envenomation, the clinician should first assess the ABCs of resuscitation:

A Airway patency should be assessed. The airway may become obstructed with swelling and edema of the face or throat. If necessary, the patient should be intubated or a tracheostomy performed.

B Breathing should be assessed by auscultation and examination of mucous membranes.

C Circulation is assessed by palpating pulses, auscultating the heart, and again assessing mucous membrane color and capillary refill. If possible, blood pressure also should be checked.

Because the most serious early complication of rattlesnake bite is hypotension, a large-bore intravenous catheter should be placed and a balanced crystalloid solution started. Volumes and fluid rate should be based on clinical signs. In general, be prepared to give a whole blood volume (90 ml/kg in dogs) in the first hour. The patient's response to fluids should guide further therapy. Be aware of the potential fluid loss associated with increased capillary permeability. Patients presented within a few hours of a bite usually swell much more in the hospital. Continuous reassessment of vital functions is mandatory. Blood and urine should be collected for baseline data, coagulation testing, and identification of early myoglobinuria.

10. When should antivenin be given?

Rattlesnake antivenin is a polyvalent compound containing serum globulins from horses immunized with venoms of the major pit vipers (family: Crotalidae). Antivenin is contraindicated only in patients with known hypersensitivity. Unfortunately, there is no correlation between positive intradermal skin reactions and identification of early antivenin reactions. Normally, the antibodies in horse serum combine with the snake's venom to neutralize it. It may be life-saving in severely affected animals and limits the morbidity of relatively minor envenomation. Use of antivenin is controversial because many animals recover without it, it is expensive, and it is not without some risk of anaphylaxis. The dose may be quite variable. In people 2–4 vials are recommended for moderate envenomation (large swelling and abnormal laboratory tests) and up to 15 vials for severe envenomation (systemic manifestations). In animals, the number of vials depends on the severity of clinical signs, size of the patient, and location of the bite (smaller patients and snakebites on the digits generally require 50% more antivenin than larger patients and nondigital bites). Routine antivenin therapy may be cost-prohibitive. Mild envenomation may be treated successfully with supportive therapy alone. Clients should be informed of the potential benefit of antivenin and the possible need to give multiple doses. Antivenin administration should be monitored closely. If a patient shows signs of anaphylaxis, discontinue the antivenin and administer corticosteroids and epinephrine.

11. Is serum sickness a common complication of antivenin therapy?

About 50–75% of humans who are given antivenin develop serum sickness, a type II hypersensitivity reaction that may occur up to 30 days after administration. Clinical signs in humans include lymphadenopathy, skin rashes, fever, and arthralgia. Evidence indicates that patients given systemic glucocorticoids have a significantly decreased risk for development of serum sickness. Serum sickness may not be a common complication in animals because of the expense of using several vials of antivenin.

12. Are any treatments contraindicated in patients with snakebite?

Tourniquets are useful only if applied immediately and should not be used for head or neck wounds. Cold packs may delay the spread of venom but also can increase the amount of tissue

damage. Electroshock therapy has been advocated to denature the protein constituents of venom. It is now believed that this treatment merely contributes to local tissue damage and should not be used. Patients with rhabdomyolysis and metabolic acidosis should not receive lactated Ringer's solution. A non–lactate-containing buffered crystalloid solution should be used. Although hetastarch is a useful colloid to manage increased vascular permeability, it should not be used in patients with coagulopathies.

13. What complications should you anticipate?

The proteolytic enzymes associated with rattlesnake venom may induce rhabdomyolysis and myoglobinuria. Myoglobin is nephrotoxic, and renal failure is a potential complication. Intravenous fluid therapy and close attention to urine character and output should identify problems early. DIC is a common complication. Patients should be screened once or twice daily with activated clotting times. Blood smears identify schistocytes, and laboratory evaluation of fibrin degradation products and antithrombin III identifies DIC.

14. How should you treat DIC associated with snakebite?

DIC should be anticipated. Aggressive supportive care, including intravenous fluid therapy, helps to treat the primary problem, dilutes the toxin, and enhances renal clearance. Antivenin may decrease the incidence of DIC but is most effective before serious complications develop. The use of fresh and fresh frozen plasma to provide clotting factors and antithrombin III can be augmented by incubating the plasma with heparin before administration. If severe anemia also develops, fresh whole blood also provides needed factors and can be incubated with heparin.

CONTROVERSIES

15. Are corticosteroids indicated for treatment of rattlesnake envenomation?

Corticosteroids are advocated by many for treatment of shock related to rattlesnake envenomation. Corticosteroids inhibit phospholipase A, the arachidonic acid cascade, complement activation, and leukocyte accumulation and activation. They may increase the response to catecholamines, resulting in bronchodilation. Steroids also may help to reduce increased capillary permeability by decreasing leukocyte aggregation. Controversy about steroid use stems from work in other forms of septic shock, which has shown increased morbidity and mortality. A major concern with corticosteroids is that decreasing the immune response leaves the host open to bacterial pathogens. Experimental and retrospective studies in patients with snakebite have demonstrated the potential benefit of steroids and to date have revealed no problems with their use.

16. What is the role of antihistamines and fasciotomy?

Although antihistamines may be used for their sedative effects, no evidence shows that they have any effect on snake venom or patient response. Fasciotomies to relieve pressure on extremities in dogs are rarely helpful.

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34. LAMENESS

Maura G. O'B*rien*, D.V.M.

1. What four principles are used to determine the location and cause of lameness?

1. **Historical information** important in determining the cause of lameness includes known traumas, duration of lameness, and response to medical management.

2. **Observation** of the dog standing, walking, and trotting demonstrates which limb(s) is affected.

3. **Physical examination**, including palpation of the muscles and joints, detects asymmetry of muscle groups as well as fractures, joint effusions, joint instabilities, or swelling.

4. **Diagnostic imaging**, such as radiography, nuclear scintigraphy, magnetic resonance imaging, and computed tomography, best define the cause of the lameness once it is localized to a specific region of the body.

2. What initial evaluations should be performed in animals presenting with lameness or fracture?

Some form of trauma is behind most lameness. Owners may notice only an obvious fracture or lameness; subtle signs of internal injury may be missed. All animals with suspected trauma should be carefully evaluated for cardiopulmonary complications and evidence of abdominal and neurologic injury. Pulmonary and myocardial contusions, head trauma, diaphragmatic hernia, uroabdomen, and internal hemorrhage are among the common sequelae of blunt force trauma. Careful physical examination, neurologic examination, thoracic and abdominal radiographs, and eletrocardiogram should be considered before attempting to correct the cause of lameness.

3. What questions provide the most information about a patient presenting with lameness?

Signalment often provides important clues to the cause of the condition. Young, rapidly growing animals may have a congenital or developmental cause of lameness, such as osteochondrosis or hip dysplasia. Older animals are more likely to develop lameness due to degenerative conditions such as arthritis or neoplasia. The onset of lameness may be associated with a known traumatic event. The clinician should ask which limb is affected, whether more than one limb is affected, how severe the lameness is, and whether the onset was acute or gradual. Additional helpful information includes duration of lameness, whether the animal will place weight on the affected limb, response to rest or exercise, and response to previously administered antiinflammatory medication.

4. What points are important in the physical examination of patients with lameness?

- Can the animal stand or support its own weight? If the animal is non–weight-bearing, is the reason due to a muscloskeletal problem, neurologic problem, or generalized weakness suggestive of metabolic or cardiovascular disease?
- Does the patient exhibit conscious proprioceptive deficits, which suggest a neurologic cause?
- Does examination reveal asymmetry of major muscle groups or alignment of limbs?
- Is joint effusion present?
- Neck or back pain elicited on palpation suggests nerve root injury as the cause of lameness.
- Evaluate the animal at a walk or trot. Does the animal's head rise abruptly when weight is placed on the affected forelimb? Do the hips move synchronously, or is an imbalance apparent, suggesting pain in a hind leg? Is the stride shortened?
- Examine the patient from the side. Are all joints moving through full range of motion?
- If lameness is not evident with gait analysis, the patient should undergo palpation of limbs and joints to see whether pain can be elicited or lameness exaggerated.

5. What is the Ortolani sign?

The Ortolani sign is significant in examining a patient for hip dysplasia. With the patient positioned in dorsal recumbency, the hindlimbs are held parallel to each other and perpendicular to the long axis of the body with the stifles flexed. Pressure is applied to the shaft of the femur proximally toward the hip. Each limb is slowly abducted. The hip is initially subluxated in dysplastic patients. As the limb is abducted, the femoral head drops into the acetabulum. This sudden reduction, which can be felt by the thumb on the trochanter, is a positive Ortolani sign. The maneuver also can be performed with the patient in lateral recumbency, but laxity of the hip joint may not be as evident.

6. What should be suspected in a dog with acute non–weight-bearing lameness of the rear limb and stifle pain?

- Rupture of the anterior cruciate ligament
- Injury to the menisci or collateral ligament
- Luxation of the medial patellar tendon
- Fracture

7. What additional tests should be performed?

The stifle is gently palpated, compared with the opposite stifle joint, and evaluated for joint effusion. Radiographic evaluation of the joint identifies fractures or joint effusion. Palpation of the joint to assess integrity of the collateral ligament and patellar luxation includes checking for the cranial drawer sign.

8. What is the cranial drawer sign?

The cranial drawer is a test of the integrity of the cranial cruciate ligament (CCL). With the stifle in flexion and extension, the tibia is pushed in an anterior direction while the femur is held in place. In a normal joint the tibia is fixed and cannot be displaced cranially to the femur. With complete rupture of the CCL, the tibia moves cranially to the femur in flexion and extension. Partial tears of the CCL may have only cranial movement when the stifle is in flexion because the craniomedial band of the CCL is more commonly torn than the thicker caudolateral band. The caudolateral band is taut in extension but relaxed in flexion, whereas the craniomedial band is taut throughout the range of motion.

9. How does an animal with luxation of the coxofemoral joint present?

Most coxofemoral luxations are craniodorsal. The dog presents with non–weight-bearing lameness, and the distal limb is rotated outward. Palpation reveals asymmetry in the location of the greater trochanter and ischium. Radiographs in both lateral and ventrodorsal positions confirm the diagnosis, evaluate for fractures, and assess the coxofemoral joint for hip dysplasia and arthritis to ensure that closed reduction is practical.

10. Describe methods to reduce and treat coxofemoral luxation.

With the patient under general anesthesia, the muscles are allowed to relax. The patient is placed in lateral recumbency, the limb is grasped by the distal femur, and pressure is applied proximally. The limb is externally rotated to free the femoral head from the shaft of the ilium. It is then abducted while pressure is applied to the greater trochanter until the femoral head pops into place. Once the femoral head is in place, the limb is placed in an Ehmer sling to prevent weight-bearing and to force the femur into the acetabulum.

If the closed procedure fails, open surgical reduction of the joint should be performed. The joint can be stabilized by capsulorrhaphy, prosthetic, toggle pin fixation, or Devita pin stabilization. As a last resort, ostectomy of the femoral head and neck provides relatively normal function.

10. What potential causes of fractures should be considered in animals with minor trauma or no history of trauma?

Pathologic fracture is more common in older animals but may affect animals of all ages. There may or may not have been a subtle lameness before fracture of the bone. Pathologic fractures may be

due to neoplasia or nutritional disorders. Nutritional disorders causing lameness are seen in young animals with congenital disease or as the result of an all-meat diet. Primary bone tumors, such as osteosarcoma and multiple myeloma, and metastatic cancers, including mammary gland adenocarcinoma and prostatic carcinoma, may present with lameness or fractures. Owners should be questioned about previous diagnosis of cancer. Possible masses should be noted by careful physical examination. Radiographs should be taken of the thorax and abdomen to look for primary or metastatic disease. Careful evaluation of bone quality at the fracture site should focus on destruction of cortical bone, mottling of the medullary canal, and any periosteal component to a recent fracture. If the cause of the fracture is in doubt, the bone should be submitted for histopathologic evaluation.

11. What is the most common type of fracture in young animals?

Physeal fractures occur in young, skeletally immature animals. The physis is the weakest region of developing bone. Physeal fractures are classified according to the Salter-Harris system:

- **Type 1** Separation of the epiphysis from the rest of the bone at the physis
- **Type 2** Fracture across the physis and into the metaphysis
- **Type 3** Fracture through the physis and epiphysis, entering the joint
- **Type 4** Fracture across the physis, involving both the epiphysis and metaphysis
- **Type 5** Crushing type of fracture to the physis, which usually results in permanent damage to the growing cells, shortened limb, and potentially an angular limb deformity

12. What is an open fracture? How is an open fracture classified?

In an open fracture, bone is exposed through a wound. In a grade I open fracture, a small puncture wound is created by the bone fragment. A grade II open fracture is characterized by exposed bone and a larger wound than a grade I fracture. Grade III open fractures have extensive loss of skin and connective tissue around the fracture and are often referred to as shear wounds. Grade III wounds also may be caused by gunshot injuries.

13. Describe the initial management of an open fracture.

During assessment and treatment of any life-threatening traumatic complication, the wound is covered with a sterile dressing or clean cloth. When the patient is stable, the dressing is removed, and the fracture and wound are assessed for vascular and neurologic integrity. If possible, the patient should be sedated or a local anesthetic block should be applied to allow clipping of hair from the wound edges and irrigation with sterile saline. Another sterile dressing can be applied while waiting for primary debridement and fracture stabilization. Broad-spectrum antibiotics are administered parenterally, and the patient is prepared for surgery. It is preferable to repair open fractures as soon as possible, but the patient's respiratory and cardiovascular status takes precedence over repair. When the fracture is repaired, the wound is debrided of devitalized or contaminated tissue and closed. If the degree of contamination and tissue loss is too great, the wound can be left open and the dressing changed daily. Debridement is done intermittently until it is appropriate to close the wound (delayed closure) or until the wound heals by second intention.

14. What causes swelling and pain of the metaphyseal region of the long bones in immature large or giant-breed dogs?

The underlying condition is hypertrophic osteodystrophy, which usually affects the distal radius but may involve other bones. Vascular supply to the metaphyseal area is disrupted, and ossification of the hypertrophic zone is delayed. The results are inflammation, hemorrhage, necrosis, fracture, and remodeling in the metaphysis. Radiographs may reveal a periosteal reaction adjacent to the metaphysis, but this finding is not consistent. Affected puppies usually present between the ages of 2 and 8 months; they may exhibit only lameness or be systemically ill with pyrexia and weight loss. Pain, heat, and swelling on palpation of the metaphysis of affected bones are variable. The cause is not known, but potential factors include vitamin C deficiency, respiratory viral infection, and congenital factors. Treatment is supportive, with analgesics such as buffered aspirin for mildly affected patients. Systemically ill patients may require intravenous

fluid therapy and nutritional support in addition to analgesics. Nursing care with attention to hygiene is important to prevent urine scald and decubitus ulcers.

15. After trauma, a dog is presented with non–weight-bearing lameness of the foreleg and no palpable fractures. The limb hangs limp with no pain or sensation elicited on palpation. During physical examination the dog is found to have Horner's syndrome. What is the most likely diagnosis? What causes the Horner's syndrome?

The patient most likely has a brachial plexus avulsion. The nerves of the brachial plexus are stretched or torn from either the spinal cord or the plexus when the forelimb is forcefully abducted from the body wall. The presence of Horner's syndrome indicates that the injury is at the level of the nerve roots instead of the plexus. Damage to the nerve roots in the spinal cord segment from C6 to T1 results in loss of sympathetic innervation to the ipsilateral eye, with a miotic pupil, enophthalmos, ptosis, and protrusion of the third eyelid. Prognosis for return of innervation to the limb after brachial plexus avulsion is extremely poor, and often the limb is amputated to prevent or treat self-trauma to the denervated limb.

16. Hypertrophic osteopathy is reported to cause lameness most commonly in humans and dogs. What is this condition? What tests should be performed to confirm the diagnosis?

Hypertrophic osteopathy (HO) is a condition in mature animals characterized by symmetrical swelling of the distal extremities. Pain is elicited when these areas are palpated, and radiographs of the bones reveal a diffuse periosteal reaction. HO is associated with a primary pulmonary condition. The pathogenesis is not understood, but it is theorized that the pulmonary condition results in an increase of blood flow. The increase in blood flow is believed to be due to a neurologic process and results in congestion of connective tissues, such as periosteum. The periosteum responds by laying down new bone. HO is most commonly seen with pulmonary metastasis but also may be seen with a primary lung tumor, abscess, and bronchopneumonia. Patients with abdominal conditions such as rhabdomyosarcoma of the bladder and adenocarcinoma of the liver also have developed this secondary condition. If a primary pulmonary condition is not found, abdominal radiographs or ultrasound should be pursued. If the primary condition can be treated (e.g., lung lobectomy for a primary tumor), HO usually resolves.

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35. INFECTIOUS DISEASE

Derek P. B*urney*, D.V.M.

1. Why is recognition of infectious disease important in the critical care setting?

Infectious diseases must be recognized so that effective methods of preventing spread of contagious organisms to animals or humans can be implemented. In a critical care setting, a large number of critically ill patients with varying degrees of immuncompromise may be in close proximity; therefore, it is important to minimize infectious disease transmission.

fluid therapy and nutritional support in addition to analgesics. Nursing care with attention to hygiene is important to prevent urine scald and decubitus ulcers.

15. After trauma, a dog is presented with non–weight-bearing lameness of the foreleg and no palpable fractures. The limb hangs limp with no pain or sensation elicited on palpation. During physical examination the dog is found to have Horner's syndrome. What is the most likely diagnosis? What causes the Horner's syndrome?

The patient most likely has a brachial plexus avulsion. The nerves of the brachial plexus are stretched or torn from either the spinal cord or the plexus when the forelimb is forcefully abducted from the body wall. The presence of Horner's syndrome indicates that the injury is at the level of the nerve roots instead of the plexus. Damage to the nerve roots in the spinal cord segment from C6 to T1 results in loss of sympathetic innervation to the ipsilateral eye, with a miotic pupil, enophthalmos, ptosis, and protrusion of the third eyelid. Prognosis for return of innervation to the limb after brachial plexus avulsion is extremely poor, and often the limb is amputated to prevent or treat self-trauma to the denervated limb.

16. Hypertrophic osteopathy is reported to cause lameness most commonly in humans and dogs. What is this condition? What tests should be performed to confirm the diagnosis?

Hypertrophic osteopathy (HO) is a condition in mature animals characterized by symmetrical swelling of the distal extremities. Pain is elicited when these areas are palpated, and radiographs of the bones reveal a diffuse periosteal reaction. HO is associated with a primary pulmonary condition. The pathogenesis is not understood, but it is theorized that the pulmonary condition results in an increase of blood flow. The increase in blood flow is believed to be due to a neurologic process and results in congestion of connective tissues, such as periosteum. The periosteum responds by laying down new bone. HO is most commonly seen with pulmonary metastasis but also may be seen with a primary lung tumor, abscess, and bronchopneumonia. Patients with abdominal conditions such as rhabdomyosarcoma of the bladder and adenocarcinoma of the liver also have developed this secondary condition. If a primary pulmonary condition is not found, abdominal radiographs or ultrasound should be pursued. If the primary condition can be treated (e.g., lung lobectomy for a primary tumor), HO usually resolves.

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35. INFECTIOUS DISEASE

Derek P. B*urney*, D.V.M.

1. Why is recognition of infectious disease important in the critical care setting?

Infectious diseases must be recognized so that effective methods of preventing spread of contagious organisms to animals or humans can be implemented. In a critical care setting, a large number of critically ill patients with varying degrees of immuncompromise may be in close proximity; therefore, it is important to minimize infectious disease transmission.

2. How can transmission of zoonotic agents to hospital staff be avoided?

Some infectious agents are zoonotic; thus, the risk to hospital personnel must be carefully evaluated. Proper measures to dispose of contaminated materials and proper disinfection procedures for the suspected organism should be followed. Personnel should wear protective clothing, such as surgical caps, masks, disposable gowns, and shoe covers, to protect the most likely routes of infection by the suspected organism.

3. How are most infectious agents of dogs and cats transmitted?

Most infectious agents are transmitted by contact with fecal material, respiratory secretions, reproductive tract secretions, or urine or by bites, scratches, reservoirs, or vectors. Some animals may be contagious but not clinically affected. Since rodents and arthropods may contribute to transmission, they should be controlled in the hospital setting.

4. What are the most common means of transmission and prevention of nosocomial infection?

Hospital employees are the most common mode of transfer of nosocomial infections. To prevent transmission of disease, hospital employees should wash hands thoroughly with a disinfectant soap between patients. Employees should be encouraged to wear disposable gloves and to obtain a clean pair for each patient. Soiled gloves should be thrown away, and soiled hands should be washed immediately. All personnel should wear a smock or scrub suit, and clothes should be changed after contact with feces, secretions, and exudates. Equipment such as stethoscopes, pen lights, scissors, clipper blades, and percussion hammer serve as excellent fomites and should be cleaned and disinfected in 0.5% chlorhexidine solution between patients. Disposable thermometer covers should be used.

Poor sanitation practices, IV catheters, and urinary catheters are large contributors to nosocomial infections. Catheter sites should be prepared as if for surgery and catheters placed aseptically. Urinary catheters should also be placed aseptically, and if indwelling catheters are used, a closed collection system should be used. The catheters should be checked at least twice daily for signs of inflammation. If inflammation is noted, the catheter should be removed immediately.

5. What clinical signs should alert hospital employees to potentially contagious diseases?

Animals with gastrointestinal or respiratory disease are likely to be the most contagious. All diarrhea, acute or chronic, should be considered infectious until proved otherwise. Infectious respiratory disease should be suspected in all sneezing or coughing animals, especially if purulent nasal discharge or productive cough is present. Cats with acute high fever, particularly if from a breeding facility, humane society, or boarding facility, carry a high index of suspicion for infectious disease.

6. How can reception personnel help to decrease contagious disease spread within the hospital?

Often clients indicate by telephone what clinical signs the pet is showing. Animals with suspected gastrointestinal or respiratory disease should be sent straight to an examination room or isolation. They should be transported by gurney to minimize contamination of the hospital facility. The gurney should be disinfected immediately after use. If possible, the clinician should examine animals with suspected infectious disease immediately to decrease hospital contamination by minimizing the time an infected patient is in the hospital.

7. What patients should be kept in isolation facilities?

Patients with suspected salmonellosis, campylobacteriosis, parvovirus, coronavirus, kennel cough syndrome, feline upper respiratory disease syndrome, rabies, and plague have contagious diseases and should be kept in isolation.

8. Where should cats with feline leukemia virus (FeLV) and/or feline immunodeficiency virus (FIV) be housed?

Cats with FeLV and/or FIV should not be kept in infectious disease isolation facilities because their immunodeficient state places them at high risk of contracting further infectious disease. Seropositive cats should not be caged next to or above seronegative cats.

9. What biosecurity measures should be used in an isolation facility?

Disposable foot covers or a foot bath with 1:64 dilution of disinfectant should be used on entering and exiting the isolation facility. Employees should remove outerwear and put on disposable gowns and Latex gloves. If working with plague-infected cats, personnel should wear masks. All sharps should be placed in dedicated containers with biohazard warnings. The isolation facility should have separate equipment and supplies, and supplies or equipment should not be moved into and out of isolation. All biologic materials submitted for laboratory analysis should be clearly labeled with the suspected infectious disease. Feces for analysis should be collected by tongue depressor or wooden applicator stick, placed in a screw-top plastic vial, and bagged in a plastic bag. The fecal sample bag should be clearly labeled with the suspected infectious disease. All disposables should be placed in heavy-duty plastic bags and sealed. The bags should be sprayed with disinfectant before removal from the isolation facility. All equipment should be cleaned and disinfected, and staff should wash their hands on conclusion of procedures in isolation.

10. How should cages be cleaned and maintained to minimize transmission of infectious disease?

Animals should stay in the same cage during their hospital stay and should not be moved from cage to cage. Soiled items should be removed from cages as soon as possible. Contaminated surfaces should be cleaned and disinfected. All surfaces should be in contact with the disinfectant for 10–15 minutes, if possible. Do not forget to clean the tops of the cages, which are often overlooked.

11. How can transmission of parasites be minimized in the hospital environment?

Cleanliness is crucial to inhibit parasite problems. Detergent and steam cleaning inactivate most parasite ova. Prompt removal of fecal material from outdoor exercise areas is extremely important.

12. What patients are at highest risk for contracting diseases in the hospital?

Immunocompromised patients, such as puppies, kittens, old animals, debilitated animals, animals with immunosuppressive diseases (e.g., hyperadrenocorticism, diabetes mellitus), animals with concurrent infections, and animals treated with glucocorticoids or cytotoxic agents, are at risk for contracting infectious diseases.

13. What environments are at most risk for transmission of infectious disease?

Veterinary hospitals, pet shows, kennels, humane societies, and parks are great reservoirs of infectious disease, especially parasites and parvovirus. Any area in which large numbers of animals from many different environments congregate is a potential infectious disease clearinghouse.

14. How can hospitals decrease transmission of disease when treating patients with infectious diseases?

Animals with infectious diseases should be treated as outpatients if at all possible. If hospitalization is required, all procedures, such as radiographs or surgery, should be delayed until the end of the day if possible. Cage identification should be used for all hospitalized animals, and the cage identification of animals suspected of contagious disease should be clearly marked with the suspected infectious agent. As the diagnosis becomes updated, the cage information should be updated. A hospitalwide biosecurity system committee may be formed to design guidelines for infectious diseases and to ensure that all personnel are familiar with the guidelines. The biosecurity committee also can periodically review procedures to ensure that the infectious disease protocol is followed and to make changes as necessary.

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IV. Ophthalmic Emergencies

Section Editor: Cynthia C. Powell, D.V.M., M.S.

36. ACUTE OCULAR TRAUMA

Cynthia C. Powell, D.V.M., M.S.

1. What are the major considerations in evaluating acute ocular injury?

Overall patient condition is the first consideration with acute trauma. Once the patient is stable, attention then should be focused on the eye. Prognosis and therapeutic options vary depending on cause and duration of injury and ocular structures involved. If other injuries preclude immediate evaluation and attention to the injured eye, it should be protected from further damage with lubricants and a protective collar if necessary. In cases of chemical injury, the globe should be examined to determine its integrity, and lavage should be instituted immediately.

2. Are certain injuries more threatening to vision or the integrity of the globe?

Ocular proptosis and injuries that rupture or perforate the globe often result in vision loss or require enucleation and carry a guarded prognosis. In general, blunt traumatic injury carries a worse prognosis than sharp penetrating injury because of the increased incidence of retinal detachment and broader scope of uveal damage. Alkali chemical burns, such as those due to ammonia, lye, lime, and magnesium hydroxide, are more likely to cause globe or sight-threatening injury than acid chemical burns.

3. Why are alkali injuries worse than acid injuries?

Most acids coagulate corneal epithelial and stromal proteins, thus forming a barrier and limiting corneal penetration. Alkalis, however, saponify plasma membrane lipids, denature collagen, and readily penetrate the cornea, increasing possibility of anterior segment damage.

4. How do you treat chemical burns of the eye?

Copious irrigation to decrease contact time and concentration should be instituted immediately if a chemical burn is suspected or confirmed. Continuous lavage with a sterile solution of lactated Ringer's and 5% dextrose in water or saline can be delivered through a standard IV set. During irrigation the conjunctival and corneal surfaces should be inspected and cleaned of chemical residue. Lavage should be continued for 30 minutes or until the pH of the ocular surface returns to normal range (7.3–7.7). After irrigation the eye should be treated for corneal ulceration, uveitis, and glaucoma when present.

5. Do any specific therapies for alkali burns help treatment and improve prognosis?

Alkali corneal burns decrease aqueous and corneal ascorbic acid levels and may result in impaired collagen synthesis in the injured cornea. Evidence suggests that topical 10% sodium ascorbate applied every 1–2 hours and high dosages of oral ascorbate, 30 mg/kg 4 times/day, may decrease the incidence (but not progression) of sterile stromal ulceration after alkali chemical injury. Treatment is continued at this level for 1 week when the topical medication is decreased to 4 times/day. Both topical and systemic medications are continued until the cornea is reepithelialized. Topical sodium citrate 10% inhibits neutrophil activity and decreases sterile ulceration and

should be used every 2 hours for the first 10 days after injury. Tetracycline derivatives inhibit neutrophil and collagenase activity and can be administered both topically and systemically.

6. What are some of the long-term sequelae of chemical burn?

Long-term complications of chemical burns include corneal scarring, uveitis, glaucoma, keratoconjunctivitis sicca, symblepharon and entropion. If uveitis is severe, synechia and cataract formation are also possible.

7. What causes proptosis of the eye?

Trauma to the head either by a car or dog fight is the most common injury associated with globe proptosis. However, in extremely exophthalmic breeds, proptosis may result from grasping the scruff of the neck or tension on the skin of the face from excessive restraint. Ocular damage is related to the amount of force needed to cause proptosis. Cats and dolicocephalic breeds of dogs are more likely than brachycephalic animals to sustain severe ocular injuries during proptosis.

8. How can you assess prognosis for vision or retention of the globe?

The amount of damage to the optic nerve, blood supply and musculature may be difficult to establish but is directly related to the prognosis. Unless the eye, optic nerve, or extraocular muscles are obviously ruptured, the prognosis for vision is difficult to determine but usually is guarded. Approximately 80% of proptosed globes will have permanent vision loss. Indicators of prognosis are summarized below:

FAVORABLE	UNFAVORABLE
Positive menace	Negative consensual pupillary light response
Miotic pupil	Midpoint or dilated and unresponsive pupil
Positive direct or consensual pupillary light response	Severe hyphema
Normal-appearing fundus	Extraocular muscle avulsion
Normal intraocular pressure	Hypotony
Good extraocular muscle tension	Retinal detachment
Short time (< ½ hr) from injury to treatment	Long time from injury to treatment

9. What emergency treatment is appropriate for the proptosed globe?

The owner should be told to keep the cornea protected and lubricated until the patient arrives at the clinic. Sterile ocular lubricants, artificial tears, or collyrium are ideal but petroleum jelly may also be used. In most cases of acute proptosis, the eye should be surgically replaced as soon as possible. Enucleation should be done if the eye is ruptured or the extraocular muscles are severely avulsed. If there is any question about the status of the eye, it should be replaced; enucleation may be done later, if needed. After the globe is replaced, temporary tarsorrhaphy prevents reprolapse and protects the cornea. Often, medical therapy for the treatment or prevention of uveitis, optic neuritis, or corneal ulceration is also needed.

10. How do you replace the globe?

When the eye prolapses, the eyelid margins become entrapped behind the globe. Relief of entrapment is necessary for globe replacement and usually requires general anesthesia. The lid margins must be pulled forward while simultaneously placing gentle pressure on the globe to replace it in the orbit. To expose the eyelid margins, grasp the rolled skin adjacent and parallel to the lid margin with a hemostat and roll the instrument outward. Alice tissue clamps are used to hold and pull the margins gently forward while the globe is pushed back into the orbit with gentle, even pressure applied over several minutes. A lateral canthotomy may be required to facilitate globe replacement in some cases.

11. How is temporary tarsorrhaphy done? How long should it be left in place?

Four to six horizontal mattress sutures of split thickness should be placed through the eyelid margins with 2-0 to 4-0 nonabsorbable suture. Because of the considerable swelling that accompanies proptosis, stents (rubber band or IV tubing) should be used and the sutures tied tightly. Leaving a small space at the medial canthus allows application of topical medications. Tarsorrhaphy sutures should be left in place until retrobulbar swelling has decreased sufficiently for complete eyelid closure. This may take up to 3 weeks. Frequent rechecks are recommended because sutures loosen as swelling subsides and may contact the cornea. Sutures tied too tightly result in necrosis of the lid margin.

12. What follow-up therapy is recommended?

Corneal ulceration, traumatic uveitis, and traumatic optic neuritis may accompany globe proptosis. Corneal ulcers should be treated with a topical broad-spectrum antibiotic 3 times/day. Topical 1% atropine sulfate is used to relieve ciliary and iris muscle spasm and to prevent posterior synechia formation when anterior uveitis is present. Conservative use of atropine is recommended because it decreases tear production; often a single application or once-daily application for a few days is sufficient. Uveitis and optic neuritis are treated with systemic corticosteroids (e.g., 0.5–2.2 mg/kg prednisolone once daily) for 7 days, then tapered over the next 2 weeks. The higher dosages are used to treat optic neuritis and more severe cases of uveitis. Topical corticosteroids are not recommended because of the high incidence of corneal ulceration with globe propotosis. Cold compresses may help to relieve initial swelling.

13. What are the long-term sequelae of proptosis?

In most cases, the eye is blind as a result of optic nerve damage; however, the eye often has a cosmetic appearance. The pupil is dilated with parasympathetic denervation or mid-point with both parasympathetic and sympathetic denervation. Most eyes have permanent lateral or dorsolateral strabismus, although it sometimes improves over several weeks. Lagophthalmos and exposure keratitis are common, especially in brachycephalic breeds of dogs, and may require permanent blepharoplastic procedures to reduce palpebral fissure size. Other sequelae include keratoconjunctivitis sicca, neurotropic keratitis, and phthisis bulbi.

14. What clinical signs indicate the extent of ocular injury?

Physical ocular trauma may be blunt or sharp, perforating or nonperforating. The degree of injury depends on the force of the injury, depth of penetration, and involvement of intraocular structures. Blunt injury causing globe rupture almost always carries a poor prognosis because it often is accompanied by severe uveal herniation, hemorrhage, and retinal detachment. Penetrating wounds by sharp objects and nonperforating blunt trauma vary greatly in the amount of damage. Clinical signs indicating a guarded or poor prognosis include large or deep corneal laceration, collapsed anterior chamber, severe hyphema (anterior chamber > $^1/_3$ full of blood), inability to visualize the iris due to corneal edema or anterior chamber opacity, uveal prolapse, lens luxation, vitreous hemorrhage, and retinal detachment.

15. How can you tell if the eye has been perforated?

Large perforating scleral wounds result in severe hypotony and often marked subconjunctival and intraocular hemorrhage. Small perforating scleral wounds are harder to detect because chemotic conjunctiva obscures the point of entry and intraocular pressure may be affected only mildly. Large, full-thickness corneal lacerations result in anterior chamber collapse and iris incarceration in the wound. Small, full-thickness lacerations may self-seal as a result of swelling of the stroma when aqueous and tears enter the cornea. The Seidel test helps to detect small perforating corneal injuries.

16. What is the procedure for the Seidel test?

A sterile fluorescein strip is moistened with sterile saline or eye wash, and a drop is administered to the wound area. As aqueous fluid mixes with fluorescein, a bright green stream of fluid

will form. If the animal is under general anesthesia, gentle digital pressure can be applied to the cornea to check for wound leakage.

17. What is the significance of a perforating wound if it has already sealed?

Eyes with full-thickness lacerations or perforations are at risk for endophthalmitis and should be treated aggressively with broad-spectrum, systemic antibiotics. In addition, perforating injuries may involve intraocular damage not easily detected, such as lens rupture or retinal tear. If the cause of the injury is not known, radiography or ultrasonography to look for a metallic foreign body (BB or pellet) is warranted.

18. What treatment should be provided by the emergency care clinician?

The primary goal of emergency therapy is to prevent or treat infection, to protect and support the wound, and to prevent sequelae by controlling intraocular inflammation. If perforation of the eye is suspected, a broad-spectrum systemic antibiotic, such as a first-generation cephalosporin, should be started as soon as possible. Trauma to the globe almost always results in some degree of anterior uveitis and should be treated with topical and/or systemic nonsteroidal antiinflammatory drugs (NSAIDs) and topical cycloplegics (see chapter on uveitis). Topical corticosteroids should be avoided in the presence of ulcerative keratitis, and ophthalmic ointments should not be used if the globe is perforated.

1. To control or prevent infection
   - If not perforated—topical antibiotic ointment or solution
   - If perforated—systemic antibiotic (e.g., cefazolin) with or without topical antibiotic solution
2. To protect and support wound
   - Suture—if > half thickness laceration
   - With or without conjunctival graft
3. To control intraocular inflammation
   - Corticosteroids—systemic (e.g., prednisolone, dexamethasone)
   - NSAIDs—topical (e.g., Voltaren, Profenal, Ocufen)
   - Cycloplegic—topical (e.g., atropine, tropicamide)

19. What kinds of protection and support should be used?

Partial tarsorrhaphy decreases the palpebral fissure size and thus helps to protect the cornea and maintain an adequate tear film. This is especially important in exophthalmic or lagophthalmic animals. A nictitans flap should be used with caution because it interferes with topical medication of the cornea and prevents observation of the wound. If self-trauma is a consideration, a protective collar should be used. Other methods of support include a conjunctival graft or flap, tissue adhesive, and collagen shields.

20. When should a corneal laceration be sutured?

Small corneal lacerations (< 3–4 mm) of less than half thickness may be treated as a corneal ulcer with topical antibiotics and mechanical support (see chapter on corneal ulceration). Larger or deeper lacerations should be closed with 7-0 to 9-0 suture. If the iris is incarcerated in the wound, it should be amputated or replaced into the anterior chamber before closure. A conjunctival graft placed over the sutured wound may be used for added support if necessary. Before suturing a laceration that has perforated the cornea, the integrity of the lens should be evaluated. Lens capsule perforation necessitates lens removal, preferably at the time of corneal repair. If this is not possible, referral for lens removal should be made as soon as possible to avoid severe uveitis associated with lens rupture.

21. When should a conjunctival graft or flap be used?

Conjunctival flaps not only provide mechanical support and surface protection to the cornea but also furnish blood supply. Leukocytes, antibodies, anticollagenases, antiproteases, and nutrients for healing and wound repair are thus brought directly to the injury. Lacerations with loss of

deep stromal tissue that prevents adequate primary closure and lacerations in which the viability of the sutured tissue is in question should be supported with a conjunctival flap.

22. How can the collapsed anterior chamber be reformed?

In a healthy eye, the aqueous humor reforms at a rate of 2.5 µl/min and 15 µl/min in dogs and cats, respectively. If the eye is not severely damaged, the aqueous production rate may be sufficient to reform the anterior chamber within several minutes after the eye has been sealed. Usually, however, the anterior chamber is reformed with lactated Ringer's or balanced salt solution. A 25- or 27-gauge needle is inserted at the limbus, parallel to the iris plane, and enough fluid is injected to restore the anterior chamber to its normal depth without creating high intraocular pressure (IOP). The IOP should be in the low-normal range (10–15 mmHg).

23. How and when should the entrapped iris be amputated or replaced?

When a prolapsed iris should be excised rather than repositioned is controversial. Recommendations are based on the time it takes for the exposed iris to become sufficiently contaminated to cause infection if replaced. Recommended times range from 1–24 hours. It is safe to assume that smaller prolapses take longer to pose a threat of infection. Magnification is essential if iris amputation or replacement is attempted. Tissue to be excised should be gently grasped with fine forceps and cut flush with the cornea. A dilute solution of epinephrine (1:10,000 in lactated Ringer's or balanced salt solution) aids hemostasis. To replace the iris, it is carefully freed from fibrinous corneal attachments with an iris spatula or irrigating cannula or dissected with viscoelastic material. After the iris is freed from the cornea, the anterior chamber is reformed with viscoelastic material (1% sodium hyaluronate or 2% hydroxypropylmethylcellulose). Care must be taken to avoid trauma to the corneal endothelium, iris, and lens. Just before placing the last suture, the viscoelastic material can be gently flushed from the anterior chamber or left in place. This procedure is difficult for inexperienced practitioners and preferably should be performed by a trained ophthalmologist.

24. What type of suture pattern should you use in the cornea?

Simple interrupted sutures are the easiest to place correctly. If you experience a lot of tension, horizontal mattress sutures may be placed first, followed by interrupted sutures. Correct suture placement is important to avoid internal wound gape (too shallow), wound override (sutures of unequal depth and length on each side of the wound), and intraocular contamination (too deep). Sutures should be approximately 90% of corneal depth, 1.5–2 mm in length, equal depth on each side of the wound, and 1–1.5 mm apart.

25. What are the common types of foreign body-related injuries?

Corneal and conjunctival foreign bodies from plant material and sand are frequently encountered in dogs, especially those used for hunting or field trials. Patients often present with an acutely red and painful eye. Linear abrasions of the cornea are an indication for eversion of the lid to examine for foreign material lodged in the upper palpebral conjunctiva. Superficial corneal foreign bodies may present with variable amounts of discomfort and usually can be detected with simple magnification (e.g., loupe or diagnostic otoscope head). Deeper corneal foreign bodies may have the appearance of a puncture wound and are harder to detect without the use of a slit lamp. Foreign body penetration into deeper ocular structures is often associated with BB-pellet, bird shot, and glass. Involvement of orbital structures, iris, lens, retina, and/or vitreous humor is possible, and the prognosis is affected accordingly.

26. How should foreign bodies involving the ocular surface be treated?

Superficial foreign bodies can be removed with topical anesthesia in many cases, but some animals may require sedation or general anesthesia. A spatula, corneal forcep, or hypodermic needle (25- or 27-gauge) is used to elevate the foreign body from the ocular surface. If loosened foreign material remains on the eye, it can be picked up with a moistened cotton tipped swab. Hypodermic needles should be held at a shallow angle to the cornea to avoid perforation. After

removal, treat topically with a broad-spectrum antibiotic drop or ointment 3 times/day for 5–7 days. A single application of 1% atropine sulfate is given if the eye is miotic.

27. What should be done to manage an intraocular foreign body?

Management of intraocular foreign bodies depends on how long the foreign body has been in the eye, its location, and what it is made of. The potential for damage during removal should be compared with the potential for damage if it is left in the eye. Organic material leads to sepsis if not removed soon after penetration. Some metals and glass, however, may cause little reaction if left alone and eventually become anchored by fibrin or scar tissue. If the foreign body is recent and located in the anterior chamber, it should be removed through a limbal incision. Surgery to remove a foreign body from the posterior segment often results in complications leading to a blind eye and carries a poor prognosis. Broad-spectrum topical and systemic antibiotics should be used to control infection. Topical corticosteroids, cycloplegics, and oral corticosteroids (anti-inflammatory dosages) or NSAIDs may be used to treat uveitis. Corticosteroids should be used with caution because of the potential for sepsis.

ORGANIC FOREIGN BODY	NONFERROUS METAL, GLASS, OR PLASTIC FOREIGN BODY	FERROUS METAL FOREIGN BODY
• Reactive	• Minimal reaction	• Highly reactive
• Sepsis possible	• Becomes walled off by fibrin and fibrous tissue	• Toxic to intraocular tissues
•Early removal		• Early removal essential

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37. OCULAR HEMORRHAGE

Cynthia C. *Powell*, D.V.M., M.S.

1. What are common causes of ocular hemorrhage?

Trauma, coagulopathies, thrombocytopenia, vasculitis, and neoplasia are potential causes for ocular hemorrhage. Trauma-related hemorrhage is probably the most common cause of ocular hemorrhage presented as an emergency.

2. What forms of ocular hemorrhage have emergency significance?

All forms of ocular hemorrhage have the potential of being associated with life-threatening systemic disease. If the cause of hemorrhage is not known, patients should be evaluated for systemic diseases, especially those causing clotting abnormalities and vasculitis. Although the ocular hemorrhage may not require emergency treatment, the disease associated with hemorrhage might. Intraocular hemorrhage alone or related to other diseases (e.g., uveitis or hypertension) can quickly become sight-threatening, and prompt medical management is important. Complications

removal, treat topically with a broad-spectrum antibiotic drop or ointment 3 times/day for 5–7 days. A single application of 1% atropine sulfate is given if the eye is miotic.

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of intraocular hemorrhage that cause vision loss include glaucoma, cataract, retinal detachment, retinal degeneration, and phthisis bulbi.

3. Why is blunt trauma so potentially damaging to intraocular tissues?

Tremendous tissue distortion results from blunt ocular trauma. The four phases of blunt injury that induce tissue damage are as follows:

- Compression
- Decompression
- Overshooting
- Oscillations

The initial anteroposterior globe compression at the cornea causes equatorial expansion and shortening of the globe along the anteroposterior axis so that the cornea may touch the iris and lens. As the momentary force of deformation is removed, the anteroposterior globe diameter increases, whereas the equatorial diameter decreases and the tissues overshoot so that the anteroposterior diameter becomes momentarily greater than normal and the equatorial diameter less than normal. The globe subsequently oscillates between these maximums and minimums with decreasing amplitude for a brief time. This extreme stretching of the ocular tissues causes injury to the choroid, lens, optic nerve, retina, and vitreous gel.

4. Describe the implications of hyphema.

Hyphema is the presence of blood within the anterior chamber. Blunt or sharp trauma to the globe is the most common cause. However, hyphema may be due to thrombocytopenia, coagulopathies, iritis, intraocular neoplasia, congenital ocular anomalies, and chronic glaucoma. Initial examination should determine whether the globe has been penetrated. Hyphema often causes little damage to the eye itself but may result in glaucoma, anterior uveitis, iris adhesions secondary to clot contraction, and capsular cataract formation. Anterior chamber bleeding may not clot completely because the iris produces fibrinolysin. Maximal clot integrity requires 4–7 days. Hyphema should be treated as a clinical sign, and its cause should be determined as soon as possible.

5. What clinical parameters should be evaluated in cases of hyphema?

A complete eye examination should be performed, and the entire animal must be evaluated to assess concomitant injury or disease. In particular, globe rupture should be ruled out. Vision should be estimated based on the degree of menace when bright light is suddenly directed into the eye. Assuming that the examination light penetrates to the posterior part of the globe, the consensual pupillary light reflex indicates whether the retina and optic nerve are functional. If a globe rupture is not present, intraocular pressure should be measured. Finally, the hyphema should be graded by the anterior chamber volume occupied by the blood. The grading system is helpful prognostically because it indicates the severity of hemorrhage and the degree of intraocular tissue damage in trauma cases. Hyphema of grade 1 severity generally clears in less than 1 week. Grades 2 and 3 take several weeks or longer to resolve. Grade 4 hyphema often is associated with globe atrophy (phthisis bulbi).

- Grade 1: less than ⅓ of the anterior chamber
- Grade 2: ⅓–½ of the anterior chamber
- Grade 3: ½ to nearly total
- Grade 4: total

6. How should hyphema be treated?

If a primary cause other than trauma is determined, initial treatment must address the underlying problem. All animals with hyphema should be kept quiet and subdued, possibly by use of sedation. A wide variety of medical treatments has been proposed, but no studies have evaluated their effectiveness. Interest in some treatments continues, whereas others remain controversial. Basically the treatments can be separated into the following categories:

- Cycloplegics
- Miotics
- Adrenergic agonists
- Corticosteroids
- Antifibrinolytic agents
- Fibrinolytic agents
- Surgical intervention

7. What cycloplegics may be useful and why?

Cycloplegics are parasympatholytic drugs that cause paralysis of ciliary body and iris sphincter smooth muscles. Thus the ocular accommodation by the ciliary body is prevented, and the pupil dilates. Prevention of smooth muscle spasm may enhance patient comfort and facilitates fundus examination. Topical atropine, 1% solution once or twice daily, is sufficient. Once mydriasis (pupil dilation) occurs, the frequency of treatment may be reduced and the drug used to effect.

8. What miotics are useful and why?

Parasympathomimetic agents are miotics that induce spasm of the ciliary body and iris sphincter smooth muscles. In theory, use of a miotic such as pilocarpine 1% should open the filtration angle. However, miotics also tend to increase intraocular inflammation and by decreasing pupil size, increase the chance of pupil obstruction by fibrin. No scientific evidence suggests that they enhance the clearance of blood from the anterior chamber. In the author's opinion, miotics should not be used to treat hyphema.

9. What adrenergic agonists have been advocated and why?

Sympathomimetic agents such as topical epinephrine 1% and phenylephrine 2.5% have been advocated to decrease anterior chamber hemorrhage by way of vasoconstriction. Such treatment may be helpful with evidence of ongoing hemorrhage but usually provides little effect. It is rarely considered an option in the treatment of hyphema in humans.

10. Which corticosteroids are best to use?

Invariably, traumatic hyphema is associated with anterior uveitis ranging from mild to severe. Thus, topical steroids such as prednisolone acetate, prednisolone sodium phosphate, and dexamethasone ophthalmic drops are used 4 times/day. Their efficacy in improving outcome is unproved. Systemic steroids are more controversial but commonly used. Certainly any concurrent anterior uveitis will be lessened, and theoretical evidence suggests that steroids may enhance clot stabilization. Controlled studies, however, are lacking.

11. When is antifibrinolytic treatment indicated?

Agents such as aminocaproic acid have been proposed as a means of reducing rebleeding in cases of traumatic hyphema. Rebleeding may result from premature clot lysis mediated by the fibrinolytic system. The theoretical rationale is that the reduced rate of clot lysis allows more time for the damaged blood vessels to heal. In humans, the current recommended dosage is 50 mg/kg orally every 4 hr for 5 days. Antifibrinolytic drugs are contraindicated in cases with intravascular clotting disorders, pregnancy, and cardiac, hepatic, or renal disease.

12. What is the purpose of fibrinolytic treatment?

Hyphema typically progresses from free blood to varying degrees of blood clot formation 1–7 days after injury. Once fibrin formation has occurred, clot lysis may be induced with fibrinolytic agents such as tissue plasminogen activator (tPA). Clinically, tPA is used by injecting 25 mg in a 100-μl volume into the anterior chamber. Clot lysis typically occurs within 30–60 minutes of injection. As clot lysis occurs, red blood cell clearance is facilitated. Topical application of tPA is also promising.

13. What surgical interventions are used for hyphema?

If hyphema persists beyond 5–10 days or intraocular pressure increases, surgical removal may be necessary. An anterior chamber wash-out is the simplest and safest surgical procedure to clear free blood from the anterior chamber. Removal of the clotted blood is not required, but rather evacuation of loose blood cells and debris. A 30-gauge needle or cannula is used to irrigate a balanced salt solution into the anterior chamber, and a second 2-mm incision is made to allow fluid egress. Removal of the entire clot is possible but may result in lens, iris, and corneal endothelial trauma. Other surgical procedures are available but should be performed by someone experienced and equipped for intraocular surgery.

14. What drugs may be contraindicated in cases of hyphema?

Based on the antiplatelet effect of the cyclooxygenase inhibitors, nonsteroidal anti-inflammatory drugs (NSAIDs) such as aspirin, flunixin megulamine, and topical ocular NSAIDs should be avoided. Although cycloplegics such as atropine are advocated for medical management of hyphema, a small percentage of patients develop glaucoma associated with use of atropine.

15. How can vitreous hemorrhage be recognized?

Disorders of the posterior segment (ocular tissues posterior to the lens) are more difficult to detect and characterize because direct examination must be performed through the pupil, or indirect imaging techniques such as ultrasound must be used. Direct examination is impaired with disease of the anterior segment and cornea . Dilation of the pupil, if possible, greatly facilitates evaluation of the posterior globe. If vitreous hemorrhage is near the lens, it may be visible with a penlight or transilluminator. Otherwise, an indirect ophthalmoscopic examination is the best way to evaluate the vitreous cavity. Vitreous hemorrhage appears as strands, sheets, or diffuse areas of blood accumulation. If the hemorrhage is preretinal (between the vitreous and retina), it may resemble a "boat keel" because of gravitational settling of the erythrocytes.

16. Does vitreous hemorrhage have special implications?

The most common cause of vitreous hemorrhage is trauma-induced rupture of uveal or retinal blood vessels. The animal should be evaluated closely for rupture of the cornea or sclera. Causes of vitreous hemorrhage may be grouped as follows:

- Tearing of a blood vessel in a congenital or acquired retinal detachment
- Retention of the fetal hyaloid artery system
- Widespread ocular disease (inflammation of the choroid and retina, optic neuritis, chronic glaucoma, and intraocular neoplasia)
- Systemic disease (hypertension, coagulopathies, and thrombocytopenia)

17. How is vitreous hemorrhage treated?

Other than dealing with the underlying ocular or systemic disorder associated with vitreous hemorrhage, no simple treatment is available. If hemorrhage occurs into the solid vitreous gel, clotting is rapidly activated because the gel matrix serves as a collagen framework for platelet adhesion. Infiltration of neutrophils and macrophages hasten clot removal but cause further vitreous gel breakdown and inflammation. Preretinal hemorrhage clots poorly. Concurrent use of topical and systemic corticosteroids is appropriate and may ameliorate the inflammatory reaction. If anterior uveitis is present, the use of topical atropine as a cycloplegic is appropriate. Depending on the hemorrhage area and density, resolution may take many months.

18. What does retinal hemorrhage look like?

The appearance of retinal hemorrhage depends on the retinal layer involved. Because of the relatively loose attachment between the retina and vitreous gel and the retina and retinal pigment epithelium, hemorrhage of large size may develop in either space. Preretinal hemorrhage (between the retina and vitreous) frequently has a "boat keel " shape due to gravitational settling of the erythrocytes. Intraretinal hemorrhages primarily are aligned vertically; their end on appearance is round, and the hemorrhages are small. Nerve fiber layer hemorrhages are typically feathered or striated and flat, because the hemorrhage follows the path of the nerve fibers. The retinal depth of a focal hemorrhage may be estimated based on which structures are positioned beneath and thus obscured or positioned above and thus visible.

19. Explain the significance of retinal hemorrhage.

Retinal hemorrhage indicates disruption or inflammation of the vasculature. If there is no clear history or physical evidence of trauma, systemic disorders must be considered. Infectious diseases capable of causing vasculitis or retinitis must be considered. Disorders that may be immediately life-threatening are coagulopathies, severe anemias, and blood dyscrasias. Chronic dis-

orders such as hypertension, hyperviscosity syndromes, and neoplasia may cause retinal hemorrhage. Although not immediately life-threatening, such conditions may cause ocular signs that can be confused with a more acute process. The clinician should consider performing a complete blood count, serum chemistry profile, and clotting profile if retinal hemorrhage is noted. A portion of the serum should be saved for potential serologic testing.

20. Is there any specific treatment for retinal hemorrhage?

There is no specific treatment for retinal hemorrhage. If an underlying systemic disorder is identified or suspected, appropriate treatment is indicated. Severe subretinal or preretinal hemorrhage can be surgically removed or lysed with intracameral injection of tissue plasminogen activator, but these procedures must be performed by someone well-versed in intraocular and posterior segment surgery.

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38. SUDDEN BLINDNESS

Cynthia C. Powell, D.V.M., M.S.

1. What are the common causes of sudden blindness as a presenting complaint?

Opacification of the normally clear ocular structures or neurologic abnormalities related to the visual system result in vision loss. In animals, gradual or incomplete loss of vision often goes undetected, and the veterinarian is presented with what the owner interprets as an acutely blind animal. A good history, including questions about changes in environment, night vision, and behavioral changes, helps to establish the true onset of blindness. Common causes of acute blindness as the presenting complaint include bilateral retinal detachment, sudden acquired retinal degeneration syndrome (SARDS), and bilateral optic neuritis. Although there are many other causes of blindness, they are often slower in onset (e.g., progressive retinal atrophy, cataracts) or have other primary presenting complaints (e.g., toxic causes, central nervous system [CNS] disorders, trauma).

2. Describe appropriate diagnostic tests for patients with sudden blindness.

Bilateral ophthalmic disease should raise the suspicion of a systemic cause. A complete blood count, platelet count, urinalysis, and serum chemistry profile are indicated to screen for infectious or other systemic diseases. In addition, because retinal detachment can be associated with hypertension, especially in older cats, thyroid hormone level and blood pressure measurements often are warranted.

3. What disorders causing acute blindness result in abnormal pupillary light reflexes (PLR)?

Bilateral optic neuritis and sudden acquired retinal degeneration always present with PLR abnormalities. The pupils are usually widely dilated in room light and are not responsive or are

orders such as hypertension, hyperviscosity syndromes, and neoplasia may cause retinal hemorrhage. Although not immediately life-threatening, such conditions may cause ocular signs that can be confused with a more acute process. The clinician should consider performing a complete blood count, serum chemistry profile, and clotting profile if retinal hemorrhage is noted. A portion of the serum should be saved for potential serologic testing.

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3. What disorders causing acute blindness result in abnormal pupillary light reflexes (PLR)?

Bilateral optic neuritis and sudden acquired retinal degeneration always present with PLR abnormalities. The pupils are usually widely dilated in room light and are not responsive or are

poorly responsive to light stimulation. If optic neuritis is not symmetrical, there may be variations in the amount of response to light in each eye. Pupil abnormalities related to bilateral retinal detachment are more subtle, but the resting pupil size is generally larger and the PLRs less brisk than normal. Bilateral lesions of the optic chiasm and optic tracts cause pupillary light reflex abnormalities similar to bilateral optic neuritis and SARDS, whereas bilateral lesions of the optic radiation or visual cortex have normal pupil size and PLRs. Blindness due to lesions of the optic chiasm, tracts, radiation or visual cortex are usually accompanied by other signs of nervous system disfunction and are not as likely to present as sudden blindness.

4. What is SARDS?

Sudden acquired retinal degeneration syndrome is a degenerative retinal disease of dogs. Middle-aged animals are predisposed, and females are more likely to be affected than males. Dogs with SARDS are often overweight and may have a history of polyuria/polydypsia or polyphagia. Laboratory changes frequently resemble those of hyperadrenocorticism, but specific tests for hyperadrenocorticism (low-dose dexamethasone suppression, adrenocorticotropic hormone [ACTH] stimulation) are usually normal. The cause of SARDS is unknown; toxic and autoimmune etiologies have been suggested.

5. How is SARDS recognized and confirmed?

The hallmark of early SARDS is acute or subacute onset of blindness coupled with an ophthalmoscopically normal fundus. A nonrecordable electroretinogram (ERG) confirms the diagnosis. Bilateral retrobulbar optic neuritis has the same clinical presentation as SARDS, but the ERG is normal.

6. Can SARDS be treated or managed?

Unfortunately, there is no treatment for SARDS. Blindness is permanent. The best way to manage an acutely blind animal is to give time for adjustment and maintain a familiar environment.

7. What are the clinical signs of optic neuritis compared with retinal detachment?

Retinal detachments severe enough to cause blindness are usually complete or almost complete and easy to diagnose with an indirect ophthalmoscope or focal light source. If not disinserted (detached at the ora ciliaris), the retina floats in the vitreous gel and often can be seen directly behind the lens. It has the appearance of a gray to white veil with blood vessels. Retinal hemorrhages also may be present, and the optic nerve may be partially covered by the floating retina, making it difficult to see. A disinserted retinal detachment hangs from and completely obscures the optic disk. As mentioned before, with acute detachment, the pupillary light responses may have only subtle abnormalities and on cursory examination may appear normal.

Optic neuritis causes dilated pupils poorly responsive to light. Funduscopic changes are found only if the inflammation involves the optic papilla (disk). Hyperemia, swelling, and hemorrhage of the optic nerve head and edema and hemorrhage of the adjacent (peripapillary) retina are evident ophthalmoscopically. Retrobulbar optic neuritis (inflammation of the optic nerve that does not extend to the nerve head) has a normal-appearing fundus and clinically resembles SARDS. Unilateral optic neuritis and unilateral retinal detachment often go undetected because behavioral changes and PLR abnormalities are usually subtle.

8. What are the common causes of optic neuritis?

The cause of optic neuritis is often elusive and classified as idiopathic. Causes that have been identified most frequently include systemic infection (canine distemper, cryptococcosis, toxoplasmosis), retrobulbar abscess or cellulitis, granulomatous meningoencephalitis (GME), neoplasia, and trauma. Cerebrospinal fluid analysis and cytology or CT scan may be helpful in the diagnosis.

9. How rapidly should optic neuritis be treated and by what means?

Treatment of optic neuritis should be instituted as soon as possible to minimize permanent structural damage to the optic nerve. When a primary cause is identified, specific therapy is required. The goal of treating idiopathic optic neuritis is rapid reduction of inflammation, which is achieved

with high dosages of systemic corticosteroids. Standard protocol is oral prednisolone given at an initial dose of 2–4 mg/kg/day and tapered over 3–4 weeks. In severe cases of inflammation, pulsed corticosteroid therapy should be considered. Pulsed therapy uses suprapharmacologic doses of methylprednisolone sodium succinate (15–30 mg/kg IV), followed by maintenance prednisolone (1–2 mg/kg/day) tapered over 3–4 weeks.

10. When should response to treatment be expected? What is the prognosis?

Irreversible damage often has occurred by the time optic neuritis is diagnosed; thus, the prognosis for return of vision is guarded. Response to treatment usually occurs within 1–10 days, if at all.

11. What are the common causes of retinal detachment?

Causes of retinal detachment are either congenital or acquired. Retinal dysplasia and optic nerve coloboma are common congenital defects associated with detachment and may affect one or both eyes. Acquired conditions include infectious and immune-mediated chorioretinitis, vascular disorders leading to edema or hemorrhage, neoplasia, hypertension, postinflammatory traction bands, and trauma. Hypertension is a common cause of retinal detachment in older cats.

12. How should retinal detachment be treated initially?

Cases of retinal detachment presented as an emergency are generally severe and require aggressive therapy if any vision is to be saved. In cases of systemic disease, treat the underlying cause. Idiopathic cases with active inflammation and serous detachments may be immune-mediated and often respond dramatically to corticosteroid or azathioprine therapy. Conventional therapy with oral prednisolone (1–2 mg/kg/day) or pulsed therapy with methylprednisolone sodium succinate (15 mg/kg IV) followed by maintenance prednisolone (0.5–1 mg/kg/day) is recommended. The starting dose of azathioprine is usually 2 mg/kg per day. The dose is reduced after 3–5 days, and blood work is monitored for evidence of hepatotoxicity and bone marrow suppression. Treatment should be continued until reattachment and then tapered and discontinued as response dictates. Inflammatory retinal detachment may be the first clinical sign of uveodermatologic syndrome, an immune-mediated disease of dogs, believed to target melanocytes.

13. Does vision return after reattachment?

Cell degeneration and death begin within hours to several days after detachment. The amount of cell death increases with duration of detachment and may continue after reattachment. The prognosis for return of vision is always guarded. Although some vision may return, normal vision is not expected.

OPTIC NEURITIS	RETINAL DETACHMENT
• Mydriasis or afferent PLR defect	• If blind, usually large or total detachment
• Optic disk changes Hyperemia Swelling Hemorrhage	• Veil with blood vessels floating in vitreous • Retinal hemorrhages • Optic disk possibly obscured
• Retinal peripapillary changes Edema Hemorrhage	• Normal to slightly reduced PLR • Unilateral cases often unrecognized
• Normal ocular fundus if retrobulbar neuritis	
• Unilateral cases often unrecognized	

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39. UVEITIS

Cynthia C. *Powell*, D.V.M., M.S.

1. What is the uvea or uveal tract?

The structure of the eye consists of an outer wall (cornea and sclera), inner retinal layer, and the uvea, a highly pigmented, vascular layer sandwiched between the sclera and retina. The uvea consists of the iris, ciliary body, and choroid. The iris and ciliary body are collectively referred to as the anterior uvea. The posterior uvea is the choroid. Although the anatomic regions have different names, the tissues are basically continuous with each other.

2. How is the uvea different from the uvula?

In contrast to the ocular uvea, the term *uvula* stems from a Latin word that means "little grape." The palatine uvula is a small, pendulous, fleshy mass hanging from the posterior soft palate edge above the root of the tongue in humans. Other structures associated with the term uvula include the bladder (uvula vesicae = a rounded elevation at the bladder neck) and cerebellum (uvula vermis = part of the cerebellum vermis between the pyramis and nodulus).

3. What is uveitis?

Uveitis is inflammation of one or more of the uveal tissues. Inflammation that involves a single tissue is termed iritis, cyclitis, or choriditis if the iris, ciliary body, or choroid is inflamed, respectively.

4. What is anterior uveitis?

Anterior uveitis denotes inflammation of both the iris and ciliary body.

5. What is posterior uveitis?

Posterior uveitis refers to choridal inflammation.

6. Can inflammation involve the anterior and posterior uvea simultaneously?

The division of the uvea into anterior and posterior does not imply a physical barrier between the two regions. Inflammation often involves both anterior and posterior portions. The terms uveitis, endophthalmitis, and panophthalmitis are used to describe diffuse uveal inflammation.

7. What is endophthalmitis?

Inflammation of the entire uveal tract is called endophthalmitis. Because of the close apposition of the choroid and retina, choroidal inflammation rarely occurs without retinal involvement (i.e., chorioretinitis). Thus, the prognosis for vision with endophthalmitis is poor.

8. What is panophthalmitis?

Uveal tract inflammation coupled with scleral and corneal inflammation is termed panophthalmitis. It is difficult to maintain a normal-appearing globe with inflammation of this severity and distribution. Preserving vision is hopeless.

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9. What are the major clinical signs of uveitis?

Anterior uveitis typically causes a painful eye with conjunctival and episcleral hyperemia, miosis, aqueous flare and cell accumulation, corneal edema, iris swelling and hyperemia, and reduced intraocular pressure (hypotony). Vision is impaired but rarely lost with simple anterior uveitis. Vision loss indicates more extensive ocular tissue damage and usually occurs with increased severity or duration of inflammation. An ophthalmoscope is required for assessment of posterior uveitis. Ophthalmoscopic signs include loss of the normal tapetal color, retinal detachment, subretinal transudation or exudation, and loss of retinal pigment epithelial cell and choroidal pigmentation. Posterior uveitis almost always also involves the retina (chorioretinitis) and may cause blindness.

10. Can the clinical signs be used as an indication of chronicity, severity, or prognosis?

The spectrum and magnitude of signs depend on the severity of insult. The list below differentiates acute vs. chronic anterior uveitis based on clinical signs. If trauma, vasculitis, or bleeding disorders are underlying causes of uveitis, hyphema and anterior chamber fibrin clots are common. Septic or neoplastic disorders also can induce the above changes and are often bilateral with varying degrees of hypopyon (white blood cells within the aqueous humor) or keratic precipitates (white blood cells and fibrin adherent to the corneal endothelial surface). Posterior uveitis warrants a guarded prognosis for vision. Acute signs include retinal edema, retinal hemorrhage, loss of normal tapetal color, subretinal fluid accumulation, and decreased vision. Chronic signs consist of hyperreflective areas in the tapetal fundus (caused by retinal atrophy and thinning), abrupt color changes of the tapetum, and pigment proliferation or loss.

Clinical Signs

ACUTE ANTERIOR UVEITIS	CHRONIC ANTERIOR UVEITIS
Mild conjunctival hyperemia	Deep corneal vascularization
Iris swelling	Iris hyperpigmentation
Aqueous flare	Iris neovascularization
Mild episcleral hyperemia	Synechia formation
Miosis	Cataract
Photophobia	Secondary glaucoma

11. What is the significance of aqueous humor flare and cell accumulation?

The blood-ocular barrier maintains the low total protein content (20–30 mg/dl) and cell-free state of the aqueous humor. Uveal inflammation disrupts this barrier, resulting in an increased amount of protein and influx of cells within the aqueous humor. The increased protein causes light directed into the eye to back-scatter, thus imparting a turbid characteristic to the aqueous humor. This phenomenon is termed *flare* and is subjectively graded using a scale ranging from 0–4+ (0 = normal and 4+ = fibrin clot formation). The accumulation of cellular material may consist of white blood cells, red blood cells, pigment, or tumor cells as well as pigment granules. The presence of increased amounts of aqueous protein indicates inflammation (with the severity approximating the magnitude of the flare reaction). Likewise, cell accumulation indicates inflammation but suggests a more severe inflammatory response. Flare and cells (including hypopyon) may be the result of sterile inflammation or infection.

12. Which is more common—anterior uveitis or posterior uveitis?

Anterior uveitis is more common, especially considering the propensity for the globe to suffer traumatic injury. The anterior segment (cornea, iris, ciliary body, and lens) is more frequently damaged than the posterior segment (vitreous, retina, optic nerve, and choroid) in ocular trauma. The posterior location of the choroid within the orbit gives the choroid considerable protection, but contrecoup forces may result in choridal contusion. Anterior and posterior uveal inflammation are both common with other causes of uveitis.

13. What are the common causes of uveitis?

Uveitis is a component of most intraocular disease processes and a frequent result of trauma to the globe. Despite the ease with which uveitis can be recognized clinically, most cases are classified as idiopathic. Many endogenous causes of uveitis have been recognized (see table below). Common causes of uveitis in companion animals presented for emergency care include blunt trauma, corneal ulceration, and perforation of the cornea or globe.

Causes of Endogenous Uveitis in Dogs and Cats

CANINE UVEITIS	FELINE UVEITIS
Infectious disease	**Infectious disease**
Algae	**Fungal**
Prototheca spp.	*Blastomyces dermatitidis*
Bacterial	*Candida albicans*
Brucella canis	*Coccidioides immitis*
Borrelia burgdorferi	*Cryptococcus neoformans*
Fungal	*Histoplasma capsulatum*
Blastomyces dermatitidis	**Parasite**
Coccidioides immitis	*Cuterebra* larva
Cryptococcus neoformans	*Dirofilaria immitis*
Histoplasma capsulatum	Metastrongylidae nematodes
Parasitic	**Protozoan**
Dirofilaria immitis	*Toxoplasma gondii*
Diptera spp. (fly larvae)	**Viral**
Ocular larval migrans (*Toxocara* and *Balisascaris* spp.)	Feline immunodeficiency virus
Protozoan	Feline infectious peritonitis
Leshmania donovani	Feline leukemia virus (tumor formation)
Toxoplasma gondii	**Miscellaneous causes**
Rickettsial	Idiopathic
Ehrlichia canis or *platys*	Trauma
Rickettsia rickettsii	**Neoplastic disorders**
Viral	Fibrosarcoma
Adenovirus	Primary tumor (melanoma)
Distemper virus	Secondary tumor (lymphosarcoma)
Herpesvirus	
Idiopathic	
Trauma	
Toxemia (e.g., pyometra, pancreatitis)	
Ulcerative keratitis	
Neoplastic and paraneoplastic disorders	
Hyperviscosity syndrome	
Granulomatous meningoencephalitis	
Primary neoplasia (ocular melanoma, adenocarcinoma)	
Secondary neoplasia (lymphosarcoma most common	
Metabolic disorders	
Diabetic cataract (lens-induced uveitis)	
Miscellaneous causes	
Coagulopathy	
Immune-mediated disorders	
Immune-mediated vasculitis	
Lens trauma (phacoclastic uveitis)	
Cataract (lens-induced uveitis)	
Uveodermatologic syndrome	

14. What significance can be attributed to anterior uveitis?

Anterior uveitis indicates injury to the anterior uveal tissue resulting from either an exogenous cause, such as trauma or surgery, or an endogenous cause, such as systemic infection. Bilateral uveitis is more likely to result from systemic disease. Although the presence of uveitis is not necessarily an indication of infection, infectious causes should be considered. However,any pathophysiologic mechanism that results in uveal damage will trigger an inflammatory response. Because many intraocular tissue antigens are not recognized by the host as self, immune responses to antigenic material released as a result of the inflammation can propagate the inflammatory process and contribute to the development of chronic uveitis. Chronic anterior uveitis often leads to development of synechia. When extensive, synechia can obstruct aqueous humor outflow, causing secondary glaucoma.

15. Can a prognosis be determined in emergency cases with uveitis?

Obviously the prognosis depends on the actual condition or injury. However, the prognosis for vision in cases with mild-to-moderate degrees of uveitis is favorable. Severe cases have a guarded prognosis. Within 24–48 hours of treatment initiation, the prognosis needs to be reevaluated and possibly upgraded or downgraded. In cases of endophthalmitis or panophthalmitis, the prognosis for vision is poor, and the prognosis for globe salvage is guarded to poor. If secondary conditions develop as a result of uveitis (e.g., hyphema, glaucoma, intensified pain), a guarded-to-poor prognosis is warranted.

16. How should anterior uveitis be treated in an emergency setting?

If not contraindicated by the patient's overall condition, nonspecific antiinflammatory therapy with topical or systemic corticosteroids is optimal. Although not as effective, NSAIDs can be used as an alternative to corticosteroids when necessary. NSAIDS should be avoided in cases associated with coagulopathies or intraocular hemorrhage. Topical preparations should be used with caution in cases of globe perforation, because the drug, vehicle, or preservatives may damage intraocular tissues. If an infectious cause is suspected, topical and/or systemic antimicrobial agents can be used. If antibiotics are indicated, use of a triple antibiotic ophthalmic solution topically and first-generation cephalosporin systemically is appropriate. The following treatment goals and grades of inflammation severity provide guidelines for initial therapy:

Mild inflammation (subtle to pronounced miosis, subtle flare, photophobia)

- Topical corticosteroids, 3 times/day **or**
- Topical NSAID, 3 times/day
- Topical cycloplegics (e.g., atropine), every 24 hr

Moderate inflammation (aqueous flare and cells, iris swelling, blepharospasm, corneal edema)

- Systemic corticosteroids (e.g., prednisone, 1 mg/kg/day)
- Topical corticosteroids (e.g., 1% prednisolone or 0.1% dexamethasone, 4 times/day)
- Topical NSAID, 4 times/day
- Cycloplegics, twice daily until mydriasis occurs

Severe inflammation (hyphema, hypopyon, aqueous fibrin, irregular pupil shape and iris swelling)

- Systemic corticosteroid pulse-therapy initially (e.g., methylprednisolone sodium succinate, 30 mg/kg IV over 20–30 min) **or**
- Systemic corticosteroids (e.g., prednisone 2 mg/kg/day in place of or 6–12 hours after pulse-therapy)
- Topical corticosteroids (e.g., 1% prednisolone or 0.1% dexamethasone, every 1–2 hr until improved, then 4 times/day)
- Topical NSAID, 4 times/day

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40. GLAUCOMA

Cynthia C. *Powell*, D.V.M., M.S.

1. What is acute glaucoma?

Glaucoma occurs when the intraocular pressure (IOP) is increased above normal and results in optic nerve degeneration. Normal intraocular pressure for companion animals is 15–25 mmHg. Acute glaucoma results from a rapid increase in IOP over a course of several hours. Once glaucoma has been present for more than several days, the problem should be considered subacute; after several weeks, chronic glaucoma is present. Because most cases of canine glaucoma do not resolve, chronic glaucoma is inevitable. Many canine glaucoma cases are chronic by the time veterinary care is sought.

2. What is the difference between primary and secondary glaucoma?

In primary glaucoma, no discernible ocular abnormalities can be found on routine examination to account for the increased IOP. Primary glaucoma is due to impairment of aqueous humor outflow through the filtration angle, although the mechanisms are poorly understood. Secondary glaucoma results from filtration angle dysfunction due to or associated with other intraocular problems such as lens subluxation, neoplasia of the iris or ciliary body, intraocular hemorrhage, or intraocular inflammation (e.g., anterior uveitis, endophthalmitis, panophthalmitis).

3. Are the glaucoma classifications of open-angle and closed-angle appropriate for veterinary medicine?

This controversial area is confused by the fact that veterinary medicine has adopted the human classification system for animal species with quite different filtration angle anatomy and physiology. The real issue in companion animals is whether the ciliary cleft is open, narrowed, or closed. The ciliary cleft is located posterior to the iris and is examined either in vivo by high-frequency ultrasound techniques (50 MHz) or in vitro by histology.

4. What are the common causes of glaucoma in companion animals?

Glaucoma is due to impairment or obstruction of aqueous humor outflow from the eye. Primary glaucoma results from structural and functional abnormalities of the filtration angle and is most common in dogs. More than 40 breeds of dogs are predisposed to primary glaucoma. Secondary glaucoma is due to problems such as anterior uveitis, lens subluxation or luxation, and intraocular neoplasia. Secondary glaucoma is most common in cats (secondary to chronic

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uveitis). If glaucoma is truly acute, the cause is most likely a primary filtration angle abnormality. Secondary glaucoma frequently results from chronic ocular disorders and is usually subacute or chronic by the time the animal is brought to a veterinarian.

PRIMARY GLAUCOMA	SECONDARY GLAUCOMA
• Breed-associated filtration angle abnormality (common in dogs) • Open ciliary cleft progressing to narrowed and closed cleft • Final stages have closed filtration angle	• Associated chronic intraocular disease causing ciliary cleft collapse and closure (common in cats) • Filtration angle closure occurs with disease progression

5. What is the cause of primary glaucoma?

The initiating cause is not known but involves poorly understood changes in the aqueous humor outflow pathways that restrict and eventually obstruct aqueous outflow from the eye. Once the IOP increases, the ciliary body and peripheral iris are forced toward the sclera, thus narrowing or collapsing the ciliary cleft and filtration angle. When the peripheral iris and ciliary body come into contact with the sclera, aqueous humor outflow through the angle is further impaired. Eventually the iris and ciliary body become adherent to the sclera (synechia), and the filtration angle is closed. As the IOP increases, pathologic degenerative changes occur throughout the globe.

6. Which breeds of dog are at greatest risk for developing glaucoma?

Breeds that have a high risk of developing primary glaucoma include the American cocker spaniel, Basset hound, chow chow, samoyed, Shar Pei, and Siberian husky. Primary glaucoma also has been identified in many other breeds of dogs.

7. How is acute glaucoma diagnosed?

Glaucoma is confirmed by measurement of the IOP, but ample clinical signs provide a strong presumptive diagnosis. Acute cases often present with a history of rapid onset of diffuse corneal clouding, conjunctival and episcleral hyperemia, ocular pain, and loss of vision (if the case is unilateral, owners often do not notice vision impairment). Examination reveals an abnormal pupillary light reflex (PLR). Miosis can appear in acute cases, however mydriasis is usually found. The affected eye is usually blind, and the PLRs are usually absent or minimal. The magnitude of increased IOP is proportional to the severity of clinical signs.

8. What is a good method of measuring intraocular pressure?

There are two basic methods of indirectly estimating the IOP:

1. Indentation tonometry uses the inexpensive Schiotz tonometer, which correlates corneal indentation, caused by the instrument plunger, with IOP.

2. Applantation tonometry estimates IOP by the force required to flatten the corneal surface by use of various electronic or pneumatic devices The Tonopen is an example of an applantation tonometer.

Both are good estimators of IOP in the normal range and give a reasonable approximation of abnormal pressure values. Topical anesthesia is required, and the animal must be gently restrained so that external forces are not directly or indirectly applied to the globe. Pressure on the jugular vein also should be avoided.

9. How is the actual IOP determined by a Schiotz tonometer?

A Schiotz tonometer measures the amount of corneal indentation, with each unit on the scale representing 0.05 mm of indentation. The scale is therefore an inverse scale; that is, high IOP yields a low-scale reading. As a general rule, the Schiotz tonometer reading of a normal eye should be within 2 of the plunger mass load. Thus, with a 5.5-gm plunger load, the reading should be between 3.5 and 7.5. If the scale reading is less than 3.5, the IOP is increased. Conversely, if the scale reading is greater than 7.5, the IOP is below normal. This same rule holds

true for plunger loads of 7.5 and 10 gm. The table below allows conversion of scale reading to mmHg for dogs and cats using the accepted human conversion table.

Calibration Table for Schiotz Tonometry

SCHIOTZ SCALE READING	IOP (mmHg) 5.5 GM WT	IOP (mmHg) 7.5 GM WT	IOP (mmHg) 10.0 GM WT
0	42	59	82
1	34	50	69
2	29	43	59
3	24	36	51
4	21	30	43
5	17	26	37
6	15	22	32
7	12	18	27
8	10	16	23
9	8	13	20
10	7	11	16
11	6	9	14
12	5	8	12
13	4	6	10
14		5	8
15		4	6
16			5
17			4

10. What signs indicate that the problem is due to chronic glaucoma?

Chronic glaucoma should be suspected if the history indicates that the problem has been present for several weeks or that several repetitive episodes have occurred. Clinical signs associated with chronicity include an enlarged globe, Haab's striae (breaks in Descemet's membrane), keratitis (vascular and pigmentary), lens subluxation, optic nerve atrophy and cupping, and peripapillary retinal atrophy (tapetal hyperreflectivity).

11. What are Haab's striae?

Persistently increased IOP causes stretching of the cornea and sclera, resulting in overall globe enlargement. Descemet's membrane is the corneal endothelial cell basement membrane along the posterior cornea. Pressure-induced stretching of Descemet's membrane causes single or branching curvilinear ruptures. As the basement membrane wound heals, permanent ridges remain and appear as white-to-gray, deep corneal opacities. Thus Haab's striae are specific for glaucoma, although the process may not be active at the time of examination.

12. How should emergency treatment of glaucoma be approached?

Emergency treatment must first focus on underlying problems that may contribute to increased IOP. If primary glaucoma is suspected or underlying problems are being addressed, focus shifts to dealing with the acute increase in IOP. Permanent retinal nerve fiber and optic nerve damage can occur within hours of an acute rise in IOP; thus, rapid intervention is essential. Emergency medical treatment is generally instituted when the IOP is > 40 mmHg and should consist of administration of a hyperosmotic agent (mannitol, 2 gm/kg IV over 30 minutes, or glycerin, 2 ml/kg orally) and a carbonic anhydrase inhibitor (dichlorphenamide, 2 mg/kg orally 2 or 3 times/day, or methazolamide, 4 mg/kg orally 2 or 3 times/day).

13. What topical drugs should be used in acute glaucoma?

A wide variety of topical drugs is available. If a veterinary ophthalmologist will eventually manage the case, he or she should be consulted early to determine appropriate topical treatment. Topical agents are expensive and must be used only if likely to be effective. Pilocarpine, a cholinergic drug, is commonly administered, but because of inherent problems with the filtration angle in dogs, it is often not effective or effective only for a brief time. Adrenergic agonists and antagonists are the most useful topical agents. Latanoprost is a prostaglandin $F_{2\alpha}$ analog that shows tremendous potential because the mechanism of action is to increase aqueous humor outflow by an alternative route (the uveoslceral pathway).

ADRENERGIC AGONISTS	ADRENERGIC ANTAGONISTS	PROSTAGLANDIN ANALOG
• Beta agonist Epinephrine 1% Dipivefrin 0.1% • Alpha agonist Apraclonidine 0.5%	• Beta 1 and 2 blockers Carteolol 1% Levobutanol 0.5% Metipranolol 0.3% Timolol 0.5% • Beta 1 blocker Betaxolol 0.5%	• Latanoprost 0.005%

14. If immediate referral to an ophthalmologist is not feasible, what agents are best?

Although there is no one correct protocol for medical management of glaucoma, most often an oral carbonic anhydrase inhibitor is given twice daily (see question 12) and either a topical beta blocker every 12 hours, topical dipivefrin every 12 hours, or topical latanoprost every 12–24 hours. More than one class of topical drug can be used simultaneously (e.g. beta blocker plus latanoprost). However, the IOP-lowering effects are diminished with each additional drug, and owner compliance is more difficult. Long-term medical management is difficult and requires careful monitoring, dosage adjustments, and drug changes.

15. What is the prognosis for acute glaucoma?

The prognosis for preserving vision is guarded to poor. Early during the course of treatment, the owner should be asked to choose one of the following primary goals: to provide the maximal chance of vision preservation, to maintain a blind but comfortable and cosmetic globe, or to achieve a comfortable, disease-free state. The degree of vision at initial evaluation or the amount of vision regained after 24–48 hours of treatment is the best that can be hoped for.

16. What causes the loss of vision associated with glaucoma?

Vision loss occurs rapidly as increased IOP damages the innermost retinal layers, retinal nerve fiber layer, and ganglion cells. The retinal nerve fiber layer is comprised of ganglion cell axons that exit the globe as the optic nerve. These central nervous system neurons do not repair cellular damage well. A few hours of increased IOP results in permanent loss of some ganglion cells and axons. As the duration and magnitude of IOP elevation continue, more neuronal damage occurs; within hours to days, the neurons have minimal-to-no remaining function. Thus, blindness is inevitable unless the IOP is quickly reduced and maintained in a normal range.

17. When is surgery indicated for glaucoma?

Long-term management of glaucoma usually requires surgical intervention, often coupled with continued medical treatment. If the animal owner is interested in surgery, procedures are best performed as soon as possible. Procedures suitable for visual eyes include placement of an anterior chamber shunt, transscleral laser ciliary body coagulation, and transscleral ciliary body cryosurgery. Blind eyes can be treated surgically by transscleral laser or cryosurgery of the ciliary body, pharmacologic ciliary body ablation with intravitreal gentamicin, evisceration, or enucleation.

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41. VISION-THREATENING CORNEAL ULCERS

Cynthia C. *Powell*, D.V.M., M.S.

1. When does a corneal ulcer threaten vision?

By definition, a corneal ulcer represents a break or disruption in the corneal epithelium. If an ulcer involves only the epithelium, healing is usually rapid with no significant loss of corneal transparency. If the epithelial defect becomes infected or involved with a purulent inflammatory response, the deeper corneal stroma is affected. Of course, the initial insult causing ulceration may directly result in stromal damage. Once the stroma is damaged, healing occurs with some degree of fibrosis and collagen disorganization, which result in loss of corneal transparency and potentially significant loss of vision. Because the cornea is less than 1 mm thick, ulceration may pose a threat to overall globe integrity. Optimal treatment of a corneal ulcer needs to be rapid and effective to minimize the chance of vision impairment.

2. What initial diagnostics should be done when evaluating a corneal ulcer?

The first objective is to determine the area of corneal involvement and lesion depth. If the ulcer margins are not readily apparent, fluorescein stain may be applied, using a sterile strip moistened with a drop of sterile saline or artificial tears. The moistened strip is momentarily touched to the superior bulbar conjunctiva, anterior nictitans surface, or the inferior conjunctival area. The animal is allowed to blink, and the excessive stain is irrigated with sterile saline. The region of denuded corneal epithelium stains a green color. Depth can be estimated by viewing the ulcer from an oblique angle across the cornea. Normal corneal thickness is about 0.75 mm. Most ulcers are associated with corneal edema that increased the corneal thickness to 1.5–2.5 mm. Ulcer depth should be classified into one of the following categories.

- Epithelial erosion
- Superficial stromal (< $\frac{1}{4}$ thickness)
- Anterior stromal ($\frac{1}{4}$ thickness)
- Midstromal ($\frac{1}{2}$ thickness)
- Deep stromal ($\frac{3}{4}$ thickness)
- Impending perforation (descemetocele)
- Perforation without iris prolapse
- Perforation with iris prolapse

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- Perforation without iris prolapse
- Perforation with iris prolapse

3. What is the second diagnostic step that an emergency clinician should perform in evaluating a serious corneal ulcer?

The second objective is to determine the cause of the ulcer. If the cause is not apparent from the history or initial physical examination, further diagnostic tests are indicated. Culture and cytology specimens should be collected from the ulcer margins and center. If epiphora is not present, a Schirmer tear test should be performed. Inspection of the cornea with a magnifying aid (head loupe or diagnostic otoscope head) allows detection of vascularization and pigmentation, both of which are indicators of chronic disease. Immediate cytologic evaluation with a Wright-Giemsa stain allows characterization of the ulcer process into suppurative inflammation, septic, and noninflammatory categories. Other cytology staining methods can be used if indicated. If the ulcer is deep, minimal pressure should be applied to the ocular tissues because rupture and uveal prolapse may result.

4. Discuss the common causes of deep corneal ulcers.

Ulcerations involving at least 30% of the corneal thickness are often due to traumatic injuries, chronic underlying disease, or direct corneal infection with bacteria, fungi, or viruses. Septic ulcers are particularly dangerous because progression may be rapid because of stromal inflammation, necrosis, and melting. Specific causes of deep corneal ulcers include trauma (blunt, foreign body, sharp), eyelid disorders (distichiasis, ectopic cilia, entropion), keratoconjunctivitis sicca, lagophthalmos (buphthalmos, exophthalmos, facial nerve paralysis), thermal injuries, chemical burns (acids, alkaline agents, detergents), and infection. Common infectious agents in companion animals are *Staphylococcus intermedius* or *aureus*, *Pseudomonas aeruginosa*, *Aspergillus* spp., *Fusarium* spp., and feline herpesvirus. Bacterial agents are often associated with rapid progress to deep ulceration.

5. What first-aid steps should be taken at home before bringing the pet with a corneal ulcer to the veterinarian?

Because the lesion depth is unknown, owners must be careful when manipulating the periocular region. At the least, the animal should be restrained to prevent self-mutilation from rubbing with the paws or against objects. Other pets should not be allowed to lick the facial area of the affected animal. If it is known that the eye is not perforated, the owner may attempt to clean the eye with sterile saline eye rinse (however, this is usually not readily available). In certain situations, the owner may be instructed to instill an antibiotic eyedrop. Potential problems include the following: (1) the medication may have been used for another problem, (2) culture results may be influenced by antibiotic use, (3) treatment may induce more trauma, and (4) the owner may be injured by the animal. Generally, the owner should be encouraged to take the animal to a veterinarian immediately.

6. When is medical treatment the only appropriate approach to corneal ulcer management?

Corneal ulcers involving the anterior ⅓ to ½ of the corneal stroma usually can be managed by medical treatment alone; however, those with evidence of infection or collagenase activity should be monitored daily for progression. Noninfected superficial ulcers should be treated with topical antibiotics 3–4 times/day to prevent infection. If evidence of infection is seen, the frequency should be increased to every 1–2 hr for at least the first 24–48 hours. Anterior uveitis is often present to some degree; thus, topical atropine should be instilled several times to induce cytoplegia and mydriasis, then maintained to effect so that mydriasis is perpetuated during healing. Systemic nonsteroidal agents are also useful for combating ulcer-induced anterior uveitis. If feline herpesvirus is suspected, a topical antiviral medication such as trifluorthymidine solution or idoxuidine ointment should be administered. Timing and frequency of reevaluation depend on the potential for progression.

7. What antibiotics are best for treating a corneal ulcer?

Ideally, a broad-spectrum bactericidal drug or drug combination should be used. Gram-positive bacteria are the most frequently isolated organisms from both normal and diseased eyes in

dogs and cats. Good preparations for routine antibiotic use include Polymyxin B/Neomycin/Bacitracin or Polymyxin B/Neomycin/Gramicidin ophthalmic solutions. Gentamicin is a good single agent ophthalmic solution, but because of widespread clinical use, most streptococcal and some gram-negative organisms, are resistant. When indicated, prescriptions can be written for ophthalmic ciprofloxacin, ofloxacin, and tobramycin ophthalmic drops; however, these antibiotics should be reserved for more severe or resistant infections. Various injectable antibiotics can be added to artificial tear solutions as single or combination agents. However, most penicillins and cephalosporins are physically incompatible with aminoglycosides. A pharmacist should be consulted before using custom-prepared antibiotics or mixtures.

8. If surgery is anticipated, how should the patient be managed preoperatively?

Because vision is not essential for life, life-threatening conditions or conditions that increase the risk of anesthesia should be addressed before surgery. Infected ulcers should be treated with topical antibiotic ophthalmic solution as frequently as every 15 minutes before surgery. Unless otherwise indicated, perioperative systemic antibiotics are usually sufficient for ocular surgery. If anterior uveitis is present, parenteral corticosteroids or nonsteriodal antiinflammatory drugs are administered (unless contraindicated by the animal's condition). Analgesics such as oxymorphone or butorphanol improve patient comfort and decrease the chance of self-trauma.

9. What surgical repairs should the emergency clinician consider?

Simple protective eyelid flaps, such as a nictitans flaps or temporary tarsorrhaphy, provide some protection and can facilitate wound healing. However, they do not provide the tissue needed for ulcers greater than half-corneal depth. In addition, these procedures prevent clinical evaluation of the healing process. Generally, nictitans flaps and temporary tarsorrhaphies are reserved for persistent superficial corneal ulcers, not deep ulcers or ulcers complicated by infection or abscess. Conjunctival grafts (conjunctival autografts to the cornea) are more difficult to perform but have the advantage of providing tissue support and a direct blood supply to the cornea. Corneal suturing requires 7-0 to 8-0 suture material; 4-0 to 5-0 suture is used for eyelid flaps.

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V. Respiratory Emergencies

Section Editor: Wayne E. Wingfield, M.S., D.V.M.

42. ALLERGIC AIRWAY DISEASE (ASTHMA) IN CATS

Wayne E. Wingfield, M.S., D.V.M.

1. What is feline allergic airway disease (FAAD)?

FAAD is reversible constriction and spasm of the smooth muscle of the airways, particularly small bronchi.

2. Describe the the underlying pathology of FAAD.

Bronchoconstriction of the small airways is caused by an underlying inflammatory process. Inflammation in the airway may be transient or chronic. In some cats, the airway seems to be hyperresponsive; the stimulus or degree of inflammation leads to a greater degree of bronchospasm than in normal cats. Inflammatory cellular infiltrates (predominantly eosinophils) are found in the submucosa, sometimes extending into the lamina propria. Evidence of chronic inflammation (epithelial, glandular, and muscular hypertrophy; fibrosis; and emphysema) is seen on histopathology.

3. Describe the proposed mediators of FAAD.

Serotonin appears to be the primary mediator in feline mast cells. Interleukin-5, which is a chemoattractant for eosinophils, also may play a role. Eosinophils are the primary effector cells responsible for pathologic changes in cats. They release substances from granules that result in airway inflammation and cellular damage. These substances also sensitize airway smooth muscle cells, making them hyperresponsive.

4. Describe the pathophysiology of bronchoconstriction in FAAD.

FAAD is an acute inflammatory disorder that is probably associated with release of serotonin and other inflammatory mediators. Affected cats have significant acute bronchoconstriction that may be triggered by specific allergens. Chronic inflammation and narrowing of the small bronchi can lead to a number of serious changes in the lung. The most significant change is emphysema, caused by chronic overdistention of alveoli. The lesions in the small bronchi primarily affect expiration. Because the negative pressure exerted by the lung parenchyma on the small bronchi during inspiration tends to "stent" the airways open, inhalation occurs normally. During exhalation, the small bronchi tend to collapse not only because they are narrowed to begin with, but also because they are weakened by inflammation, with subsequent reductions in closing volume. Bronchiectasis is another relatively unusual complication of chronic bronchial disease.

5. What criteria are applied in making a diagnosis of FAAD?

1. Historic and clinical findings, coupled with response to treatment for airway obstruction
2. Radiographic changes consistent with FAAD (bronchial thickening with evidence of hyperinflation)
3. Clinicopathologic evidence of airway inflammation

6. What other disorders should be considered in the differential diagnosis?

- Primary cardiac disease
- Neoplasia
- Infectious pulmonary diseases
- Pulmonary foreign body
- Pulmonary thromboembolism
- Heartworm disease
- Upper airway disease
- Pleural diseases

7. Give the signalment, clinical signs, history, and physical findings in FAAD.

FAAD is a disease of all breeds of cats, with a possible predilection for Siamese and Himalayans. There is no gender predilection, and all ages may be affected. The most common historical finding is cough, although some cats present with acute respiratory distress as the first sign of asthma. Physical examination between attacks may be unremarkable. Expiratory respiratory distress, wheezing, and increased bronchovesicular sounds may be auscultated in some cases.

8. Should the term "dyspnea" be used in veterinary species?

Technically, no! Dyspnea means a "complaint" of respiratory distress. Unless your cat can verbalize that it is having a hard time breathing, dyspnea is probably not the correct term. In veterinary patients, the more correct term is "respiratory distress."

9. Describe the ancillary tests recommended in FAAD. What are the most common findings?

Complete blood counts may reveal peripheral eosinophilia, but the presence or absence of eosinophilia should not be the only guideline to rule in or out FAAD. Biochemical profiles and urinalysis are not helpful in establishing a definitive diagnosis but may help to eliminate other disorders. Fecal examination for parasites is indicated in all cases. Sampling of cells from airways (via transtracheal wash, bronchoalveolar lavage, or bronchial brushing) may demonstrate eosinophils, but they are not pathognomonic for FAAD. Bacterial and mycoplasmal cultures of tracheal or bronchial secretions are controversial. Some authors believe that microorganisms contribute directly to airway reactivity, some believe that they may be secondary invaders, and others consider them irrelevant. Studies show that 24% of cats with bronchial disease have positive bacterial cultures, and *Mycoplasma* sp. has been cultured from cats with airway disease. Therefore, submission of fluid for culture may be indicated in cats with FAAD.

10. What is the first line of emergency management for FAAD?

Cats that present with severe respiratory distress should be placed in an oxygen cage and manipulated as little as possible.

11. Should emergency thoracic radiographs be taken of a cat with FAAD?

Although radiographs are a vital part of the diagnosis of FAAD, manipulation and restraint of the cat severely compromise respiratory function. It is best to give medical therapy and take radiographs after the drugs have improved the cat's condition.

12. What are the radiographic findings in FAAD?

It is not unusual for the lungs to have a normal appearance! Similarly, in chronic, elderly cats, a peribronchial pattern often is seen without evidence of clinical disease. Typical findings include:

- Peribronchial pulmonary pattern
- Flattening of the diaphragm, indicating overdistention of the lungs
- Increased lucency of the lung fields (suggestive of air trapping)
- Atelectasis of the right middle lung lobe (11% of cats)
- Bronchiectasis and pneumothorax (occasional findings)

13. What drugs are used in the treatment of FAAD? How do they work?

- **Corticosteroids** are the mainstay of treatment for FAAD. They address the inflammatory process, decrease edema, and minimize mucus production and subsequent bronchospasm.
- **Bronchodilators** (aminophylline and theophylline) have been used extensively in the past with variable efficacy. They have minimal direct bronchodilatory action. Their chronotropic action on the heart may compromise the animal's ability to respond to the crisis.

Beta-1 agonists usually are reserved for cats unresponsive to oxygen and corticosteroids.

Other drugs tried in the treatment of FAAD include cyproheptadine (serotonin antagonist), and cyclosporin A (blocks T-cell activation and therefore interleukin production).

14. What are the dosages for the drugs listed in question 13?

DRUG	DOSAGE	USE
Corticosteroids		
Prednisone sodium succinate	50–100 mg/cat IV	Emergency treatment
Dexamethasone	1 mg/kg IV or IM	Emergency treatment
Prednisone	1–2 mg/kg PO 2–4 times/day	Maintenance treatment
Methylprednisolone	10–20 mg/cat IM every 2–4 wk, then every 2–8 wk	Maintenance treatment
Bronchodilators		
Methylxanthines: sustained-release tablets (Theo-Dur or Slo-BID)	50–100 mg/cat every 24 hr at night	Maintenance treatment
Beta agonists		
Epinephrine	20 µg/kg IV, IM, IT, SC	Emergency treatment
Terbutaline	0.01 mg/kg or 0.625 mg/cat PO every 12 hr	Maintenance treatment
Miscellaneous		
Cyproheptadine	1–2 mg/cat PO every 12 hr	Maintenance treatment
Cyclosporin A	10 mg/kg PO every 12 hr (measure blood levels)	Maintenance treatment

IV= intravenous, IM = intramuscular, PO = oral, IT = intrathoracic, SC = subcutaneous.

15. What information should you give the client about long-term management of FAAD?

Although FAAD can be controlled, it is seldom cured. Some degree of coughing may always be present. Most environmental triggers are never identified in the cat. Changing kitty litter to newspaper or low-dust litter formulations is helpful. Because specific triggers are not often identified, medication is required.

16. How should the FAAD cat be monitored?

Recommendations vary, depending on the severity of disease. Severely affected cats may require evaluation until signs are controlled, then every 3–6 months, as needed. Owners should contact the veterinarian if signs of worsening airway disease or acute respiratory distress occur.

CONTROVERSIES

17. Should cats in severe respiratory distress be intubated?

Intubation of an awake, hypoxic animal results in a vagal response, often leading to ventricular asystole. If the cat is exhausted, has a change in mental alertness, or is unresponsive to emergency treatments, intubation after sedation may be attempted, but the prognosis for recovery is grave.

18. What is the role of histamine in FAAD?

Although histamine is unquestionably an important mediator of asthma in people, research has raised questions about its role in the pathogenesis of FAAD. In fact, some antihistamines may exacerbate the signs of FAAD.

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43. ASPIRATION PNEUMONITIS

Elisa M. *Mazzaferro*, M.S., D.V.M.

1. Define aspiration pneumonitis.

Aspiration pneumonitis is the pulmonary inflammatory response to the inhalation or aspiration of liquid or particulate matter.

2. What underlying conditions predispose an animal to develop aspiration pneumonitis?

- Any cause of persistent vomiting
- Altered level of consciousness (sedation, anesthesia, central nervous system disorders)
- Oropharyngeal conditions (force feeding, cleft palate, laryngeal paralysis)
- Esophageal disorders (vascular ring anomalies, megaesophagus, esophageal stricture, motility disorders)
- Disruption of normal defense barriers (esophagostomy tubes, tracheostomy tube, endotracheal tube)
- Gastroesophageal reflux
- Surgery for laryngeal paralysis

3. Which bacteria are commonly isolated from patients with aspiration pneumonitis?

Pulmonary bacteria from patients with aspiration pneumonitis typically originate from the oropharynx and upper gastrointestinal tract. Examples include *Escherichia coli, Klebsiella* spp., *Pasteurella* spp., *Pseudomonas* spp., *Bordetella* spp., *Streptococcus* spp., and *Mycoplasma* spp.

4. List four types of aspiration pneumonitis.

1. Chemical pneumonitis, which is the inflammatory response to any inhaled substance toxic to the lower pulmonary tract
2. Aspiration of inert substances secondary to reflux airway closure
3. Aspiration of inert fluids or particulate matter secondary to mechanical obstruction
4. Inoculation of oral flora, causing infection

5. Name three factors that determine the severity of the pulmonary reaction in chemical aspiration pneumonitis.

- pH of fluid aspirated
- Volume of fluid aspirated
- Presence or absence of particulate matter

Aspiration of any substance with a pH < 2.5 causes immediate pathologic changes within the lung parenchyma. Gastric contents, even with a more neutral pH of 5.9, can cause intrapulmonary shunting, resulting in hypoxia. Particulate matter, regardless of pH, also worsens the degree of hypoxia.

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6. What radiographic changes are seen in patients with chemical pneumonitis?

Initially after aspiration, radiographic changes are minimal unless a large volume of acid is aspirated. Within 12–36 hours, radiographic changes may occur. However, the degree of alveolar infiltrates correlates poorly with degree of arterial hypoxemia and prognosis.

7. Describe the classic distribution of affected lung lobes in patients with aspiration pneumonitis.

The area of lungs most typically affected are the dependent areas of the lungs. The right middle lobe is most commonly affected, followed by the right and left cranial lobes.

8. Why is supplemental oxygen not always effective in increasing the partial pressure of oxygen in arterial blood (PaO_2) in patients with aspiration pneumonitis?

Severe aspiration pneumonitis results in collapse of alveoli and ventilation/perfusion mismatch. Perfusion of collapsed alveoli results in intrapulmonary shunting. Nonventilated alveoli, therefore, cannot contribute to a rise in PaO_2, even with supplemental oxygen. In patients with severe hypoxemia who respond poorly to supplemental inspired oxygen, positive pressure ventilatory support is indicated. Ventilator therapy helps to expand collapsed alveoli and results in marked increases in PaO_2.

9. What are the clinical signs of aspiration pneumonitis?

Patients with severe aspiration pneumonitis may have an acute onset of respiratory difficulty (dyspnea), cyanosis, cough, inappetance, weakness, or collapse. If infection is present, a fever may be present. In some cases, aspiration of inert substances may result in transient hypoxemia and respiratory distress that is self-limiting.

10. If a patient has a known history of aspirating acid, should treatment consist of neutralizing the acid?

Aspiration of acid typically results in immediate injury to the alveoli. Within minutes, the aspirated acid is neutralized by normal pulmonary secretions. Therefore, it is not necessary to neutralize the acid unless a large volume has been aspirated and the procedure can be performed immediately. Large volumes of fluid can worsen the pneumonitis and decrease pulmonary compliance. If small particulate matter was aspirated along with the acid, flushing large volumes of fluid into the airways and lungs may distribute the particulate matter further into the pulmonary tree.

11. Are prophylactic antibiotics necessary in treatment of chemical aspiration pneumonitis?

In many human cases of chemical aspiration pneumonitis, antibiotics are not routinely administered unless signs of infection, such as fever, are present. Prophylactic use of antibiotics may allow the development of resistant bacteria. However, secondary bacterial infection is a common sequela to chemical aspiration pneumonitis. For less severe cases, a broad-spectrum, first-generation cephalosporin may be used. In more severe cases, a four-quadrant approach is better, usually with ampicillin and enrofloxacin. Doxycycline also may be used for its antiinflammatory effects and efficacy against *Mycoplasma* spp. Samples should be obtained for bacterial culture and susceptibility via transtracheal wash or bronchoalveolar lavage. If the patient is not stable enough for these procedures, empiric therapy should be instituted with broad-spectrum antibiotics. Antibiotic therapy should be continued for a minimum of 4 weeks or until 10 days beyond resolution of radiographic signs of disease.

12. List four clinical signs suggestive of pneumonitis after apsiration.

1. Fever
2. Leukocytosis
3. Mucopurulent nasal or oropharyngeal discharge
4. Radiographic signs of a consolidating lung pattern with air bronchograms

13. What are the advantages and disadvantages of bronchodilator therapy in patients with aspiration pneumonitis?

Bronchodilators such as terbutaline, aminophylline, and isoproterenol can be used in acute severe aspiration pneumonitis. Because hypoxemia is partially due to airway obstruction, bronchodilator therapy may be useful in the initial stages of hypoxemia. Bronchodilators such as aminophylline also may be useful by decreasing inflammation and reducing the work of breathing by limiting respiratory muscle fatigue. However, long-term use after 48 hours is not indicated and is not beneficial, because methyxanthine derivatives may decrease normal host immune responses, potentially prolonging recovery.

14. Are glucocorticoids indicated in the treatment of aspiration pneumonitis?

In severe acute cases of aspiration pneumonitis, one injection of a short-acting steroid such as dexamethasone (2–4 mg/kg) may be beneficial in decreasing inflammation. Steroid therapy theoretically should be beneficial by decreasing platelet and polymorphonuclear cell aggregation, stabilizing host membranes, and decreasing inflammation. However, many studies have demonstrated no beneficial effect with steroid use in patients with aspiration pneumonitis. Furthermore, human patients in whom steroids were administered experienced slower recovery due to delayed healing and prolonged low-grade inflammation. Because steroids have no known benefit in improving PaO_2, cardiac output, or pulmonary arterial pressure or in preventing pathologic changes, and because in fact they may increase morbidity, their use is not advocated in patients with aspiration pneumonitis.

15. What therapy should be used for patients with aspiration pneumonitis?

- Oxygen (humidified in an oxygen cage or via nasal catheter; endotracheal intubation and ventilation in severe cases that do not respond to less invasive methods of increasing the fractional concentration of oxygen in inspired gas [FiO_2])
- Nebulization (saline)
- Physiotherapy (coupage) followed by short periods of exercise (short walks)
- Antibiotics (broad-spectrum)
- Fluid therapy (crystalloids)

16. What is nasal oxygen insufflation? How is it performed?

Nasal oxygen insufflation is an effective means of increasing FiO_2 if an oxygen cage cannot be provided. Small feeding tubes or urinary catheters (3.5–5 French for cats, 5.0–8.0 French for dogs) can be used. First, prepare the nostril by placing a few drops of 2% lidocaine (or proparacaine) in the nostril. Next, measure the catheter from its distal tip to the medial canthus of the eye, and place a mark. Insert the tube into the ventral meatus of the nostril, and advance forward to the preset measurement. The tube can be secured with a suture placed at the tip of the nose, in a Chinese finger-trap method. Another suture can be placed between the eyes or on top of the head to secure the tube further. An Elizabethan collar should be placed to prevent the patient from dislodging the tube. The end of the tube can be attached to a source of humidified oxygen, delivered at a rate of 0.1 L/kg/min. If the patient appears not to tolerate the tube by sneezing, topical anesthetics can be applied into the affected nostril. Nasal oxygen insufflation can provide a 30–40% oxygen concentration.

17. Why is intravenous fluid therapy indicated in the treatment of patients with aspiration pneumonitis?

Intravenous fluid therapy is necessary in the successful management of patients with aspiration pneumonitis. Many patients present in a state of dehydration or, in severe cases, hypovolemic shock secondary to accumulation of fluid in the pulmonary alveoli. Patients in shock initially should be given ¼–½ of a calculated shock dose (90 ml/kg/hour) of fluids and rehydrated over a period of 8 hours. A minimal volume of maintenance fluids (calculated volume = [(30 × body weight in kg + 70] ml/24 hours) should be instituted, and central venous pressure should be monitored with a jugular catheter to prevent overhydration and worsening of pulmonary alveolar flooding. Bronchial secretions are approximately 95% water. Therefore, judicious use of crystalloids is

necessary not only to maintain intravenous and interstitial hydration, but also to maintain the consistency of bronchial secretions and aid in their dissolution.

18. What are the characteristic features of an arterial blood gas sample from a patient with aspiration pneumonitis?

- Hypoxemia
- Mild decrease in pH
- Presence or absence of hypercapnia

Patients with aspiration pneumonitis are characteristically hypoxemic and may have a mild degree of metabolic acidosis. Hypercapnia may occur, particularly in end-stage aspiration pneumonitis, because of inadequate ventilation.

19. Name two essential features of aspiration pneumonitis.

1. Compromised lower airway defense mechanisms
2. Pathologic event resulting from the aspiration insult

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44. DIROFILARIASIS

Wayne E. *Wingfield*, M.S., D.V.M.

1. Why is dirofilariasis such an important disease in dogs and cats?

Few, if any, diseases are better known to animal owners than heartworms. Many veterinary organizations and competitive commercial interests promote heartworm awareness. Thus, interest in this disease is sustained by the affluent animal-owning public and major commercial markets.

2. What is the causative agent of heartworm disease?

The filaroid, *Diroflaria immitis*, causes heartworm disease.

3. Describe the life cycle of *D. immitis*.

Infected mosquitoes spread heartworm disease. They acquire microfilaria when ingesting blood from infected hosts. The microfilaria undergo two molts within the mosquito and then are capable of infecting a dog when the mosquito next feeds. The larvae (L3) enter the skin and migrate

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through the host for approximately 3.5 months. During migration they mature into young adult heartworms (L5) and enter the vascular system and travel to the pulmonary arteries. Adult females then produce microfilaria (L1), which enter the animal's bloodstream and are available for ingestion by another mosquito.

4. Describe the pathogenesis of heartworm disease.

The particular host's immune response to adult heartworms is responsible for the pathologic lesions noted in heartworm infection. Adult heartworms cause endothelial damage. The damaged endothelium attracts leukocytes and platelets, stimulates release of various trophic factors, and loses its properties of selective permeability. The pathognomonic histopathologic change is myointimal proliferation on the endothelial surface of pulmonary arteries. These changes result in pulmonary hypertension and local inflammation with interstitial fluid accumulation. Hypertension within the pulmonary vasculature increases the work of the right ventricle; consequently, the right ventricle dilates and then hypertrophies in response to increased demand. Congestive heart failure eventually results in most dogs.

5. What laboratory and diagnostic tests should be performed before initiation of adulticide therapy? Are any tests predictive of future complications?

Complete blood count, biochemical profile, urinalysis, radiography, and echocardiography are recommended before initiation of adulticide treatment. Although blood work is helpful to rule out concurrent disease (particularly liver and renal disease), only radiography may be helpful in determining the extent of pulmonary disease and in predicting which patients may be at increased risk for pulmonary thromboembolism. Echocardiography is helpful in the diagnosis of pulmonary hypertension and postcaval heartworm syndrome. Occasionally the worms are visualized on echocardiography.

6. What specific screening tests are used to diagnose heartworm disease?

Since 1992, the American Heartworm Society has recommended antigen testing as the primary mode of screening for heartworm infection. Very few dogs have circulating microfilaria without also having detectable antigenemia. If this scenario does occur, it is generally a transient phase in lightly infected cases at about 6.5 months after infection when microfilariae begin to appear. Most dogs become antigenemic by the time they are scheduled for retesting.

Microfilaria concentration tests and direct smears of whole blood are still used occasionally to screen dogs for heartworm disease. It is estimated these tests may miss as many as 20–25% of cases. Tests geared to detect circulating microfilaria are important only in dogs receiving daily diethylcarbamazine (DEC) therapy; life-threatening side effects may develop if DEC is administered to microfilaremic dogs.

7. What is an "occult" infection?

Heartworm infection in dogs without microfilaria is referred to as "occult."

8. Do commercial antigen test kits detect infection in all cases of heartworm disease?

No! None of the commercial antigen test kits is able to detect infections composed of only male heartworms. Each kit possesses a high degree of sensitivity for the female worms. Because females require about 7 months to reach maturity, a few false-negative tests may be anticipated before that time. The amount of antigen in the circulation bears a direct, though nonlinear, relationship to the number of mature females.

9. What is the fewest number of female worms that result in a positive antigen test?

Infections of three or more female worms are generally detected.

10. Why is antigen testing so important in a chemoprophylaxis program?

Testing is an integral first step for chemoprophylaxis. One must know the infection status if infection due to subsequent lapses in protection is to be distinguished from preexisting infections.

11. How often should an animal on chemoprophylaxis be tested?

In highly endemic regions, a second negative test result 1 year after starting chemoprophylaxis is recommended. Thereafter, surveillance should be continued by retesting approximately every 2–3 years or after an appropriate interval following a lapse in protection.

12. When is the best timing for testing?

Antigen is not found consistently until 7 months after infection. Therefore, testing a puppy before 7 months may be pointless.

13. What are the recommended adulticide treatments? What is the appropriate timing of treatment?

There are two recommended treatments: the organoarsenical thiacetarsamide and the newer melarsomine dihydrochloride. Thiacetarsamide is given over 48 hours, with two treatments on each day. Although originally given at 12-hour intervals, new data support the pairing of doses 8 hours apart, starting in the morning of each day, with no longer than 16 hours between the second dose on day 1 and the first dose on day 2. Melarsomine is administered in 2 doses 24 hours apart, with retreatment in 4 months.

14. What are the potential complications of adulticide therapy?

Thiacetarsamide is hepatotoxic and extremely caustic if given perivascularly. Melarsomine has the advantage of intramuscular administration, although pain and swelling at the injection site are common. Melarsomine does not cause hepatotoxicity. Pulmonary thromboembolism secondary to worm kill is an important complication of adulticide therapy, occurring 10–21 days after therapy. Strict rest is the single most important treatment of thromboembolism; it is a much more difficult problem to treat than to prevent. Treatment for pulmonary thromboembolism includes oxygen, cage rest, corticosteroid therapy, and antithrombotics.

15. What tests are used to confirm adulticide therapy?

First, clinical improvement in treated dogs is suggestive of at least partial kill of heartworms. Antigenemia disappears in 3 months after treatment if all or most of the adults are eliminated. Periodic monitoring of antigen tests at approximately 3-month intervals is recommended. Affirmative (even weak positive) results indicate the persistence of adults, usually females.

16. What microfilaricides are available? Discuss timing of treatment and complications.

No microfilaricides are approved by the Food and Drug Administration. Extra-label use of ivermectin or milbemycin oxime is accepted as a safe microfilaricide treatment; both drugs are generally given 3–4 weeks after completion of adulticide therapy. Milbemycin oxime is an excellent microfilaricide at prophylactic doses, and one dose is usually sufficient to eliminate microfilaria in adulticide-pretreated dogs. Ivermectin, 1 dose of 50 mg/kg orally, is also an effective microfilaricide. Side effects of both drugs are related to rapid die-off of microfilaria and include weakness, pale mucous membranes, and tachypnea. The signs are mild and generally subside with supportive care. Most authors recommend that dogs be hospitalized for several hours after therapy.

17. What heartworm preventatives are currently available for dogs? What are their side effects?

Both ivermectin and milbemycin oxime are effective preventatives. They are given on a monthly basis and are usually safe. Diethylcarbamazine (DEC) is rarely given as a daily heartworm preventative; microfilaremic dogs may have severe reactions to DEC.

18. At what point do preventative doses of ivermectin and milbemycin become microfilaricidal? How does this change the diagnostic tests used to detect heartworm infections?

After 6–8 months of administration, both are microfilaricidal. Therefore, antigen tests should be used to screen for heartworm infection.

19. How frequently should dogs be tested for heartworm infection?

Frequency of testing is controversial, although most clinicians recommend yearly testing for dogs in endemic areas, with testing every 1–2 years in areas of low prevalence.

20. What other treatments occasionally are used as adjunctive therapy for heartworm disease? What are the criteria for using adjunctive treatments?

The need for other medications and the criteria for their use remain controversial. Corticosteroids are at the center of the controversy. Many recommend their use in both cats and dogs with radiographic evidence of allergic lung disease (eosinophilic pneumonitis). Corticosteroids must be withdrawn 1 week before initiation of adulticide therapy, or kill rates of adult heartworms will be reduced. Aspirin therapy often is initiated before adulticide therapy if signs of pulmonary vascular changes (without pneumonitis) are present. In addition, aspirin therapy may reduce the incidence of pulmonary thromboembolism.

21. What controversies surround pretreatment with ivermectin before adulticide therapy in dogs?

Some clinicians advocate the use of ivermectin before adulticide therapy is started. Ivermectin kills the L4 larvae, which may develop into adults while adulticide therapy and subsequent microfilaricides are administered.

22. What larval stages are destroyed by ivermectin?

Evidence suggests that L5 larval stages are killed by ivermectin after 5–6 months of treatment. In addition, some research suggests that ivermectin may destroy even adult heartworms after 18–20 months of continuous use.

23. What is caval heartworm syndrome?

Caval heartworm syndrome occurs in patients with high worm burdens. It is characterized by circulatory collapse and shock, accompanied by icterus and hemoglobinuria or hemoglobinemia secondary to red blood cell fragmentation. Large numbers of adult worms obstruct the tricuspid valve and right atrium, sometimes extending into the caudal vena cava. Echocardiography is used to confirm the diagnosis. Such patients must be distinguished from dogs with severe heartworm disease without obstruction.

24. How is caval heartworm syndrome treated?

The treatment of choice (and necessity) is surgical removal of the worms via the jugular vein using forceps.

25. What is the reported prevalence of heartworm disease in cats?

Heartworm infection in the cat was first identified in 1922. Despite numerous reports since then, many veterinarians believe that cats are not at risk. This belief is most unfortunate, because cats are indeed susceptible and have more severe clinical signs than dogs, even when the worm burden is small. Studies from the Southeast report a prevalence of 2.5–14%. Atkins reported a prevalence of 25% at North Carolina State University. The incidence in cats is approximately 5–20% of the incidence in dogs in a given area.

26. Why is the diagnosis of feline heartworm disease uncommon?

- Many veterinarians have a low index of suspicion.
- Cats are frequently amicrofilaremic.
- Serologic tests have lacked sensitivity or specificity in cats.
- Cats have small worm burdens.
- Clinical signs are often nonspecific and different from those in dogs.
- Eosinophilia is transient or absent.
- Electrocardiographic changes are minimal.
- Radiography lacks sensitivity and specificity.

27. What are the most common signs of heartworm disease in cats? What is the best diagnostic test in cats?

Vomiting and respiratory signs (coughing) are the most common signs in cats with chronic disease. The heartworm antigen test, if positive, is a strong indicator of heartworm disease in cats.

28. What are the controversies about treatment of heartworm disease in cats?

Atkins recommends treating cats with heartworm prophylaxis in areas with increased incidence of infection, because treatment regimens in cats are not benign and carry a high risk of death. Adulticide therapy with thiacetarsemide is dangerous; normal cats often develop fatal pulmonary reactions. Many cats develop pulmonary thromboembolism after receiving adulticide therapy. Many authors do not recommend adulticide therapy in cats unless clinical signs are of sufficient severity to warrant the risk. Others recommend pretreatment with ketamine because of its antiserotonin activity (serotonin is implicated as a potent bronchoconstrictor in cats). The new adulticide melarsomine has not been used in cats. Microfilaricides are unnecessary because most cats do not exhibit microfilaremia.

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45. PULMONARY THROMBOEMBOLISM

Elisa M. Mazzaferro, M.S., D.V.M.

1. What underlying diseases have been associated with the development of pulmonary thromboembolism (PTE) in dogs?

- Immune-mediated hemolytic anemia
- Hyperadrenocorticism
- Disseminated intravascular coagulation
- Pancreatitis
- Protein-losing nephropathy/nephritic syndrome
- Cardiac disease
- Neoplasia
- Sepsis
- Hypothyroidism
- Renal amyloidosis
- Trauma
- Major surgery
- Phlebitis secondary to IV catheterization

2. What is Virchow's triad?

Virchow's triad is a list of three pathophysiologic states that predispose to thrombosis:

1. Venous stasis
2. Endothelial injury
3. Hypercoagulability

3. Name the most characteristic physical examination findings in patients with PTE.

- Dyspnea
- Tachypnea
- Cyanosis
- Tachycardia
- Weakness or collapse

Other findings may include cough, change in mental status, hemoptysis, adventitious lung sounds, split second heart sound, muffled heart and lung sounds, jugular pulses, and epistaxis.

4. What causes altered mental status in patients with PTE?

Acute transient hypoxemia, resulting in cerebral ischemia, can cause obtundation or altered mental status.

5. What echocardiographic abnormalities are found in patients with PTE?

Signs of right ventricular overload, including right ventricular and right atrial dilation, dilation of the main pulmonary artery, and increased right atrium-right ventricular gradient are supportive of pulmonary hypertension and may be associated with PTE. Since these findings are not pathognomonic for PTE, other causes of right ventricular overload, including left-to-right shunt, pulmonic stenosis, and chronic obstructive pulmonary disease must also be ruled out.

6. What are characteristic arterial blood gas abnormalities in patients with PTE?

Patients with PTE typically have hypoxia (decreased partial pressure of oxygen in arterial blood [PaO_2]) with normo- or hypocapnea (respiratory alkalosis). The hypoxemia is often, but not always, responsive to supplemental oxygen. The alveolar-arterial oxygen gradient in patients with PTE is increased (see question 18).

7. What are the mechanisms of hypoxemia in a patient with PTE?

Hypoxemia secondary to PTE is associated with severe ventilation-perfusion mismatching, physiologic shunting, and increased dead space ventilation.

8. What radiographic abnormalities may be found in patients with PTE?

Thoracic radiographs from patients with PTE are often normal, making radiographic diagnosis difficult. However, abnormal findings may include pleural effusion, cardiomegaly, loss of

pulmonary artery segments, interstitial to alveolar infiltrates, focal oligemia, hyperlucent lung areas, and an enlarged main pulmonary artery segment. A mediastinal shift toward the area of embolism or a cranial shift of the hemidiaphragm on the side of the lesion may be observed. The radiographic signs are nonspecific and not pathognomonic for PTE.

9. Why does supplemental oxygen improve the hypoxia in a patient with PTE?

Hypoxia associated with PTE is due to severe ventilation-perfusion mismatch. Ventilation is normal, but perfusion is abnormal. Regional blood flow is diverted to areas of the lung not supplied by the embolized vessel. Increasing F_iO_2 (fractional concentration of oxygen in inspired gas) increases the total oxygen content in the circulating blood volume, thus improving hypoxia.

10. Why do some patients with PTE not respond to "oxygen step-up"?

In some patients with PTE, the degree of pulmonary vascular occlusion exceeds 50% of the surface area of the pulmonary vascular bed. In such cases, intrapulmonary shunting can lead to venous admixture of blood, resulting in decreased responsiveness to supplemental oxygen. Therefore, the presence or absence of a response to supplemental oxygen cannot necessarily confirm or deny the presence or absence of PTE.

11. What are the best techniques to diagnose PTE?

Pulmonary angiography is the best technique to evaluate for the presence of PTE. However, nuclear perfusion scans, using 99m-technetium-labeled albumin, are less invasive and can be used to rule out PTE. If the perfusion scan is normal, PTE is ruled out. However, an abnormal scan can be associated with PTE or other causes, such as pulmonary parenchymal disease, chronic obstructive pulmonary disease, and bronchoconstriction. Nuclear perfusion scans are contraindicated in patients with right-to-left cardiac shunts.

12. What diagnostic tests should be performed in patients suspected of having PTE?

- Arterial blood gas
- Thoracic radiographs
- Coagulation panel (activated clotting time [ACT], prothrombin time [PT], activated partial thromboplastin time [APTT])
- Electrocardiogram (ECG)

The above tests may not definitively diagnose PTE but help the clinician rule out other causes of respiratory distress and hypoxemia.

13. What ECG abnormalities may be found in patients with PTE?

- Sinus tachycardia
- Right axis deviation
- Cor pulmonale
- ST segment depression secondary to myocardial ischemia
- Ventricular arrhythmias

14. What is the classic triad of signs in humans with PTE?

Dyspnea, chest pain, and hemoptysis.

15. How may isoproterenol be helpful in the treatment of PTE?

Isoproterenol, a pure beta-adrenergic agonist, can improve cardiac output, dilate pulmonary vessels, and may enhance right ventricular contractility, thereby improving oxygen delivery and decreasing ventilation-perfusion mismatch.

16. Describe the pathogenesis of dyspnea in patients with PTE.

Reflex bronchoconstriction secondary to mechanical and humoral mediators and hypoxemia secondary to ventilation-perfusion mismatch can result in dyspnea.

17. What hypercoaguable states in dogs may predispose to thrombosis and development of PTE?

- Malignancy
- Hyperadrenocorticism
- Antithrombin III (ATIII) deficiency
- Nephrotic syndrome
- Disseminated intravascular coagulation
- Abnormalities of platelet function
- Diabetes mellitus
- Myeloproliferative disorders
- Vasculitis
- Immune complex disease
- Heartworm disease
- Venous stasis
- Hyperviscosity
- Central venous catheters

18. How do you calculate an alveolar-arterial oxygen gradient (A-a gradient)?

1. Obtain an arterial blood gas sample.
2. Use the following formula to calculate alveolar oxygen tension (P_AO_2):

$$P_AO_2 = [(BP - WVP) \times FiO_2] - PaCO_2/0.8$$

where BP = barometric pressure in mmHg, WVP = water vapor pressure = 47, and F_iO_2 = fractional inspired oxygen = 0.21 on room air.

3. Subtract PaO_2 (derived from arterial blood gas analysis) from P_AO_2
4. Thus, A-a gradient = $P_AO_2 - PaO_2$

19. Why do patients with PTE have an increased A-a gradient?

Patients have an increased A-a gradient because typically P_AO_2 is normal, even in the presence of arterial hypoxia. Therefore, the calculated value is increased. In normal patients, A-a gradient is less than 10. However, this value may be significantly higher in patients with PTE or other pulmonary parenchymal diseases.

20. List four treatment modalities for medical management of patients with PTE.

1. Treat the underlying cause
2. Supplemental oxygen
3. Hemodynamic support in the form of crystalloid fluids
4. Anticoagulation to prevent worsening of thrombi formation

21. Should thrombolytic agents be used in the treatment of PTE?

The use of specific thrombolytic agents has not been successful in decreasing morbidity and mortality in many veterinary patients with confirmed PTE. Thrombolytic agents available for use in veterinary medicine include streptokinase, ureakinase, and tissue plasminogen activator. Often their cost is prohibitive. In addition, therapeutic doses have not been established in veterinary medicine. This, combined with cost and relative risk of severe hemorrhage, makes their use of questionable benefit except in cases of life-threatening PTE.

22. What role do anticoagulants play in the treatment of PTE?

Anticoagulant therapy with low-dose aspirin, heparin, or warfarin may be used as adjunctive therapy in patients with PTE to prevent further clots from forming and to prevent existing clot(s) from enlarging. Coagulation parameters such as ACT and PT must be monitored closely to prevent bleeding tendencies. If warfarin is used, it must be started in combination with heparin therapy to prevent worsening of the hypercoaguable state. Measurements of PT 1.5–2.0 times normal are ideal for prevention of further thrombosis without clinical bleeding.

23. What role may dextrans play in the treatment of PTE?

Low-molecular-weight dextran molecules coat platelets and decrease clotting ability. Dextrans, therefore, may be useful in preventing existing clots from enlarging.

24. What is the mechanism by which cytotoxic drugs may predispose patients to PTE?

Cytotoxic drugs may result in the release of endothelium-derived mediators that contribute to hypercoaguability and venous stasis, favoring the formation of thrombi.

25. What causes hypercoaguability and predisposes patients with hyperadrenocorticism to develop PTE?

Patients with hyperadrenocorticism have increased production of coagulation factors (V, VIII, IX, X), ATIII, fibrinogen and plasminogen, which predisposes them to thrombosis. The mechanism by which increases in ATIII favor thrombi formation is not understood, because prothrombotic states are also associated with ATIII deficiency.

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46. LARYNGEAL PARALYSIS

Elisa M. *Mazzaferro*, M.S., D.V.M.

1. What underlying conditions have been associated with the development of laryngeal paralysis?

Congenital laryngeal paralysis has been reported in Siberian huskies, Bouviers des Flandres, English bulldogs, Dalmatians, and bull terriers. Laryngeal paralysis also has been documented in young Rottweilers as part of laryngeal paralysis-polyneuropathy syndrome. Acquired laryngeal paralysis may occur secondary to systemic neuromuscular disorders or metabolic diseases (hypothyroidism, hypoadrenocorticism, myasthenia gravis), trauma, inflammation, infection, and neoplasia. Acquired laryngeal paralysis can occur in any breed of dog but has been most commonly associated with older large-breed dogs such as Labrador retrievers, Chesapeake Bay retrievers, Irish setters, Saint Bernards, golden retrievers, Afghan hounds, and standard poodles.

2. What is the mechanism of congenital laryngeal paralysis?

Congenital laryngeal paralysis is due to Wallerian degeneration of the recurrent laryngeal nerve or degeneration of the nucleus ambiguus.

3. What is the primary abductor muscle of the larynx?

The primary muscle to abduct the larynx and vocal folds is the cricoarytenoid dorsalis muscle, innervated by the recurrent laryngeal nerve.

25. What causes hypercoaguability and predisposes patients with hyperadrenocorticism to develop PTE?

Patients with hyperadrenocorticism have increased production of coagulation factors (V, VIII, IX, X), ATIII, fibrinogen and plasminogen, which predisposes them to thrombosis. The mechanism by which increases in ATIII favor thrombi formation is not understood, because prothrombotic states are also associated with ATIII deficiency.

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3. What is the primary abductor muscle of the larynx?

The primary muscle to abduct the larynx and vocal folds is the cricoarytenoid dorsalis muscle, innervated by the recurrent laryngeal nerve.

4. What emergency measures should be performed to alleviate acute respiratory distress in animals with laryngeal paralysis?

1. Examine the oropharynx for any foreign body or obstruction.
2. Administer oxygen.
3. Provide sedation.
4. Give glucocorticoids to alleviate laryngeal edema, if present (2–4 mg/kg dexamethasone-SP).
5. Use endotracheal intubation or tracheotomy if severe respiratory distress is present.
6. Give furosemide if pulmonary edema is present secondary to upper airway obstruction

5. Describe the typical respiratory pattern in a patient with laryngeal paralysis.

Animals with laryngeal paralysis have characteristic inspiratory stridor with loud upper airway noises, and respiratory distress, primarily associated with inspiration.

6. List the common presenting complaints in patients with laryngeal paralysis.

- Exercise intolerance
- Respiratory distress
- Coughing and gagging or retching while eating or drinking
- Inspiratory noise that worsens with exercise
- Voice change in dogs
- Absence of purring (rarely, when laryngeal paralysis has been reported in cats)

7. Why is laryngeal paralysis one of the first signs in dogs with polyneuropathies?

The recurrent laryngeal nerve, the longest nerve in the body, innervates the intrinsic muscles of the larynx. The recurrent laryngeal nerve originates from the nucleus ambiguus of the brainstem, travels through the vagosympathetic trunk, goes around the aortic arch and right subclavian vein, then courses cranially to innervate the cricoarytenoid dorsalis muscle of the larynx. Because of its length, the recurrent laryngeal nerve is susceptible to damage at any point along its tract. Damage at any point causes decreased innervation to the larynx, resulting in inadequate arytenoid cartilage abduction during inspiration (laryngeal paralysis).

8. Describe the protocol for laryngeal examination in patients with suspected laryngeal paralysis.

In dogs, light sedation with a short-acting barbiturate or propofol can be used to evaluate the larynx for vocal fold abduction during inspiration. If sedation is too heavy, laryngeal function may be adversely decreased, making the diagnosis difficult or equivocal. In cats, propofol or ketamine (upon awakening) allows a proper laryngeal examination. The dose of the sedative should be titrated to provide adequate restraint for examination of the larynx without suppressing spontaneous ventilation. Dopram-hydrochloride also can be used to stimulate respiration. The arytenoid cartilages should be observed closely for abduction, using a laryngoscope during all phases of respiration.

9. What diagnostic tests should be performed to evaluate the cause of laryngeal paralysis?

Laryngeal examination should be performed under heavy sedation in any patient that presents with laryngeal paralysis to evaluate laryngeal function. Cervical and pharyngeal radiographs also should be performed to evaluate for the presence of a mass causing damage to the larynx or recurrent laryngeal nerve. A complete blood count, serum biochemistry panel, thyroid panel (thyroid-stimulating hormone, thyroxine [T_4], free T_4), and adrenocorticotropic hormone (ACTH) stimulation tests should be performed to rule out inflammatory causes, hypothyroidism, or hypoadrenocorticism. If other neurologic signs are present, muscle and nerve biopsies, nerve conduction studies, and a myasthenia gravis titer should be included in the diagnostic work-up.

10. List surgical procedures for treatment of laryngeal paralysis.

- Partial arytenoidectomy with vocal fold resection
- Castellated laryngofissure with or without vocal fold resection

- Arytenoid lateralization (unilateral or bilateral)
- Neuromuscular pedicle graft
- Ventral ventriculocordectomy
- Permanent tracehostomy

11. Is unilateral arytenoid lateralization successful in treating laryngeal paralysis?

Unilateral arytenoid lateralization appears to improve respiratory function in approximately 90% of patients with bilateral laryngeal paralysis. The incidence of aspiration pneumonitis is lower with this procedure than with bilateral arytenoid lateralization, although aspiration pneumonitis may still occur.

12. Does laryngeal paralysis only occur in dogs?

Laryngeal paralysis, unfortunately, is also a common syndrome in horses because of damage to the recurrent laryngeal nerve. Laryngeal paralysis also has been documented in cats, usually secondary to recurrent laryngeal nerve damage with tumors or abscesses.

13. Name the most common complications of surgical treatment of laryngeal paralysis.

- Aspiration pneumonitis
- Fever
- Hemorrhage
- Granuloma or scar tissue formation
- Pharyngeal collapse

14. Why may a patient who presents for acute respiratory distress secondary to laryngeal paralysis develop pulmonary edema?

Upper airway obstruction due to laryngeal paralysis causes sympathetic stimulation and hypoxic changes in the pulmonary vasculature, which open endothelial tight junctions. Intrathoracic pressure increases when the patient attempts to inspire against a closed glottis, compounding vascular leakage into the alveoli, ultimately flooding the alveolar space and resulting in the development of pulmonary edema.

15. What is the prognosis for patients with laryngeal paralysis?

Even with surgical intervention, the long-term prognosis for patients with laryngeal paralysis is poor, primarily because of recurrence of respiratory difficulty and aspiration pneumonitis.

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47. NEAR DROWNING

Linda G. *Martin*, D.V.M., M.S.

1. Define the various terms that have replaced the term drowning, which refers to a submersion accident resulting in death.

Immersion syndrome: sudden death after contact with cold water.

Submersion injury: submersion resulting in death within 24 hours of submersion (drowning), at least temporary survival (near drowning), or water rescue or removal of victim from the water.

Secondary drowning: death from complications of submersion more than 24 hours after submersion.

2. What causes the vast majority of deaths after a near-drowning episode?

Almost all patients who ultimately die do so not because of the pulmonary insult and resulting hypoxemia but rather because of anoxic brain injury. The degree of central nervous system insult seems to be the limiting factor for survival. Diffuse anoxic injury to the brain results in intracellular swelling and increased intracranial pressure.

3. What is the mechanism for fresh water drowning?

Aspiration of fresh water causes inactivation of surfactant, which leads to atelectasis and ventilation-perfusion mismatch. In addition, water in the alveoli interferes with gas exchange by diffusion impairment. Once in the alveoli, fresh water tends to move rapidly into the intravascular space. Depending on the initial volume of aspirated water, intravascular volume may significantly increase as the fluid shift takes place. In the vast majority of cases, despite the increase in free water, significant electrolyte disturbances do not occur.

4. What is the mechanism for salt water drowning?

The major pathophysiologic change that accompanies salt water drowning is alveolar flooding. Hypoxemia develops primarily from inability to oxygenate because of fluid-filled alveoli. The fluid probably remains in the alveoli longer than fresh water. The increased osmolarity of salt water predisposes fluid movement from the intravascular space into the alveoli, which results in decreased blood volume and hypotension. Unlike fresh water, salt water does not interfere with surfactant production by type II alveolar cells or inactivate surfactant. Therefore, alveolar collapse is not a predominant feature of salt water drowning.

5. Is it possible for drowning victims not to aspirate significant volumes of water?

Yes. Minute amounts of water drawn into the mouth may cause significant and severe laryngospasm. Hypoxemia may result from persistent laryngospasm. Further attempts to breathe may result in negative pressure pulmonary edema secondary to laryngospasm and glottis closure.

6. What other secondary problems may occur in near-drowning victims?

Aspiration of water and hypoxemia may lead to cardiac arrhythmias, myocardial ischemia, cardiac arrest, acute respiratory distress syndrome, pneumonia, acute renal failure, acute hepatic

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Aspiration of water and hypoxemia may lead to cardiac arrhythmias, myocardial ischemia, cardiac arrest, acute respiratory distress syndrome, pneumonia, acute renal failure, acute hepatic

failure, anoxic central nervous system (CNS) injury, multiple organ dysfunction syndrome, and disseminated intravascular coagulation.

7. What leads to CNS dysfunction after submersion injury?

CNS dysfunction may be secondary to the initial hypoxic injury or caused by progressive injury due to postresuscitation cerebral hypoperfusion. Postresuscitation cerebral hypoperfusion is caused by a variety of mechanisms, including increased intracranial pressure, cytotoxic cerebral edema, cerebral arteriolar spasm due to calcium entry into the vascular smooth muscle, and oxygen-derived free radicals.

8. What is the initial therapy for submersion injury victims?

Resuscitation should begin by establishing an airway, breathing for the patient (preferably with 100 % oxygen), starting chest compressions if the patient is pulseless, and establishing intravenous access.

9. When is the use of continuous positive airway pressure (CPAP) or positive end-expiratory pressure (PEEP) indicated?

Because of the inactivation of surfactant and atelectasis associated with fresh water near drowning, CPAP or PEEP helps to maintain lung expansion and to improve gas exchange. Salt water near drowning generally does not require the same degree or duration of mechanical ventilation as fresh water near drowning.

10. Should intravenous fluids be withheld from victims of a submersion accident?

No. Hypovolemia is not uncommon, and fluid resuscitation may be necessary with isotonic crystalloids, hypertonic crystalloids, or colloids. Such patients may have an increased risk for developing cerebral and pulmonary edema. Therefore, intravenous fluids should be used judiciously. However, the basic paradigm of ensuring adequate hemodynamic stability and optimal cerebral perfusion remains the goal of any CNS resuscitation and also applies to victims of a submersion accident.

11. Does glucocorticoid therapy have a role in the treatment of submersion injury?

No. No evidence indicates that steroid therapy provides any benefit, nor does it improve the recovery of the lung after near drowning.

12. Do antibiotics have a role in the treatment of near drowning?

Prophylactic antibiotics are of no proven benefit, but antibiotic therapy may be appropriate if immersion has occurred in a body of water known to be contaminated. In addition, loss of consciousness may result in aspiration of stomach contents and require antibiotic therapy.

13. What is the approach to patients exhibiting CNS deficits?

Hypoxemia leads to cerebral edema and a subsequent increase in intracranial pressure. Cerebral resuscitation is directed toward reducing intracranial pressure and ensuring efficient oxygen delivery. Emergency treatment of patients who appear to have suffered a severe CNS event includes osmotic diuretics, treatment of seizures if they occur, sedation to reduce agitation, judicious fluid therapy, supplemental oxygen administration, and controlled ventilation via endotracheal tube and mechanical ventilation, if necessary.

14. Dose sodium bicarbonate have a role during resuscitation?

No. Respiratory and metabolic acidosis should be treated by proper ventilation and fluid therapy.

15. Can hypothermia at the time of immersion provide protective effects?

Yes. Cold water has potentially beneficial effects. Submersion in cold water theoretically induces the mammalian diving reflex in which blood is shunted from the periphery to the central core. Hypothermia also causes a decrease in cerebral metabolic rate, thus reducing potential hypoxic injury in prolonged asphyxia.

16. What monitoring techniques can be used to assess victims of a submersion accident?

Pulse oximetry, capnography, arterial blood gases, electrocardiogram, indirect or direct blood pressure, central venous pressure, urine output, serum electrolytes, blood urea nitrogen and creatinine, PCV/TS, and glucose are among the parameters that can be monitored. Because victims of submersion accidents may have multiple organ system involvement, monitoring strategies need to be individualized to each patient.

17. What factors affect the prognosis and outcome of a patient with submersion injury?

The success of resuscitation at the site of the submersion accident is the major determinant of a good outcome. Patients that have been successfully resuscitated have a good chance of surviving. Submersion time is also a strong predictor of outcome. The longer the duration of submersion, the poorer the outcome. In addition, cold water submersion is associated with better outcomes than warm water submersion. Finally, the absence of some degree of neurologic recovery by 48–72 hours after the initial submersion accident is likely to be associated with a poor long-term prognosis.

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48. PULMONARY EDEMA

Elisa M. *Mazzaferro*, M.S., D.V.M.

1. Define pulmonary edema.

Pulmonary edema is the abnormal accumulation of fluid in the extravascular tissues of the lung.

2. List six physiologic variables that affect the rate of transport of fluid across the vascular space.

1. Degree of vascular permeability to solutes, particularly proteins like albumin
2. Interstitial hydrostatic pressure
3. Interstitial fluid colloid oncotic pressure
4. Intravascular hydrostatic pressure
5. Intravascular colloid oncotic pressure
6. Vascular surface area capable of fluid transport

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3. Describe the mechanisms for the development of pulmonary edema.

- Pressure or cardiogenic edema, secondary to increased intravascular hydrostatic pressure
- Permeability or low-pressure edema, secondary to increased vascular permeability to fluid and proteins
- Combination of pressure and permeability edema
- Decreased capillary oncotic pressure
- Decreased interstitial hydrostatic pressure
- Decreased lymphatic drainage
- Altered alveolar surface tension

4. What is the predominant force that causes fluid to move out of the pulmonary circulation into the interstitium?

Hydrostatic pressure in the capillaries.

5. What is the primary force opposing fluid movement from the vascular space?

Intravascular colloid oncotic pressure.

6. What are the clinical signs of pulmonary edema?

- Open mouthed breathing or respiratory distress
- Tachypnea
- Rapid shallow breathing with expiratory push consistent with restrictive breathing pattern
- Cyanosis
- Serous nasal discharge
- Frothy discharge (with or without blood) from nares or mouth
- Harsh crackles on thoracic auscultation

7. How can you quantitatively measure the variables responsible for the development of pulmonary edema?

1. Estimate intravascular hydrostatic pressure using pulmonary capillary wedge pressure, which approximates the pressure in the left atrium in the absence of obstruction of the pulmonary veins.
2. Measure serum albumin concentration as an indirect measure of intravascular oncotic pressure.
3. Colloid osmotic pressure is an indirect measure of intravascular oncotic pressure.
4. Measure vascular permeability through use of radioisotope marker techniques.
5. Measure vascular permeability by assessing serum protein vs. alveolar protein concentrations.

8. Aside from heart disease, what other diseases may cause high-pressure edema?

Intravascular volume overload may result from crystalloid administration. Crystalloid fluids increase intravascular hydrostatic pressure and concurrently decrease intravascular oncotic pressure by protein dilution.

Renal disease with subsequent decrease in urine output increases intravascular hydrostatic pressure, particularly during treatment with volume expansion.

Neurogenic pulmonary edema initially causes pulmonary hypertension; later increased pore size of the pulmonary endothelium results in fluid efflux from the vascular space into the pulmonary interstitium. Neurogenic pulmonary edema may be associated with head trauma, electrocution, seizures, or increased intracranial pressure.

9. Pulmonary edema secondary to left heart disease will occur when intravascular hydrostatic pressure exceeds what number?

The pressure at which pulmonary edema forms is called the *critical pressure*. Pulmonary capillary venous and capillary pressure exceeding 20–25 mmHg result in the development of pulmonary edema.

10. Define permeability edema.

Increased leakage of the pulmonary vascular endothelium to fluid and protein causes permeability edema in the lungs. The increased leakiness may be associated with vascular endothelial injury and increased pore size, and disruption of endothelial tight junctions. Decreased intravascular oncotic pressure also may contribute to the development of permeability edema.

11. Describe cellular mechanisms associated with the development of permeability edema.

Trauma or any inflammatory disease process (e.g., pancreatitis, sepsis) can lead to activation of the complement cascade, resulting in neutrophil chemotaxis and adherence in the pulmonary endothelium. Subsequent damage to the endothelium causes disruption of the endothelial barrier, increased pore size, and increased permeability. Leakage of fluid and proteins also stimulates activation of the inflammatory cascade, liberating cytokines, oxygen free radicals, leukotrienes, hydrogen peroxide, platelet-activating factor, and lysosomal enzymes. The liberation of these cytotoxic substances further worsens damage to the endothelial membrane, resulting in acute respiratory distress syndrome (ARDS). Other conditions that may cause structural changes in the alveoli and result in permeability edema include inhalation of noxious chemicals or gases (carbon monoxide), smoke inhalation, near drowning, uremia, and aspiration pneumonia.

12. Name six physiologic consequences of pulmonary edema.

1. Decreased lung volume
2. Decreased pulmonary compliance
3. Decreased ventilation in affected areas
4. Decreased perfusion in areas affected with pulmonary edema
5. Ventilation-perfusion mismatch
6. Pulmonary alveolar shunting

13. Are arterial blood gas analyses necessary in the diagnosis and treatment of pulmonary edema?

No. History, signalment, and clinical signs should make a clinician suspicious of pulmonary edema. In fact, arterial blood gas samples and degree of hypoxemia often correlate poorly with the degree of severity of pulmonary edema in dogs. Arterial blood gas samples may be used to gauge treatment and patient response to oxygen and ventilatory therapy. However, arterial blood gas samples may be difficult to obtain in an animal struggling to oxygenate and therefore may be contraindicated early in the course of treatment.

14. What diagnostic test can be performed to evaluate whether changes in pulmonary vascular permeability are contributing to pulmonary edema?

The level of protein in pulmonary edema fluid obtained through bronchoalveolar lavage may be helpful as a rough indicator of the integrity of the pulmonary vascular endothelium. Typically, protein levels are lower in the fluid of pure high-pressure edema than in serum, whereas in pulmonary edema associated with increased vascular permeability the protein level is comparable to or higher than that of serum. Protein levels < 0.5 gm/d are suggestive of high-pressure edema, whereas protein levels > 0.5 gm/dl are associated with increased vascular permeability.

15. List treatment goals in patients with pulmonary edema.

1. Eliminate the cause of pulmonary edema.
2. Decrease excessive extravascular lung water (through use of diuretics).
3. Meet minimal total oxygen demands (by providing supplemental oxygen).
4. Normalize arterial oxygen content and tissue oxygen delivery (pressor agents may be needed if cardiac output is compromised).

16. Why is morphine useful in the treatment of pulmonary edema?

Low-dose morphine acts as a sedative and relaxes the patient. It also acts centrally to slow breathing and increase tidal volume. All of these effects help to decrease the work of breathing,

thereby decreasing total body oxygen requirements. In addition, morphine dilates coronary arteries, thus improving oxygen delivery to the myocardium, and splanchnic vessels. By decreasing vessel capacitance and increasing venous return and lymphatic drainage, dilation of splanchnic vessels aids in removing pulmonary edema fluid.

17. Name three indications for mechanical ventilation in patients with pulmonary edema.

- Inability to maintain normal partial pressure of oxygen in arterial blood (PaO_2) on 40% oxygen (< 70 mmHg)
- Persistent hypercarbia with partial pressure of carbon dioxide in arterial blood ($PaCO_2$) > 60
- Persistent respiratory distress despite conservative oxygen and diuretic therapy

18. In patients that remain unresponsive to oxygen supplementation, how does mechanical ventilation improve hypoxemia?

Ventilatory therapy using positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) increases pulmonary compliance and improves ventilation-perfusion mismatches associated with pulmonary edema. PEEP prevents alveolar collapse at the end of expiration, thereby increasing functional residual capacity and decreasing the work of breathing by ventilating areas of the lung that are atelectic.

19. List four classes of drugs that may be used in patients with high-pressure pulmonary edema. Give examples of each, including their mechanisms of action.

Venodilators: nitroglycerine, by causing systemic venodilation, decreases vessel capacitance and increases venous return.

Loop diuretics: furosemide causes venodilation and fluid wasting in a normally functioning kidney, thereby decreasing total vascular fluid volume.

ACE inhibitors: captopril, enalapril, and benazapril inhibit the effects of angiotensin-converting enzyme (ACE).

Balanced vasodilators: nitroprusside causes systemic arterial and venous dilation, decreasing cardiac preload (by decreasing venous return) and afterload.

20. Discuss therapy for patients with permeability edema.

Therapy should be directed first at treating the primary cause of inflammation. Supplemental oxygen with or without mechanical ventilation can be used to treat hypoxemia. Maintain minimal intrapulmonary vascular pressure while preserving cardiac output. Maintenance of a relatively low pulmonary intravascular pressure decreases the rate of transvascular leakage in patients whose pulmonary vasculature has increased permeability.

21. Define re-expansion pulmonary edema. In what situations may it develop?

Re-expansion pulmonary edema develops after re-expansion of previously atelectic lung areas, resulting in the accumulation of protein-rich fluid in the alveoli. It has been reported in humans within 24 hours after treatment of pneumothorax, thoracocentesis, and treatment of bronchial obstruction. It has been reported in cats and dogs within 2 hours after surgical repair of diaphragmatic hernias and pectus excavatum. Re-expansion of chronically hypoxemic lungs can cause free radical formation, resulting in injury to the pulmonary vasculature and increased leakage of fluid into the alveolar space. It also may be associated with decreased surfactant concentrations and a rapid increase in negative interstitial pressures, causing rapid increase in pulmonary capillary pressure and blood flow.

22. How can pulmonary edema develop secondary to obstruction of the upper airways?

Obstruction of the upper airways can result in hypoxic changes to the pulmonary endothelium. Abrupt release of catecholamines increases left ventricular afterload and decreases stroke volume, causing blood to accumulate in the pulmonary circulation. Increased intrathoracic pressure results from inspiring against a closed glottis, and increased interstitial hydrostatic

pressure results in transudation of fluid from the pulmonary vasculature. Net flow of fluid into the interstitium overwhelms the lymphatic drainage capacity, resulting in fluid accumulation in the alveoli.

23. Which upper respiratory diseases can cause airway obstruction and subsequent pulmonary edema?

- Laryngeal paralysis
- Pharyngeal foreign body
- Choke (leash, collar)
- Laryngeal mass effect (polyp, neoplasia)
- Laryngeal edema
- Smoke inhalation

24. What radiographic changes are associated with the different causes of pulmonary edema?

Radiographic signs of **pulmonary edema secondary to left heart failure** typically include an increased interstitial-to-alveolar lung pattern first displayed in the perihilar region. Changes consistent with left heart disease, such as left ventricular and left atrial enlargement, and tracheal elevation may be observed.

Radiographic signs of **permeability edema** are often more diffuse in nature, resulting in a patchy interstitial pattern throughout the lung field.

Neurogenic pulmonary edema often has a patchy interstitial-to-alveolar lung pattern, typically in the dorsocaudal lung field on a lateral view of the thorax.

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49. HEMOPTYSIS

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is hemoptysis?

Hemoptysis is expectoration of blood originating from the lower respiratory tract (trachea, bronchi, or lung parenchyma).

2. What is pseudohemoptysis?

Pseudohemoptysis is the expectoration of blood originating from a source other than the lower respiratory tract. Pseudohemoptysis may result from aspiration of blood from the gastrointestinal tract or drainage of blood into the larynx or trachea from bleeding sites in the oral cavity, nasopharynx, or larynx.

3. How is hemoptysis classified?

Massive: expectoration of < 200 ml of blood in 24–48 hours.
Gross: expectoration of > 200 ml of blood in 24–48 hours.

4. Since a dog or cat will not voluntarily expectorate into a measuring container, how does one quantitate the volume of hemoptysis?

A technique that seems to work well is simply to estimate the volume visually and multiply this estimate by two! The same technique is used for estimating the volume of urine, vomitus, or diarrhea.

5. What is the differential diagnosis for hemoptysis?

Tracheobronchial disorders
- Tracheobronchitis
- Aspiration pneumonitis
- Bronchial neoplasia
- Bronchial metastasis
- Bronchiectasis
- Bronchitis
- Foreign body aspiration
- Tracheobronchial trauma
- Tracheoesophageal fistula

Localized pulmonary lesions
- Actinomycosis
- Ascariasis
- Aspergillosis
- Coccidioidomycosis
- Congenital and acquired cysts
- Cryptococcosis
- Histoplasmosis
- Metastatic cancer
- Nocardiosis
- Paragonimiasis
- Pulmonary abscess
- Pulmonary contusion

Cardiovascular disorders
- Congenital heart diseases
- Congestive heart failure
- Pulmonary arteriovenous malformation
- Dirofilariasis
- Pulmonary thromboembolism
- Pulmonary hypertension

Diffuse parenchymal disease
- Viral pneumonia
- Systemic lupus erythematosus

Hematologic disorders
- Disseminated intravascular coagulopathy
- Rodenticide toxicity
- Thrombocytopenia
- Erlichiosis
- Anticoagulant therapy

Other
- Iatrogenic (secondary to diagnostic procedures)
- Idiopathic

6. What diagnostic procedures should be performed in patients with hemoptysis?

Unless an iatrogenic cause of hemoptysis is suspected, the minimal database should include complete blood count and platelet count, biochemical profile, heartworm test, fecal examination for parasites, urinalysis, and chest radiograph. If a coagulopathy is highly suspected based on historical and physical findings, platelet count, prothrombin time, partial thromboplastin time, and mucosal bleeding time should be measured. Further diagnostic tests, such as echocardiography, transtracheal washes, transthoracic pulmonary aspiration, and bronchoscopy, may be indicated if other routine tests are not suggestive of a particular problem.

7. Describe the immediate management of massive hemoptysis.

Goals of immediate management of animals with massive hemoptysis include maintenance of airway patency, stopping of ongoing hemorrhage, and prevention of rebleeding.

8. Describe how airway patency can be maintained in massive hemoptysis.

1. Do not stress the animal excessively.
2. If hemorrhage is from a focal site and the site is known, the animal is positioned with the bleeding side dependent to prevent contamination of noninvolved airways.
3. If the site of hemorrhage is unknown or diffuse, attempt to position the animal with the head lower than the lower extremities.
4. Selective bronchial cannulation can be attempted in some animals.

9. How is hemoptysis treated?

If the cause is known, specific therapy should be initiated to stop ongoing hemorrhage. Coagulopathies should be corrected with administration of appropriate blood products. Life-threatening hemorrhage requires more aggressive strategies. Surgical resection should be considered in animals with adequate underlying lung function. Focal hemoptysis in animals with severe underlying respiratory disease has been treated by cautery using bronchoscopy. Other techniques used in humans include embolization of the bronchial artery, occlusion of the involved pulmonary artery with a Swan-Ganz catheter, iced normal saline lavage of hemorrhaging lung segments, topical administration of epinephrine, and intravenous administration of vasopressin.

CONTROVERSY

10. Should antitussives be aggressively administered to animals with massive hemoptysis?

For: Excessive, harassing, violent cough aggravates and stimulates hemorrhage, promoting continued bleeding and rebleeding in animals in whom hemorrhage is stopped.

Against:

1. Excessive administration of narcotic antitussives may result in oversedation or narcosis.
2. An effective cough is required to clear blood from the airways and avoid asphyxiation.
3. Oversuppression of the cough reflex may result in retention of blood in the lungs and/or aspiration, both of which may contribute to development of pneumonia or atelectasis.

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50. SMOKE INHALATION AND BURN INJURIES

Linda G. *Martin*, D.V.M., M.S.

1. What is the leading cause of death in fires?

Smoke inhalation—not burn injuries.

2. Why is smoke inhalation lethal?

Carbon dioxide and carbon monoxide, the major components of smoke, are responsible for a drop in the concentration of the ambient oxygen from 21% to 5–10%. Carbon monoxide also preferentially binds with hemoglobin in place of oxygen, thus decreasing oxygen delivery. Carbon monoxide and, more rarely, hydrogen cyanide block the uptake and utilization of oxygen, leading to severe tissue and cellular hypoxemia.

3. What are the primary mechanisms of direct tissue injury to the respiratory tract caused by smoke inhalation?

Thermal injury and chemical irritation.

4. Which portion of the respiratory tract is primarily injured as a result of inhaling hot gas and smoke?

Thermal injury is usually limited to the upper airway (above the vocal cords) and trachea.

5. What levels of the respiratory tract can be damaged by smoke inhalation?

Upper airway, lower airway, and alveoli.

6. The anatomic level(s) at which smoke inhalation causes damage to the respiratory system depends on what factors?

- Ventilatory pattern
- Smoke constituents (particulate concentration, particulate size, chemical components)
- Anatomic distribution of particulate deposition

7. What mechanisms limit thermal injury of the lower airway?

The nasopharynx and oropharynx together provide a highly effective mechanism for cooling inspired air because of their relatively large surface area and associated air turbulence as well as their mucosal water lining, which acts as a heat reservoir. Sudden exposure to hot air also may trigger reflex closure of the vocal cords, reducing the potential for lower airway injury.

8. What are common thermal injuries to the airway?

Common thermal injuries include mucosal and submucosal edema, erythema, hemorrhage, and ulceration of the upper airway structures, generally above the vocal cords, but the trachea also may be affected.

9. How does smoke inhalation cause pulmonary injury by direct chemical irritation?

Smoke particles may interfere with normal physiologic mechanisms, such as inhibition of mucociliary clearance and surfactant inactivation. In addition, activation and recruitment of circulating leukocytes, stimulation of intrapulmonary macrophages, and release of chemotactic factors, oxygen radicals, and tissue proteases cause changes in vascular permeability. The results are pulmonary injury and edema.

10. How common is alveolar injury following smoke inhalation?

Alveolar injury occurs in a small percentage of cases, and clinical signs usually appear hours to days after smoke inhalation. The injury resembles increased permeability pulmonary edema or

acute respiratory distress syndrome (ARDS). Alveolar injury is more likely to be seen after inhalation of smoke generated from plastics and poorly water-soluble gases, after combined smoke inhalation and burn injury, and after the onset of sepsis or systemic inflammatory response syndrome (SIRS).

11. How is the inhalation of superheated steam different from most other thermal injuries caused by smoke inhalation?

Superheated steam inhalation may cause severe injury to the lower airways and alveoli because energy is released in the respiratory tract as the steam condenses to water.

12. What mechanisms can lead to both small and large airway obstruction secondary to smoke inhalation?

- Airway edema
- Sloughing of necrotic epithelial mucosa
- Impairment of mucociliary clearance of secretions
- Bronchoconstriction due to release of inflammatory mediators such as thromboxane A_2

13. Victims of smoke inhalation are commonly hypoxemic. Name the mechanisms which result in hypoxemia.

- Decreased FiO_2 (decrease in the ambient oxygen concentration due to production of carbon dioxide and carbon monoxide)
- Hypoventilation (pain, decreased elastic compliance associated with burns to the thorax, or central nervous system depression due to carbon monoxide or cyanide poisoning)
- Shunt (atelectasis due to surfactant inactivation, airway obstruction due to edema and sloughing mucosa, or impaired clearance of secretions)
- Ventilation-perfusion mismatch (release of inflammatory mediators and cytokines that alter pulmonary blood flow)
- Diffusion impairment (increased permeability pulmonary edema)

14. How does carbon monoxide affect the oxyhemoglobin dissociation curve?

Carbon monoxide shifts the curve to the left, thereby impairing oxygen unloading at the tissue level.

15. What are common complications after smoke inhalation and burn injuries?

Pneumonia, ARDS, and sepsis or SIRS.

16. What information is important in asking about the fire?

In obtaining a history, emphasis should be placed on data specific to the smoke exposure. Exposure in a closed space, such as a building, indicates that smoke was less diluted by ambient air, resulting in greater pulmonary exposure to carbon monoxide and smoke constituents than open-space exposure. The duration of exposure is also helpful, because it correlates with the severity of lung injury. Information about the probable fuel types burned at the scene may alert the clinician to the possibility of parenchymal lung injury and systemic side effects.

17. Should thoracic radiographs be done on all patients with a history of smoke inhalation?

This issue is controversial. Thoracic radiographs can be insensitive in detecting severely injured lungs early after smoke exposure. False-negative results as high as 92% have been reported in human medical studies. The appearance of radiographic abnormalities is delayed, and they are fairly nonspecific with regard to the presence of the inhalation injury. Delayed radiographic abnormalities also may be confused with pneumonia, pulmonary edema, or ARDS rather than inhalation injury. However, two recent retrospective studies found a high percentage of animals with abnormalities evident on thoracic radiographs. Unfortunately, these studies do not specify when the radiographs were taken in the course of illness. Therefore, thoracic radiographs are generally not indicated in asymptomatic patients and only as a baseline in symptomatic patients.

18. Is there any benefit in using bronchoscopy in patients with smoke inhalation?

Fiberoptic bronchoscopy has been described as the gold standard for diagnosis of inhalation injury. This technique allows visualization of the upper airway, glottis, and tracheobronchial structures to the level of the lobar bronchi. Findings of erythema, soot deposition, epithelial ulceration, and edema are pathognomonic of inhalation injury. However, the procedure requires both specialized equipment and skilled personnel and may not influence therapy beyond what is indicated by other more routine examinations. Furthermore, the procedure may be hazardous in some high-risk patients. Bronchoscopy is probably indicated only for re-expansion of atelectic lung lobes by removal of obstructing intrabronchial secretions or pseudomembranes.

19. If pulse oximetry in normal, does arterial blood gas analysis yield additional information?

Yes. Pulse oximetry cannot differentiate oxygenated hemoglobin (oxyhemoglobin) from carboxyhemoglobin. Therefore, it consistently overestimates the true oxyhemoglobin saturation. In addition, pulse oximetry gives no information about ventilatory status or acid–base balance.

20. If blood cyanide levels cannot be measured, what is the best alternative diagnostic test?

Plasma lactate concentrations correlate well with cyanide levels because of anaerobic metabolism and lactic acidosis.

21. What are indications for active airway management?

Evidence of progressive airway obstruction demands immediate action. Edema may develop acutely in the upper airway and lead to airway obstruction within 12–24 hours, if not sooner. Early airway management under controlled conditions is preferable to potentially hazardous circumstances that may develop later (unwitnessed airway obstruction and increasingly difficult intubation due to progressive edema).

22. Which routes of intubation are appropriate?

Orotracheal intubation allows direct visualization of the oropharynx and larynx as well as atraumatic placement of the endotracheal tube. Emergency tracheostomy is indicated if edema is severe enough to prevent the passage of the endotracheal tube.

23. How should victims of smoke inhalation be managed?

All victims should be placed on 100% oxygen as soon as possible, even if they are asymptomatic, to accelerate wash-out of carbon monoxide. The concentration of carboxyhemoglobin is reduced by approximately 50% every 30 minutes if 100% oxygen is breathed. Endotracheal intubation should be performed for patients in respiratory distress.

24. How is the need for mechanical ventilation in addition to supplemental oxygen assessed?

By repeated arterial blood gas analysis. Refractory hypoxemia in patients on supplemental oxygen and hypoventilation that results in respiratory acidosis with a pH < 7.25 are evidence of serious parenchymal lung injury and ventilatory failure, which indicate the need for intubation and ventilation with high inspired oxygen fractions or positive end-expiratory pressure (PEEP).

25. Why is PEEP particularly helpful to patients with smoke inhalation?

Because of the frequent presence of atelectasis after the exposure to smoke, PEEP is often necessary to maintain small airway patency.

26. What other mode of mechanical ventilation has emerged as a useful adjunct in the management of inhalation injury?

High-frequency percussive ventilation decreases barotrauma associated with conventional ventilators and mechanically mobilizes retained secretions in the tracheobronchial tree.

27. How should fluids be administered to patients with smoke inhalation?

A combination of isotonic crystalloid and colloid solutions may be used during the resuscitation phase at a rate needed to restore and maintain adequate perfusion based on standard monitoring parameters. Biologic or synthetic colloids should be used if hypoproteinemia is present. Patients with smoke inhalation and dermal burns usually have considerable losses of fluid and protein from the skin surface and therefore may have high fluid requirements. Underhydration in an attempt to keep the lungs "dry" is known to increase cardiopulmonary instability and morbidity.

28. Do prophylactic antibiotics have a role in patients with smoke inhalation?

Prophylactic antibiotics are not indicated in the acute treatment of inhalation injury. Their use has not been shown to protect against development of pulmonary infection. However, specific antibiotics are indicated in treating subsequent bacterial pneumonias. Antibiotic choice ideally should be based on culture and sensitivity results.

29. Are corticosteroids indicated in smoke inhalation?

Acute administration of corticosteroids after smoke inhalation is not recommended as a means of protecting against airway obstruction due to edema. Although their antiinflammatory effects may reduce the peak edema response, corticosteroids require hours to take effect and do not guarantee airway patency. After isolated inhalation injury in humans, corticosteroids have been shown to be of no benefit, and in cases of combined inhalation and burn injuries their use is associated with increased mortality and infection rates. Corticosteroids may be of use in patients who depend on exogenous steroids for preexisting medical illness or patients who present with severe bronchospasm unresponsive to bronchodilators.

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VI. Cardiovascular Emergencies

Section Editor: Steven L. Marks, B.V.Sc., M.S., M.R.C.V.S.

51. MITRAL VALVE INSUFFICIENCY DUE TO ENDOCARDIOSIS

Steven L. Marks, B.V.Sc., M.S., M.R.C.V.S.

1. What is the basic pathophysiology of mitral valve disease and left-sided congestive heart failure?

The basic pathophysiology of mitral valve disease is multifactorial and complex. Endocardiosis or myxomatous change of the valve causes inappropriate apposition of the valve leaflets, which leads to a regurgitant volume of blood into the left atrium. The result is a decrease in left ventricular forward cardiac output and an increase in left atrial pressure. In response to reduced cardiac support and organ perfusion, the renin-angiotensin-aldosterone pathway and sympathetic nervous system are activated. Although initially compensatory, these mechanisms eventually lead to decompensation. Structural changes in the heart, such as hypertrophy or dilation, occur. When left atrial pressures peak, pulmonary edema forms, and congestive heart failure is present.

2. Describe the sound and location of the murmur associated with mitral valve disease.

The typical murmur associated with mitral valve disease is a midsystolic regurgitant murmur early in the disease that may progress to a holosystolic or pansystolic murmur with increased intensity. The location of the murmur on auscultation or point of maximal intensity is at the left apex between intercostal spaces 3–5 on the left hemithorax. The murmur may radiate to the right hemithorax.

3. How are murmurs graded?

Grade I	Murmur barely audible
Grade II	Murmur softer than S1 (first heart sound)
Grade III	Murmur equal to S1
Grade IV	Murmur louder than S1
Grade V	Murmur with palpable thrill
Grade VI	Murmur with palpable thrill can be heard with stethoscope off chest

4. What is the incidence of mitral valve disease?

Mitral valve insufficiency is the most common cardiovascular disease in dogs. The prevalence increases with age and is reported as high as 75% in dogs 16 years of age. All breeds may be affected, but small and toy breeds are affected more commonly. Males appear to be more commonly affected than females. The Cavalier King Charles spaniel is predisposed to mitral valve disease.

5. What is the clinical significance of mitral valve disease?

Mitral valve disease may be a common finding in older, small-breed dogs. During physical examination a mitral murmur is often an incidental finding. Because mitral valve disease is a progressive disorder and may lead to congestive heart failure, it should be carefully monitored. The incidence of mitral valve insufficiency in cats without primary myocardial disease is low, and the significance is unknown.

6. What are the clinical signs of mitral valve disease?

The clinical signs of mitral valve disease are related to the severity of lesions. Many animals with early lesions are asymptomatic. Weakness, exercise intolerance, or syncope may be seen with decreased left ventricular forward flow. Coughing may be seen with left atrial enlargement, causing bronchial compression, and dyspnea or tachypnea may be seen with increased left atrial pressures, leading to congestive failure and pulmonary edema. The most common clinical sign in dogs is a nonproductive cough, which is generally worse at night or with exercise. Animals with late-stage disease may present in fulminant congestive heart failure and display all of the above clinical signs as well as cyanosis.

7. What diagnostic tests should be done to evaluate mitral valve disease?

The diagnostic evaluation of mitral valve disease is similar to that of any cardiopulmonary disease. A thorough physical examination and cardiac auscultation should be performed as well as thoracic radiographs and electrocardiography. Echocardiography should be considered if further documentation is required. Because of the therapeutic options available, the minimal database also should include blood urea nitrogen, creatinine, electrolytes, and urinalysis.

8. What electrocardiographic (ECG) changes are commonly seen with mitral valve disease?

The most common ECG abnormality in dogs with mitral valve disease is a widened P-wave or P-mitrale, suggestive of left atrial enlargement. If animals have significant atrial enlargement, premature supraventricular contractions also may be seen as well as supraventricular tachycardia and atrial fibrillation. Sinus tachycardia may be seen in both compensated and decompensated left-sided congestive heart failure. If myocardial hypoxia or myocardial disease is present, ventricular premature contractions may be seen and progress to ventricular tachycardia. Changes in the left ventricle may be seen as tall or wide QRS complexes.

9. What radiographic changes are seen with mitral valve disease?

Thoracic radiographs often provide valuable information for the clinician. The major goal of thoracic radiography is to identify anatomic changes in pulmonary vasculature, left atrium, left ventricle, and mainstem bronchi. It is also valuable to assess for the presence of pulmonary edema. Left atrial enlargement, which is the earliest and most common radiographic finding with mitral regurgitation, leads to loss of the caudal waist of the cardiac silhouette and elevation of the airway on lateral thoracic radiographs. On the dorsoventral projection, the enlarged left atrium can be seen overlying the cardiac silhouette and caudal to the tracheal carina. Pulmonary veins enlarge before pulmonary edema forms. Early pulmonary edema may appear as a peribronchial pattern before progressing to an alveolar pattern. In dogs, pulmonary edema first appears in the perihilar region. In cats, pulmonary edema starts in the periphery and has a patchy distribution.

10. Is coughing due to respiratory disease or heart disease?

This distinction can be one of the most challenging tasks facing the veterinary clinician.

11. A small-breed, coughing dog with a systolic murmur is presented for examination. How can respiratory disease be differentiated from cardiac disease?

Clinical signs discovered on physical examination are often helpful, but some overlap is common. A cough of cardiac origin is most often nonproductive, whereas the cough of respiratory origin may be productive or nonproductive. As a sweeping overgeneralization, dogs with respiratory disease usually do not have higher than normal heart rates. Dogs with heart disease may have normal to higher-than-normal heart rates. Thoracic radiographs may help to differentiate pulmonary disease and airway disease from heart disease. If the pulmonary pattern is equivocal, a trial of diuretic therapy may help to distinguish early pulmonary edema from airway disease. Electrocardiographic and echocardiographic studies also may be beneficial. Sinus arrhythmia, wandering pacemaker, and bradycardia-all of which are signs of increased vagal tone-suggest respiratory disease. Electrocardiographic findings such as P-mitrale, wide or tall QRS complex morphology, and arrhythmias suggest cardiac disease.

12. What therapy is provided for mitral valve disease?

Therapy for mitral valve disease is based on the stage of disease. For asymptomatic animals in early stages of disease, no therapy may be required. If any signs of heart failure are present, therapy with a diuretic, angiotensin-converting enzyme (ACE) inhibitor, and low sodium diet is suggested. The use of digoxin at this stage is at the discretion of the clinician. If advanced progressive heart failure is present, digoxin is added to the above therapy. If the animal does not improve, other vasodilators, such as hydralazine, should be considered.

13. What therapy is suggested for life-threatening heart failure?

- Oxygen therapy
- Intravenous furosemide
- Topical nitroglycerin
- Hydralazine or nitroprusside
- Dobutamine infusion
- Morphine
- Theophylline
- Antiarrhythmic therapy

CONTROVERSIES

14. Should asymptomatic animals be treated?

Although some evidence in experimental models of heart failure suggests that vasodilator therapy delays progression of disease in animals with acquired mitral valve disease, no consistent evidence indicates that this finding can be extrapolated to asymptomatic cases. Some cardiologists believe that if significant cardiomegaly is present, ACE inhibitors should be used. In considering this therapy in asymptomatic animals, cost may be the limiting factor. No published studies currently document the benefits of ACE inhibition in the early stages of heart failure.

15. Is diuretic monotherapy a viable treatment option?

A diuretic agent has historically been the drug of choice for congestive heart failure for many clinicians. Specifically, furosemide has commonly been used as a single agent. Understanding the pathophysiology of congestive heart failure argues against the use of diuretics as monotherapy. Overzealous use of diuretics may lead to decreased venous return, decreased cardiac output, and initiation of compensatory mechanisms that may lead to decompensation. People with congestive heart failure who are treated with diuretic monotherapy deteriorate more rapidly than people using combination therapy with digoxin and ACE inhibitors.

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52. DILATED CARDIOMYOPATHY

Jonathan A. Abbott, D.V.M.

1. What is dilated cardiomyopathy?

Cardiomyopathy is a heart muscle disease that is associated with cardiac dysfunction. Specifically, dilated cardiomyopathy (DCM) is a disorder of impaired systolic myocardial function. DCM is a morphopathologic and functional designation; it is characterized by ventricular and atrial dilation that are consequences of systolic myocardial dysfunction. Most often, left ventricular or biventricular dilation is present. In occasional cases, the right ventricle is affected primarily.

2. What is the pathophysiology of DCM?

When stroke volume declines as a result of systolic myocardial dysfunction (decreased contractility), the end-systolic ventricular volume is increased. This residual volume augments pulmonary venous return, which serves to increase diastolic ventricular pressure and provide a stimulus for ventricular dilation. In addition, the renin-angiotensin-aldosterone system (RAAS) is activated by diminished cardiac output. One effect of RAAS activation is the retention of salt and water, which serves to expand the intravascular volume. Expansion of intravascular volume further increases preload and contributes to progressive ventricular dilation. Elevated ventricular filling pressures, along with atrioventricular (AV) valve incompetence due to dilation of the valve annulus, causes atrial dilation.

Loss of systolic myocardial function, therefore, causes ventricular hypokinesis and initiates a series of events that leads to progressive ventricular dilation. Systolic myocardial dysfunction may result from loss of cardiomyocytes due to necrosis or from functional disorders that affect the contractile apparatus. However, the hemodynamic consequences of impaired systolic myocardial function are generally the same, regardless of the cause.

3. Suggest causes of dilated cardiomyopathy.

DCM is a syndrome rather than a specific disease; in a sense, it is an end-stage heart and likely represents the common expression of virtually any pathologic insult to the myocardium. This insult may take the form of a viral infection, toxin, metabolic derangement, or nutritional deficiency. For example, nutritional taurine deficiency has been associated with DCM in cocker spaniels. In some dogs, myocardial carnitine deficiency likely has a role in the pathogenesis of DCM. In addition, antineoplastic agents such as doxorubicin may result in irreversible myocardial dysfunction. Spontaneous DCM in dogs is generally idiopathic.

4. Suggest a typical signalment for a patient with dilated cardiomyopathy.

Large- and giant-breed dogs, including Doberman pinschers, Labrador retrievers, Great Danes, and boxer dogs are most commonly affected. At least in some affected breeds, males are more commonly affected than females; this sex predisposition is strong in Doberman pinschers. In contrast, sex predispositions have not been observed in affected Newfoundland dogs or Irish Wolfhounds. Dogs with DCM are often middle-aged or older. A 6-year-old male Doberman pinscher is a typical signalment for DCM.

5. Are there differences in presentation among the breeds commonly afflicted?

In general, the course of DCM is similar in all dogs. The development of DCM is probably an insidious process characterized by a subclinical or occult phase of variable length that is terminated in some patients by the onset of congestive heart failure or sudden death. However, a few breeds develop myocardial disease that is sufficiently distinctive in its presentation to warrant mention. DCM of boxer dogs is characterized by a high incidence of ventricular

tachyarrhythmias and sudden death. Harpster classified the manner of presentation of boxer dogs with DCM as follows:

Category 1: Ventricular arrhythmias with no associated clinical signs
Category 2: Syncope presumably related to ventricular tachyarrhythmia
Category 3: Congestive heart failure (CHF) due to systolic myocardial dysfunction

There are similarities between the DCM of boxer dogs and Doberman pinschers. The incidence of ventricular tachyarrhythmia in affected Dobermans is high, as is the incidence of sudden cardiac death. CHF in Doberman pinschers with DCM is often associated with a short and rapidly progressive course. Relative to other affected dogs, giant breeds with DCM are more likely to have signs of biventricular congestive failure manifest as ascites and/or pleural effusion together with pulmonary edema. Furthermore, the disease often is complicated by atrial fibrillation. In the author's experience, however, Doberman pinschers with DCM commonly develop atrial fibrillation in addition to ventricular tachyarrhythmia. Furthermore, all patients with DCM should be considered at risk for sudden cardiac death.

6. What prompts the owner of a dog with DCM to seek veterinary attention?

Patients with occult or subclinical dilated cardiomyopathy may be identified by directed screening evaluation or when auscultatory abnormalities such as arrhythmias are detected during routine examinations. However, patients with DCM are usually presented for evaluation of clinical signs related to CHF. In the emergency setting, the history may reveal respiratory distress, cough, abdominal distention due to ascites, and syncope. In addition, the owner may observe exercise intolerance, weight loss, depression, and inappetance.

7. The physical findings in DCM often suggest the diagnosis. What may be expected on auscultation of the heart?

Because patients with DCM often present with CHF, tachycardia is common, and arrhythmia may be evident on auscultation. Often, but not invariably, a murmur of functional AV valve incompetence results from dilation of the AV valve annulus. This murmur is due to mitral valve regurgitation and is heard best over the left cardiac apex. The murmur is plateau-shaped, occurs during systole, and is usually soft.

In some affected dogs, audibility of the third heart sound results in a triple rhythm known as a gallop. Rapid deceleration of early diastolic transmitral flow is the hemodynamic association of an S3 gallop. Thus, the gallop rhythm results from accentuation of a physiologic event; a gallop rhythm is not an arrhythmia. The rapid deceleration of early diastolic flow is probably related to the presence of a large end-systolic volume and reduced ventricular compliance. In the presence of an audible third heart sound, pulmonary crackles suggest the presence of pulmonary edema.

8. What is the most specific abnormality detected on physical examination?

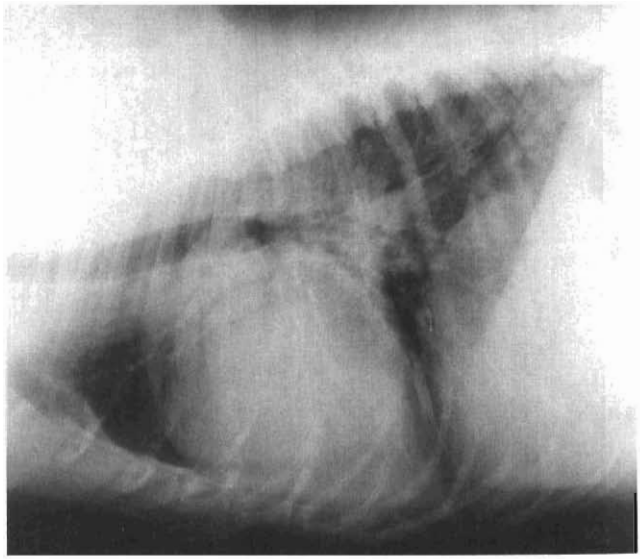
In small animals, audibility of the third heart sound is usually a specific indicator of myocardial dysfunction. The presence of a gallop rhythm in a dog or cat is an indication for detailed cardiovascular evaluation, even in the absence of clinical signs. Care must be taken to differentiate a gallop from other transient sounds, such as splitting of the first or second heart sound and clicks (which usually occur during mid systole), and from arrhythmias.

9. What abnormalities are detected on electrocardiographic examination?

The electrocardiogram (ECG) provides information about heart rate, rhythm, and size. Elucidation of disturbances of cardiac rhythm is the primary use of ECG. In DCM, the ECG may reveal premature ventricular complexes, ventricular tachycardia, atrial premature complexes, atrial or junctional tachycardia, or atrial fibrillation. Sometimes there is evidence of ventricular hypertrophy, intraventricular conduction disturbances, such as left bundle-branch block, or left atrial enlargement. Broadening of the P-wave beyond 40 msec suggests left atrial enlargement. Concurrent P-wave notching may increase the specificity of P-wave broadening as a marker of left atrial enlargement.

10. Describe the expected radiographic findings in DCM.

Usually the cardiac silhouette is enlarged, with radiographic evidence of left atrial enlargement. When the left atrium is enlarged, pulmonary opacities indicate the presence of pulmonary edema and CHF. Initially, pulmonary edema results in interstitial pulmonary opacities. With the accumulation of greater amounts of lung liquid, the small airways are flooded and an alveolar pulmonary infiltrate is observed. Often cardiogenic pulmonary edema has a symmetrical and central distribution. However, pulmonary edema of acute onset may have a patchy or generalized distribution. The ability of plain chest radiographs to resolve specific cardiac chambers is limited, and the radiographic appearance of DCM is variable. Some Doberman pinschers, for example, have minimal radiographic evidence of cardiac enlargement, showing only loss of the caudal cardiac waist, indicating left atrial enlargement, and alveolar pulmonary infiltrates of edema. Pleural effusion and ascites also may be observed radiographically, particularly in giant-breed dogs.



Enlargement of the left atrium with pulmonary opacities indicating the presence of pulmonary edema and congestive heart failure. (From Abbott JA: Small Animal Cardiology Secrets. Philadelphia, Hanley & Belfus, 2000, with permission.)

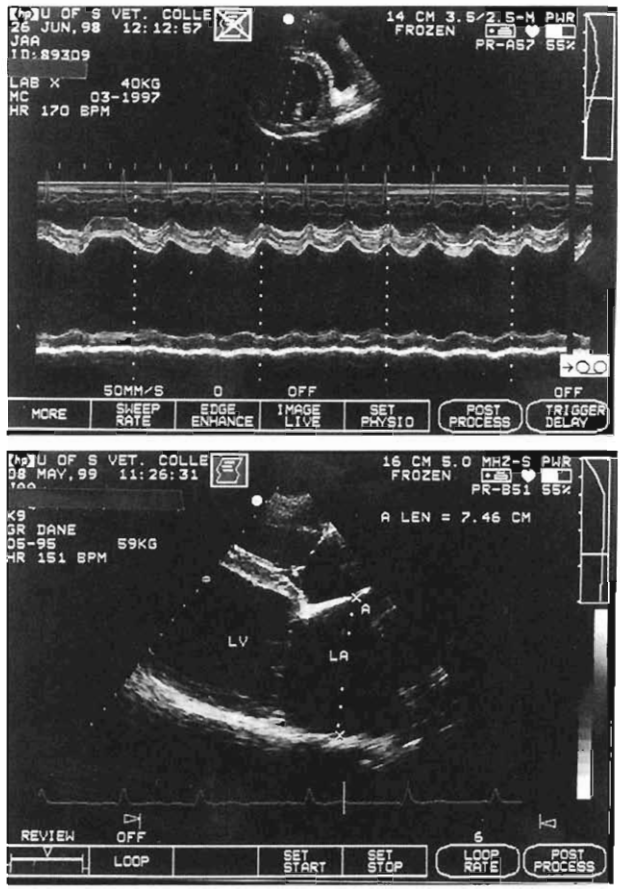
11. When is echocardiography indicated?

Echocardiography provides a noninvasive assessment of cardiac chamber dimensions and myocardial function. It is the means by which to obtain a definitive noninvasive diagnosis of DCM and should be considered in all patients suspected of myocardial disease. Echocardiography is indicated when the cause of dyspnea remains unclear after radiographic examination. In some instances, echocardiography can be performed with the patient standing or in sternal recumbency with minimal restraint and, therefore, less stress to the patient. When available, echocardiography should be considered before radiography in dyspneic patients with physical findings that suggest DCM. Although echocardiography cannot provide a diagnosis of CHF, it can be used to determine whether the patient has structural cardiac abnormalities that may reasonably represent a substrate for development of CHF.

12. What echocardiographic findings typify dilated cardiomyopathy?

In DCM, echocardiography demonstrates atrial and ventricular dilation with hypokinesis. Usually, there is left ventricular or biventricular dilation; occasionally, the right ventricle is preferentially affected. Shortening fraction (SF), a measure of systolic myocardial function, is low, often in the range of 5–15%. Extracardiac disorders, such as sepsis, also may impair myocardial

function and result in a decrease in SF. Despite what may be a rapid clinical course, the development of DCM is usually a gradual process. Therefore, diminished SF in the absence of ventricular and atrial dilation may be related to extracardiac disease or method of measurement; it seldom explains signs of CHF. In DCM, the valves are structurally normal, although Doppler studies often demonstrate mitral and tricuspid valve regurgitation.



Top, M-mode echocardiogram of the left ventricle of the patient in the figure on page 205. M-mode echocardiography provides a one-dimensional view of the heart; the ordinate measures distance from the transducer and the abscissa, time. The two-dimensional image from which this M-mode was derived is shown in the inset. The echocardiogram demonstrates moderate left ventricular dilation and hypokinesis. The cardiac rhythm is atrial fibrillation. *Bottom,* Systolic right parasternal long-axis echocardiographic image obtained from a 4-year-old Great Dane with dilated cardiomyopathy and atrial fibrillation. The left atrium (LA) and left ventricle (LV) were dilated. (From Abbott JA: Small Animal Cardiology Secrets. Philadelphia, Hanley and Belfus, 2000, with permission.)

13. What are the goals in the management of acute CHF?

In CHF the intravascular volume is increased, and elevated ventricular filling pressures are reflected in venous congestion and the resultant accumulation of tissue fluid in the associated capillary bed. Pulmonary edema, the consequence of left ventricular failure, is immediately life-threatening. Right ventricular failure results in ascites and sometimes pleural effusion; it is generally better tolerated than pulmonary edema. The goals of acute CHF management are urgent restoration of normal pulmonary gas exchange and preservation or augmentation of tissue perfusion. These goals are

accomplished largely through pharmacologic manipulation of three of the main determinants of cardiac output—preload, afterload, and contractility.

14. How is preload manipulated in acute CHF?

In fulminant pulmonary edema, a diuretic is administered intravenously. Loop diuretics are potent, act quickly, and may be effective in patients with renal dysfunction. Furosemide is used most commonly. In severe pulmonary edema, it may be administered at doses of 1–6 mg/kg; dosage intervals should be determined by clinical response. Furosemide affects the transport of electrolytes across the walls of the nephron and favors the production of large volumes of dilute urine. The resulting diuresis reduces intravascular volume and, therefore, ventricular filling pressures. When ventricular filling pressures are reduced, the lymphatic vessels can clear the accumulated tissue fluid.

Nitroglycerin (NG) may be administrated transdermally. Controlled dosing patches and a cream are commercially available. Nitrates cause vasodilation through a pathway that increases intracellular cyclic guanosine monophosphate (cGMP). The effect of nitroglycerin is most pronounced in the venous circulation and in specific arteriolar beds such as the epicardial coronary vasculature. Venodilation reduces intrathoracic blood volume and therefore decreases ventricular filling pressures and venous congestion. Although the efficacy of NG in veterinary patients has not been established, an NG patch or cream may be applied to any hairless area of skin as adjunctive therapy in patients who have received furosemide. Application to the inguinal area or trunk may result in more predictable absorption than application to the pinnae of the ear. Interventions that reduce preload are necessary and may resolve pulmonary edema rapidly. However, except in special circumstances, such measures do not have a salutary effect on cardiac output. When the ventricle is dilated, the reduction of preload has favorable clinical effects but little effect on stroke volume. Excessive diuresis, however, may reduce cardiac output and tissue perfusion.

15. How is afterload manipulated in acute CHF?

CHF due to systolic myocardial dysfunction is associated with a mismatch of afterload and contractility. It is useful to consider the relationship among perfusion pressure, vascular resistance, and cardiac output. By analogy to Ohm's law, $BP = SVR \times Q$, where Q = cardiac output, BP = blood pressure, and SVR = systemic vascular resistance. Systemic vascular resistance is an important determinant of afterload, and pharmacologic dilation of arterioles may have a beneficial effect in patients with CHF. In CHF due to DCM, judicious vasodilation reduces afterload and thus increases stroke volume without a detrimental effect on perfusion pressure.

Nitroprusside is a balanced vasodilator that has a pronounced effect on the systemic arterioles. Metabolism of nitroprusside is rapid and results in the release of cyanide and nitric oxide. The nitrate metabolite possesses vasodilatory properties. Nitroprusside is infused intravenously at doses of 1–10 mg/kg/min. It is a potent vasodilator and should be used only in carefully controlled circumstances. Measurement of systemic blood pressure is recommended, and the dose should be titrated based on serial blood pressure measurements and indices of peripheral perfusion. Because cyanide toxicosis is a potential adverse side effect, the use of nitroprusside should be limited to less than 48 hours.

16. Is inotropic support indicated?

In DCM impaired systolic myocardial function is the primary pathophysiologic basis for CHF. Pharmacologic inotropic support is indicated in patients with low cardiac output and congestive signs.

17. Compare and contrast the available positive inotropes.

Essentially all of the positive inotropes act by increasing the availability of calcium within the sarcomere. An exception to this rule is **pimobendan**, a phosphodiesterase inhibitor that also increases the calcium sensitivity of the contractile apparatus. The available positive inotropes fall in one of three pharmacologic categories: (1) digitalis glycosides (digoxin, digitoxin); (2) phosphodiesterase inhibitors (the bipyridine derivatives, amrinone and milrinone); and (3) catecholamines or synthetic analogs (dopamine, dobutamine, epinephrine).

Digoxin can be administered intravenously or orally. The cardiac glycosides bind to and inhibit the sodium-potassium pump of the cardiomyocyte. The resultant change in intracellular sodium concentration affects a membrane sodium-calcium exchanger and leads to an increase in intracellular calcium concentration; this, in turn, increases the inotropic state. The digitalis glycosides also have autonomic effects that are likely favorable in patients with CHF as well as antiarrhythmic properties. However, the glycosides are relatively weak inotropes, and their therapeutic index is low. They are indicated in the chronic therapy of CHF but have a relatively limited role in the critical care setting.

Amrinone and milrinone are relatively potent positive inotropes that also exert a vasodilatory effect. Their action is mediated through inhibition of phosphodiesterase, an enzyme that catalyzes the breakdown of cyclic adenosine monophosphate (cAMP). Inhibition of phosphodiesterase results in an increase in cAMP, an intracellular second messenger that has many effects, including elevation of the intracellular calcium concentration. Clinical trials in people have not shown that inotropes, other than digitalis and possibly low-dose vesnarinone, have a beneficial effect when given chronically. Consequently, the phosphodiesterase inhibitors are not available for oral administration and must be administered by intravenous infusion. The increase in intracellular calcium concentration is potentially arrhythmogenic, and EKG monitoring is recommended during administration.

Dobutamine and other catecholamine derivatives or analogs stimulate adrenergic receptors. Adrenergic receptors are coupled by G-proteins to adenylate cyclase, an enzyme that catalyzes the release of cAMP. Increases in cAMP levels result in increased intracellular calcium concentration. Catecholamines must be administered by intravenous infusion. Dobutamine is a relatively selective agonist of beta-adrenergic receptors. In contrast, dopamine is a "flexible" molecule that can stimulate beta-adrenergic receptors, dopaminergic receptors, and alpha-adrenergic receptors. All catecholamine analogs lose receptor specificity at higher doses. Consequently, their use may increase peripheral vascular resistance to the patient's detriment. The administration of dobutamine results in greater increases in stroke volume relative to increase in heart rate; for this and other reasons, dobutamine is superior to dopamine. ECG monitoring is recommended during infusion of adrenergic agents.

18. Is supplemental oxygen administration indicated? If so, what routes of oxygen administration should be used?

Oxygen should be administered to dyspneic patients with CHF. An oxygen cage is probably the most convenient method, although the use of a nasal cannula is appropriate if tolerated by the patient. Mechanical ventilation using positive end-expiratory pressures may be considered in cases of severe, fulminant pulmonary edema. However, when the patient with DCM and CHF presents for the first time, the resolution of dyspnea and pulmonary edema is often surprisingly rapid even with conservative measures, at least in those who are destined to survive the initial episode of failure; thus the need for mechanical ventilation is obviated.

19. What agents are appropriate for the chronic management of DCM?

A regimen that includes digoxin, an ACE inhibitor, and furosemide has become accepted for the management of CHF due to DCM. ACE inhibitors, which include captopril, enalapril, and benazepril, inhibit the enzyme that catalyzes the conversion of angiotensin I to angiotensin II (AII). AII is a vasoconstrictor that has numerous other effects, including modulation of the adrenergic nervous system, stimulation of antidiuretic hormone and aldosterone release, and trophic effects on myocardium. The efficacy of enalapril in dogs with CHF due to DCM has been demonstrated in a double-blind, placebo controlled trial.

20. What is the role of digitalis in DCM?

Digitalis compounds have a positive inotropic effect and modulate the function of the adrenergic nervous system. They are unique in that they exert a positive inotropic effect yet lower heart rate and control the ventricular response rate in atrial fibrillation. Congestive heart failure due to DCM is an accepted indication for digoxin.

21. How is atrial fibrillation managed in the setting of DCM?

Experimentally, a critical mass of atrial myocardium is required to support the arrhythmia of atrial fibrillation (AF). Only a few breeds of dog are sufficiently large to develop AF in the absence of structural cardiac disease. In dogs, AF usually signifies the presence of marked and possibly irreversible atrial enlargement. Because the predisposing cause of AF generally cannot be corrected in DCM, attempts to effect conversion to sinus rhythm are not generally recommended. Furthermore, the risk of thromboembolism, which may complicate AF in people, seems to be low in dogs. Therefore, conversion to sinus rhythm is seldom attempted. Therapy of AF in the setting of DCM is directed toward optimizing stroke volume and myocardial oxygen demand through slowing of the ventricular response rate.

22. What drugs are available for slowing ventricular response rate in AF due to DCM?

Digoxin is used initially to control heart rate in AF or other supraventricular tachycardias that complicate DCM. Digoxin has a relatively long elimination half-life and a narrow therapeutic index. For these reasons, the use of loading doses is not generally recommended. It may take 2–5 days to achieve therapeutic plasma levels when maintenance doses are administered. Other drugs can be considered when the urgent control of heart rate is indicated.

It is important to consider several factors before negatively chronotropic drugs are used in the critical care setting. Other than digitalis, all of the currently available drugs that slow the heart are negative inotropes. The rapid ventricular response to AF that can be observed in DCM is a compensatory mechanism; some patients with severe CHF are critically dependent on elevated heart rate and what diminished contractile function remains in order to maintain perfusion pressure and cardiac output; consequently, they have little in the way of cardiovascular reserve and may tolerate negative inotropes poorly. Furthermore, unlike some pathologic tachycardias, the rate that the heart in AF adopts is at least partly subject to physiologic influence. Often control of congestive signs reduces anxiety, and a decrease in the ventricular rate in AF is likely to accompany the resolution of pulmonary edema. Rapid slowing of rapid ventricular rate in AF, therefore, must be undertaken only with caution.

Given these caveats, it is likely that AF with ventricular response rates > 240 beats/min is deleterious because it is associated with diminished stroke volume and high myocardial oxygen demand. The cautious use of calcium channel blockers or beta-adrenergic antagonists may be considered. Injectable or oral diltiazem is the author's first choice in this scenario. Diltiazem has a restraining effect on the AV node but a relatively weak negative inotropic effect. A beta-adrenergic antagonist such as esmolol may be considered, although the potent negative inotropic properties of beta blockers must be recognized. The optimal heart rate in AF with overt CHF is not known, although reducing the rate to 180–200 beats/min may be reasonable. The optimal ventricular response rate after congestive signs have been controlled is probably lower.

23. What are the roles of calcium channel antagonists, beta blockers, and digitalis in AF due to DCM?

Digoxin is used to control the ventricular response rate in AF associated with DCM. In some patients with DCM slowing of the heart rate does not occur despite control of congestive signs. The cautious use of diltiazem, a calcium channel blocker, or a beta-adrenergic antagonist such as atenolol or propranolol may be considered as adjunct therapy. Recent evidence obtained in clinical studies of people suggests that the long-term use of beta-adrenergic antagonists in CHF related to systolic myocardial dysfunction may have a beneficial effect on hemodynamics and survival. For this reason, these agents may be preferred when it is necessary to use drugs in addition to digoxin for slowing of heart rate in AF associated with DCM.

24. What monitoring is appropriate for patients with CHF due to DCM?

Patients with CHF are fragile. The relative risk-to-benefit ratio of manipulation for diagnostic procedures must be carefully considered. Invasive monitoring, including placement of a Swan-Ganz catheter and cannula for direct measurement of systemic blood pressure, provides nearly complete hemodynamic information that can be used to modify therapy. However, such complete instrumentation requires intensive nursing care and is difficult to maintain as well as expensive.

Devices that measure blood pressure indirectly provide useful information if their limitations are recognized. Systemic blood pressure is a valuable measure because a perfusion pressure of about 60 mmHg is necessary to maintain glomerular filtration rate and viability of vital capillary beds. However, most veterinary patients with CHF are normotensive at presentation. Furthermore, blood pressure is not a measure of flow, and it is possible for blood pressure to be maintained at the expense of cardiac output.

The measurement of central venous pressure (CVP) provides useful information, and the technique is relatively easy. CVP is a measure of right ventricular filling pressure; it does not provide information about pulmonary venous pressure in the setting of heart disease.

When available, the measurement of blood gases provides information about ventilation and tissue oxygenation. The calculation of the alveolar–arterial oxygen gradient estimates the degree of ventilation/perfusion mismatch due to pulmonary edema. Estimation of oxyhemoglobin saturation with pulse oximetry is noninvasive and serves as a worthy substitute for measurement of blood gases when the patient cannot tolerate the stress of arterial puncture.

Despite the availability of numerous relatively elaborate monitoring techniques, most patients with CHF due to DCM can be managed with careful attention to vital signs. Monitoring of heart rate and respiratory rate and character, assessment of femoral arterial pulse, and observation of mucous membranes provide invaluable information about response to therapy and short-term prognosis.

25. What is the prognosis of CHF due to DCM?

The prognosis of CHF due to DCM is generally poor. If the patient survives beyond the initial presentation, survival of 6–12 months and occasionally longer is possible with careful medical management. A few patients may respond favorably to supplementation with nutrients such as carnitine or taurine. However, DCM in dogs is usually terminal.

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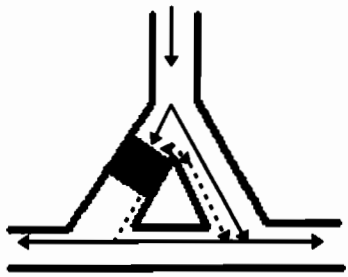
53. CARDIAC ARRHYTHMIAS

Andrew Beardow, B.V.M.&S., M.R.C.V.S.

1. What are the fundamental mechanisms of arrhythmogenesis?

Three mechanisms are commonly described in the induction of arrhythmias: (1) reentry, (2) enhanced automaticity, and (3) triggered activity.

Reentry. Loops of cells or tissues with differing conduction properties are established, and disparities of conduction within the loop allow perpetuation of an impulse that otherwise would be extinguished. If the timing is right, such impulses trigger ectopic depolarizations in nonrefractory tissue. The loops may occur at the microscopic, cellular level or the macroscopic level. The microscopic loop consists of Purkinje cells and myocytes and a region of diseased tissue that acts as a unidirectional block in one limb of the loop. As an impulse passes down the conduction pathway, it is blocked from antegrade conduction through the diseased pathway. The impulse continues past this region in other portions of the loop and is then conducted in a retrograde direction in the diseased portion because this limb of the loop was not depolarized and therefore is not refractory. If the timing is correct, the tissue beyond the block is ready to conduct another impulse, setting up a reentry loop.



Area of unidirectional block.

Macroreentry loops use larger circuits composed of existing conduction pathways, i.e., reentry loops within the the atrioventricular (AV) node or by an accessory pathway, as in Wolff-Parkinson-White (WPW) syndrome. In humans up to 85% of supraventricular tachyarrhythmias (SVTs) may be due to macroreentry loops utilizing disparity of conduction velocities in the fast and slow pathways through the AV node. These pathways also exist in the canine AV node, but it is unclear how many SVTs in dogs are generated through this mechanism.

Enhanced automaticity. In this mechanism of arrhythmogenesis, either normal pacemaker tissues show abnormal activity or cells that are not usually automatic become so. Automaticity is a property of phase 4 of the action potential. In automatic cells a leakage of ions allows the resting membrane potential to change, moving it toward threshold. When the threshold is

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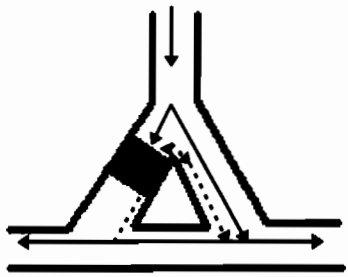

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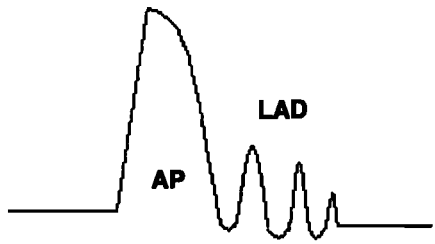
reached, depolarization is triggered. The rate of change of this potential determines the rate at which it reaches threshold and hence how frequently the pacemaker will fire. Changes in the membrane or the prevailing autonomic tone may affect this mechanism and hence enhance automaticity. Diseased cells that normally do not show automaticity may start to do so. For example, the membranes of diseased myocardial cells may develop an abnormal permeability to calcium ions. This leak allows the membrane to depolarize spontaneously, reach threshold, and trigger a premature beat.

Triggered activity. As the name indicates, triggered activity does not occur spontaneously but requires one wave of depolarization to trigger another. It is believed that oscillations in the membrane potential following an action potential are responsible for this activity. Disease states or, in some cases, drugs render the membrane unstable and likely to allow such oscillations. Described as afterdepolarization, these oscillations are further classified, depending on their relationship to the action potential, as either early or late. Late afterdepolarizations are typically cited as causing the arrhythmias induced by digoxin intoxication.



Triggered activity. AP = action potential, LAD = late afterdepolarization.

2. What steps are taken to determine the focus of an arrhythmia?

1. Try to identify a normal PQRST, i.e., a complex that originated from the sinoatrial (SV) node, was conducted through the AV node, and depolarized the ventricle with a normal timing and conduction pattern. A normal PQRST may show some abnormalities because of underlying disease, such as abnormal AV nodal conduction, aberrant ventricular conduction, or an abnormally shaped P-wave due to atrial changes. If you are in doubt, try to identify several complexes that look the same; all of them may have the same abnormality, but in each a P-wave is followed after an appropriate interval by a QRS complex and a T-wave.

2. Compare the normal complex with others on the strip. If the abnormal complexes have only a QRS complex and a T-wave, do they look like the normal QRS-T complex? If so, the arrhythmia most likely arises at or above the AV node and is therefore supraventricular in origin. If not, the arrhythmia is probably ventricular in origin.

3. Try to identify any P-waves on the strip. Do they have a temporal relationship to the abnormal QRS complexes? The answer may help to determine whether the source of a supraventricular arrhythmia is atrial or junctional.

3. Arrhythmias are common in emergency patients. Clinical signs compatible with arrhythmia, such as syncope or weakness, may be described. What techniques help to correlate clinical signs with arrhythmia?

1. **Observation of clinical signs** while the patient is monitored in hospital. If you are lucky, you may be monitoring the EKG when clinical signs develop.

2. **Event recording.** A small device, about the size of a pager, is attached to the patient and records the EKG continuously in a 5-minute electronic loop memory. The owner activates the unit when the patient has an episode, and the unit locks the EKG into memory. Because the unit is programmable, the amount of EKG recorded before and after activation may be varied. The batteries typically last up to 7 days, and some units record up to 5 events. Such devices are useful if an episode typically occurs once weekly. The major disadvantage is that the owner must witness the event.

3. **Holter monitoring.** Holter monitors record the EKG for 24 or 48 hours. The recording is made either on a cassette tape or with solid-state technology. However the data are recorded, the entire 24-hour EKG is analyzed by a computer, allowing documentation of the frequency as well as the presence of arrhythmia. Holter monitors often have an event button that can be activated by the owner, thus allowing correlation of the EKG with the event. The owner need not be present, however, for the device to record an arrhythmia that may be judged serious enough to cause clinical signs. The major disadvantages of Holter monitors are the size of the unit, which tends to limit their use to patients weighing over 10 kg, and the fact that only 24 hours of recording time are available, which limits their use when clinical signs occur infrequently.

4. **Response to therapy.** Although frequently the method of choice, observation of response to therapy is the least satisfactory method of establishing a cause-and-effect relationship between arrhythmias and clinical signs. Both clinical signs and arrhythmias may resolve spontaneously, independently of therapy. Conversely, use of a single EKG to measure response to therapy may give false evidence of efficacy; for example, the EKG may have been recorded during the 2 minutes when the arrhythmia was temporarily quiescent. In either circumstance, the patient may be condemned to a prolonged course of inappropriate therapy.

4. In examining the EKG of a patient with tachyarrhythmia, what is the most important first step?

Try to establish whether the arrhythmia is supraventricular or ventricular in origin. Broadly speaking, this distinction, above all others, is the most useful first step in choosing the most appropriate therapy. Even if you cannot definitively categorize the arrhythmia, first-line therapy stands a better chance of success if it is based on your best guess. It is not unusual to have to reassess your diagnosis frequently throughout the management of tachyarrhythmias because of inappropriate therapeutic response or a change in the underlying arrhythmia.

5. Describe the classification system for antiarrhythmic drugs. To which class(es) do lidocaine, procainamide, diltiazem, and propranolol belong?

The Vaughan-Williams classification for antiarrhythmic drugs is based on their effect on the action potential of the cardiac myocyte:

Class I drugs, frequently described as membrane stabilizers, block the fast sodium channel. Class I drugs are subdivided according to their effect on the action potential in terms of automaticity, conductivity, contractility, AV conduction, and fibrillation threshold.

Class IA	Decreased automaticity	Procainamide	SVT
	Decreased conductivity	Quinidine	VT
	Decreased contractility		WPW
Class IB	Decreased automaticity	Lidocaine	VT
	Decreased contractility	Tocainide	
	Increased AV conduction	Mexiletine	
	Increased fibrillation threshold		
Class IC	Decreased automaticity	Flecainide	VT
	Decreased conductivity	Encainide	WPW
	Decreased contractility		
	Decreased AV conduction		

Class II drugs are the beta blockers, which decrease automaticity and conductivity. They cause variable degrees of depression of both contractility and AV node conduction, depending on the drug in question. Beta blockers are used to manage supraventricular tachycardia (SVT), ventricular tachycardia (VT), and Wolff-Parkinson-White syndrome (WPW).

Class III drugs are the neural adrenergic antagonists, which recently have received a great deal of attention in management of arrhythmias refractory to class I drugs. Class III drugs decrease automaticity and conductivity and increase the fibrillation threshold. Many have significant side effects that must be taken into consideration. The most commonly used class III drugs are bretylium, amiodarone, and solotol.

Class IV drugs, which block the slow calcium channel, have their most profound effects on AV node conduction. They also decrease automaticity, conductivity, and contractility, although the magnitude of these effects varies widely across the group. The most commonly used class IV drugs are verapamil and diltiazem.

6. How does the Vaughan-Williams classification help to determine the choice of antiarrhythmic drug?

The ion that carries the action potential differs according to the location of the myocyte. For example, the action potential in the pacemaker cells of the SA and AV nodes is carried principally by the calcium ion. To treat arrhythmias arising from these tissues (SVTs), a class IV drug (calcium channel blocker) such as diltiazem is appropriate. Class I drugs act principally on the sodium channel and are therefore most useful for VTs because the sodium channel carries the depolarization phase of the action potential in ventricular myocytes.

7. What is proarrhythmia?

Proarrhythmia represents a change in or development of arrhythmias during treatment with antiarrhythmic drugs. This phenomenon was first galvanized into the minds of physicians when asymptomatic patients with arrhythmias began to die as a result of antiarrhythmic drugs. Proarrhythmia must be considered whenever antiarrhythmic drugs are used. All antiarrhythmic drugs affect the myocardial action potential. Although this effect is often beneficial, it may prove unpredictable, especially in diseased tissue. Hence drugs that suppress conduction velocity may affect the timing of conduction through reentrant loops in such a way as to fine-tune the loop and exacerbate the arrhythmia. Clinicians must consider the risk/benefit ratio of such drugs before they are used. Asymptomatic patients with premature ventricular contractions (PVCs) do not invariably need antiarrhythmic therapy.

8. Which medications are often selected for management of acute SVTs in dogs?

The short-acting beta blocker esmolol, the unclassified agent adenosine, intravenous calcium channel blockers (diltiazem and verapamil), or intravenous digoxin is often selected.

Intravenous digoxin is the most difficult to manage and tends to be used less frequently. An exception is the patient with an SVT that may be atrial fibrillation and suspected dilated cardiomyopathy (DCM); beta blockers and calcium channel blockers are negative inotropes and should be used with extreme caution in such patients. Digoxin is also appropriate when dobutamine is indicated for the acute management of DCM in patients suspected of atrial fibrillation. Dobutamine increases the rate of conduction through the AV node and thus the ventricular response rate, thereby exacerbating tachycardia.

Of the calcium channel blockers, **diltiazem** may cause less myocardial depression than verapamil and thus may be the better choice.

Adenosine is a purine nucleotide found in every cell in the body. When exogenous adenosine is administered, it is presumed to bind to an extracellular purine receptor. It then decreases intracellular levels of the universal second messenger, cyclic adenosine monophosphate (cAMP), by blocking adenylate cyclase. Adenosine has profound inhibitory effects on AV node conduction and depresses SA node and ventricular automaticity. Cyclic AMP mediates many of the effects of catecholamines; therefore, adenosine ameliorates the arrhythmogenic properties of catecholamines.

9. When should a ventricular arrhythmia be treated?

Two major factors should be considered in deciding whether to treat a ventricular arrhythmia:

1. **Underlying disease process.** Certain emergency problems are often complicated by the onset of ventricular arrhythmias (e.g., gastric dilatation, volvulus). Frequently the ventricular rate is the same as the underlying sinus rhythm, and the patient is hemodynamically stable. Correction of underlying fluid deficit, acid–base disturbance, or pain may negate the need for antiarrhythmic therapy if the patient remains stable.

2. **Frequency and rate of arrhythmia.** There are no hard and fast rules about the need for therapeutic intervention in the management of arrhythmia. Typically therapy is indicated if the patient shows clinical signs associated with the arrhythmia or if the type of arrhythmia and signalment have a strong association with sudden death. For instance, boxer dogs with myocarditis and cardiomyopathy frequently die suddenly, presumably because of a fatal arrhythmia. Therefore, you may be more inclined to treat an asymptomatic boxer with frequent PVCs, especially if paroxysmal ventricular tachycardia is documented, than an otherwise healthy Labrador retriever with 18 single, uniform PVCs per minute.

10. How should an arrhythmia of ventricular origin be treated?

For immediate management of life-threatening arrhythmias, lidocaine is the drug of choice. Typically the initial dose is 2 mg/kg administered as an IV bolus. Lidocaine should be used without epinephrine. Diazepam may be given to control seizures. Cats invariably have seizures when given 2 mg/kg of lidocaine; therefore, in cats the dose is reduced to 0.2 mg/kg. Lidocaine is metabolized rapidly; for sustained effect, infuse 50–100 μg/kg/min. If there is any delay between the initial bolus and administration of the infusion, another bolus may be necessary.

Commonly used oral drugs include procainamide, mexiletine, and quinidine.

11. What concurrent problems affect the required dose of lidocaine?

Reduced blood flow to the liver decreases the required dose of lidocaine and may increase side effects, including mental depression. Low cardiac output and beta blockade decrease hepatic blood flow. Liver failure and administration of cimetidine also decrease hepatic clearance of lidocaine.

12. What if a bolus of lidocaine fails to convert the patient with ventricular arrhythmias?

- Combinations of antiarrhythmic drugs may help to convert patients who are refractory to monotherapy. Lidocaine may be combined with parenteral procainamide. In patients with no evidence of myocardial depression, beta blockers (e.g., propranolol, atenolol, esmolol) may be used.
- Class III antiarrhythmic drugs (amiodarone, sotolol, bretylium) also have been used in patients refractory to more conventional therapy, although experience with these drugs is limited.
- Reassess the patient, and correct fluid deficits, acid–base status, hypoxia, or any identifiable underlying disease.

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54. CARDIAC PACEMAKERS

Eric Monnet, D.V.M., Ph.D.

1. What are the most common indications for pacemaker implantation in small animals?

- High-grade second-degree atrioventricular (AV) block
- Third-degree AV block
- Sick sinus syndrome
- Persistent atrial standstill with a slow ventricular escape rate

2. What are the clinical indications for a pacemaker?

Pacemaker implantation is indicated when clinical signs such as exercise intolerance, syncope, or congestive heart failure are related to bradycardia.

3. How do you stabilize a patient with clinically significant bradycardia before implantation of a permanent pacemaker?

It is necessary to increase the heart rate either with a temporary external pacemaker or pharmacologically. If a temporary external pacemaker is available, a flow-directed, ballon-tip bipolar electrode is introduced into the jugular vein and wedged in the trabeculae of the right ventricle under local anesthesia and light sedation. The ECG documents capture of the ventricle when the electrode is properly wedged in the trabeculae. Fluoroscopy also may be used to assist with placement of the electrode and to confirm its position. If a temporary external pacemaker is not available, constant intravenous infusion of a beta agonist (isoproterenol, 0.01 mg/kg/min) may be used during anesthesia to increase the rate of the escape rhythm, but this method is less reliable.

4. What techniques are available for permanent pacemaker implantation?

- Transvenous implantation through the jugular vein. The pulse generator is implanted in a subcutaneous pocket in the neck or thorax.
- Transdiaphragmatic implantation after celiotomy. The pulse generator is implanted in a pocket in the abdominal wall between the transverse abdominal and internal oblique muscles.

5. What are the three-letter codes on the pacemaker?

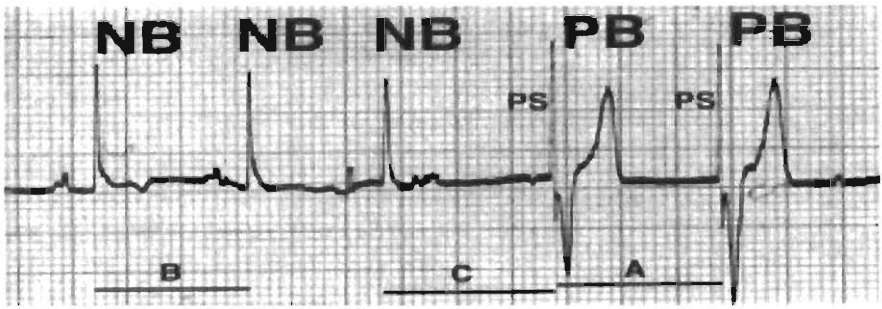
Pacemakers operate in different modes. A three-letter code has been developed to identify the different modes.

FIRST LETTER: CHAMBER PACED	SECOND LETTER: CHAMBER SENSED	THIRD LETTER: RESPONSE TO SENSING
A (atrium)	A	I (inhibited)
V (ventricle)	V	T (triggered)
D (dual atrium and ventricle)	D	D (I and T)
	O (no sensing)	O (no response)

A pacemaker in VVI mode will pace and sense a ventricle and will not fire an impulse if a heart beat has been sensed (inhibited) (see figure at top of next page). VVI is the most commonly used mode in veterinary medicine.

6. What is a demand pacemaker?

Demand pacemakers have an adjustable heart rate. A piezoelectric crystal in the pacemaker senses vibration due to increased activity of the patient. The piezoelectric crystal sends information to the pacemaker to increase the heart rate according to preset parameters. Demand pacemakers are characterized by a fourth letter in the letter code system (D).



Electrocardiogram of a dog with sick sinus syndrome treated with a permanent pacemaker. The pacemaker was sensing and capturing appropriately. Each pacemaker spike is associated with a depolarization wave. **A** represents the normal time between two paced beats if no normal beats are sensed. Note that **B** < **A** and **C** = **A**. NB = normal beat, PB = paced beat, PS = pacemaker spike.

7. What is dual pacing?

Dual pacing consists of pacing the atrium and ventricle sequentially. This method allows better synchronization of atrial and ventricular contractions. A delay between the atrial and the ventricular contraction can be optimized to achieve the best-possible left ventricular filling.

8. What is sensing?

Sensing is the ability of the pacemaker generator to recognize intrinsic myocardial activity. Sensing is a function of the ability of the sensing amplifier to recognize a P or R wave. Sensing sensitivity is usually set at 1.0 mV. The P or R wave must be greater than 1.0 mV to inhibit the pacemaker generator.

9. What type of electrodes may be used to pace the heart?

Electrodes may be unipolar or bipolar. With unipolar electrodes the electric current goes from the tip of the electrode (cathode) to the metallic box of the generator (anode). With bipolar electrodes, the anode and cathode are within the tip of the electrode. These leads may be further divided into endocardial or epicardial leads. Endocardial electrodes are usually bipolar, whereas epicardial electrodes are usually unipolar.

10. What is threshold to capture?

Threshold to capture is the minimal amount of energy required to induce a myocardial depolarization on the ECG (i.e., to capture the heart). Threshold to capture is determined by gradually decreasing the output of the generator until no QRS complex is seen on the ECG monitor. The output is then increased until the heart is captured again. For safety we set the output of the generator at 2 times the threshold. Threshold is measured in milliamperes (mA).

11. What are the major postoperative concerns?

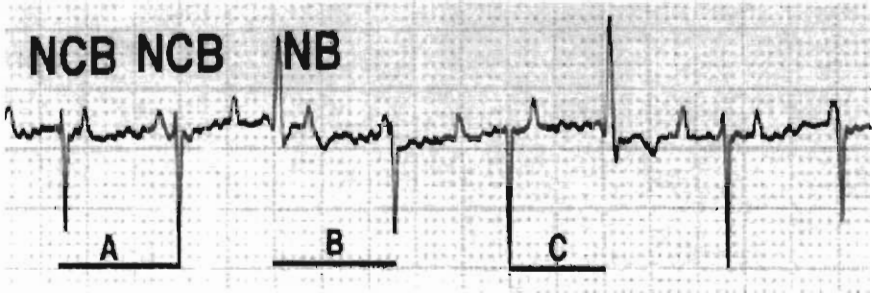
- Continuous ECG monitoring for 24 hours to confirm proper function of the pacemaker.
- Heart rate should not drop below the preset rate of the pacemaker.
- Premature ventricular contractions (PVCs) often are seen after surgery because of the myocardial trauma from the lead implantation. Lidocaine may be used to suppress PVCs, but usually this is not necessary.
- The temporary transvenous lead is left in place for 24 hours as a back-up in case the permanent pacemaker has problems.

12. What are the most common causes of pacemaker failure?

- Failure to capture
- Failure to sense (oversensing and undersensing)
- Pulse generator failure

13. What is failure to capture?

Failure to capture occurs when the pulse generator fires an impulse at the appropriate time, but no depolarization of the myocardium is associated with the impulse.



Electrocardiogram of a dog in third-degree AV block treated 4 weeks before this tracing with a permanent pacemaker demonstrates failure to capture. There are six pacemaker spikes (NCB = noncaptured beat) not associated with a depolarization wave and two escape beats (NB = normal beat). Because **A** = **B** and **C** < **A**, the pacemaker is sensing appropriately. Correct sensing implies that the lead is not broken.

14. What causes failure to capture?

- Increased lead impedance 4–5 weeks after initial surgery due to fibrous tissue
- Lead fracture
- Lead dislodgment

15. What is failure to sense?

Failure to sense occurs when the pacemaker does not recognize appropriate myocardial electrical activity. Failure to sense is recognized on the ECG by the presence of a nonpaced heart beat between two normally timed paced beats or an absence of paced beats at the appropriate timing. Failure to sense places the animal at risk for competitive tachycardia and ventricular fibrillation. Failure to sense is caused by both oversensing and undersensing.

16. What are oversensing and undersensing?

Oversensing occurs when the sensing amplifier of the pulse generator detects inappropriate electrical activity and inhibits the pacemaker. It results from a high sensing sensitivity. Electrical activity may originate from extracardiac signals (myopotential, electromagnetic interference) or from intracardiac signals (lead problems, T-wave sensing, far-field sensing).

Undersensing occurs when the sensing amplifier of the pulse generator does not detect electrical activity and does not inhibit the pacemaker. It results from a low sensing sensitivity and is most commonly due to lead fracture or dislodgment.

17. What is generator failure?

Generator failure occurs most often when the battery runs out of power. Circuitry problems also may induce generator failure. A failing generator has erratic behavior; that is, it may fail to capture or to sense, or it may reset the pacing rate by itself.

18. What should be done if a dog with a pacemaker presents with sudden onset of syncope?

- Count the pulse rate, which should be higher than the preset pacing rate.
- Perform an ECG to differentiate failure to capture from failure to sense or generator failure.
- Evaluate cardiac function with echocardiography.
- Evaluate lead integrity with radiographs.
- Do exploratory surgery to evaluate the pulse generator and lead insertion in the generator and to measure lead impedance and R or P wave amplitude.

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55. PERICARDIAL EFFUSION

Dianne Dunning, D.V.M.

1. What is the pericardium?

The pericardium is a two-layer sac that envelopes and surrounds the heart. The outer layer (fibrous pericardium) is continuous at the heart base with the great arteries and veins. At its apex, the fibrous pericardium forms the sternopericardial ligament, which attaches the pericardial sac to the ventral muscular diaphragm. The inner layer, which is formed by a single layer of mesothelial cells, adheres to the visceral or epicardial surface of the heart and turns back on itself to form the parietal layer, which is attached to the fibrous pericardium. Within the sac is 0.5–1.5 ml of serous fluid, which is an ultrafiltrate of serum. This fluid is maintained via osmosis, diffusion, and lymphatic drainage across the serosal surface.

2. What are the functions of the pericardium?

- Prevention of cardiac overdilation
- Myocardial lubrication
- Protection of the heart from infections or adhesions
- Maintenance of the heart in a fixed position within the chest
- Regulation of stroke volume between the two ventricles
- Prevention of right ventricular regurgitation when ventricular diastolic pressures are increased

Normal cardiac function may be maintained without the pericardium, as seen in dogs with congenital absence of the pericardium or dogs with pericardiectomy.

3. What are the causes of pericardial effusion?

The most common causes of pericardial effusion are neoplasia (58%) and idiopathic pericardial effusion (19%). Other less common causes of pericardial effusion are as follows:

- Infection
- Congestive heart failure
- Uremia
- Trauma
- Foreign bodies
- Coagulopathies
- Congenital or acquired peritoneopericardial hernias
- Pericarditis
- Left atrial rupture

4. What are the common tumors associated with pericardial effusion?

- Right atrial hemangiosarcoma (33%)
- Chemodectoma (12%)
- Metastatic adenocarcinoma (5%)
- Lymphoma (3%)
- Thymoma (3%)
- Undifferentiated carcinoma (3%)

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- Thymoma (3%)
- Undifferentiated carcinoma (3%)

5. What is idiopathic pericardial effusion?

Idiopathic pericardial effusion is a condition in which a serosanguinous fluid accumulates within the pericardial sac with no evidence of underlying disease or bacterial infection. This syndrome is seen predominantly in giant or large-breed male dogs, 8–9 years of age. The diagnosis is confirmed when no evidence of neoplasia is found at surgery and there is no evidence of infection on bacterial culture. Pericardial histopathology reveals a chronic nonspecific, inflammatory, hemorrhagic pericarditis. Other terms for idiopathic pericardial effusion include idiopathic hemorrhagic pericardial effusion, idiopathic pericardial hemorrhage, spontaneous pericardial effusion, benign idiopathic pericardial effusion, and benign pericardial effusion. The term *benign* is a misnomer and has fallen out of favor because pericardial effusion may be a life-threatening problem.

6. Which common organisms are associated with infectious pericardial effusion? What is their route of entry?

Actinomyces and *Nocardia* spp. are the two most common organisms isolated from animals with infectious pericardial effusion. These bacteria cause a chronic, suppurative tissue reaction with granuloma formation that is difficult to distinguish grossly from neoplasia. Granules within the tissue or exudate are characteristic but may not be present in all cases. The granules represent colonies of the organism. Differentiation between actinomycosis and nocardiosis can be confirmed only by culture of the organism. If antimicrobial therapy has been instituted before obtaining the samples for culture, as is often the case, the organisms may be difficult to culture. *Actinomyces* spp. generally responds best to penicillins, whereas *Nocardia* sp. responds best to potentiated sulfonamides. The route of entry is difficult to document but is usually from penetration of the pericardium by a foreign body via the trachea or esophagus. Actinomycoses and nocardiosis often are associated with plant awn penetrations and are a common problem in the western United States.

7. What is the pathophysiology of cardiac tamponade?

Pericardial effusion is the accumulation of fluid within the pericardial sac and may result in cardiac tamponade. Rate of fluid accumulation, volume of fluid, and characteristics of the pericardial sac play a role in determining signs associated with pericardial effusion. Rapid fluid accumulation, large quantities of fluid, and a diseased, noncompliant pericardial sac contribute to signs associated with cardiac tamponade. Cardiac tamponade occurs when intrapericardial pressure exceeds the ventricular diastolic pressure. The results are systemic venous congestion and decreased cardiac output. This is a life-threatening problem that must be quickly recognized and treated.

8. What are the most common findings in the clinical history of pericardial effusion?

- Lethargy (19.0%)
- Dyspnea (16.7%)
- Anorexia (14.3%)
- Collapse (14.3–32.6%)

9. Describe the most common clinical signs of pericardial effusion.

Clinical signs may be acute or chronic, depending on the rate and volume of pericardial fluid accumulation and characteristics of the pericardial sac. No pathognomonic signs of pericardial effusion exist. The most prevalent clinical signs associated with the disease are as follows:

- Muffled heart sounds (50.0%)
- Weakness (40.5%)
- Abdominal distention (35.7–58.7%)
- Cachexia (28.6%)
- Tachycardia (heart rate > 150 bpm) (28.6–41.3%)
- Weak arterial pulse (26.2%)

Jugular distention is the cardinal sign of cardiac tamponade in humans but appears to have a low prevalence in animals (2.4%), making it an unreliable indicator of disease. This may be due to lack of detection. Thick hair coats and neck collars may impede direct visualization of the jugular groove and thus camouflage any distention.

10. What is the diagnostic test of choice for pericardial effusion?

Echocardiography detects effusion in more than 90% of dogs. It is considered the diagnostic test of choice because of its accuracy and noninvasive nature. Up to 43% of tumors causing pericardial

effusion are detected with two-dimensional echocardiography. Positive results are reliable with a specificity of 77%, but the absence of a visible mass on echocardiography does not rule out the presence of a mass lesion. Two-dimensional echocardiography has a greater sensitivity and specificity (66% and 100%, respectively) at detecting right atrial hemangiosarcoma. Right atrial hemangiosarcoma has a worse prognosis than other cardiac tumors. Diagnosis, prognosis, and therapeutic recommendations for dog with pericardial effusion are generally based on results of echocardiography.

11. Is the central venous pressure (CVP) useful in detecting pericardial effusion?
Absolutely. CVP > 12 cmH_2O is a consistent finding with pericardial effusion.

12. Describe the value of the ECG in diagnosing pericardial effusion.
ECG generally reveals normal sinus rhythm or sinus tachycardia. Electrical alternans is defined as a phasic alteration of the amplitude of the QRS complex from one cardiac beat to the next and is seen in 6.1–34.8% of cases with pericardial effusion. These phasic alterations are believed to be caused by the swinging of the heart within the pericardial sac. Small-amplitude complexes were once believed to be due to the poor conduction of the electrical impulses through the fluid, but they more likely result from decreased ventricular filling.

13. Are thoracic radiographs valuable in diagnosing pericardial effusion?
Thoracic radiographs are indicated as part of the minimal database to rule out metastatic disease or concurrent thoracic disease. The most common radiographic abnormalities in dogs with pericardial effusion are cardiomegaly (87.9%), pleural effusion (56%), and metastasis (68.8%).

14. What is the emergency treatment for an animal with significant pericardial effusion?
Pericardiocentesis.

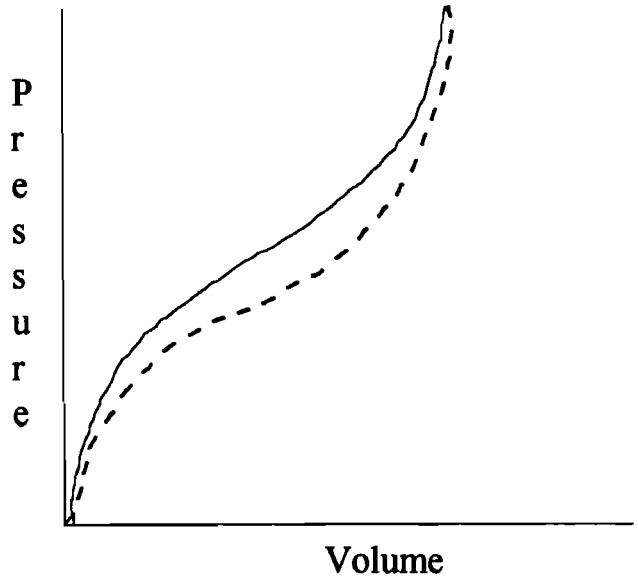
15. How do you perform a pericardiocentesis?
Clip and surgically prepare the skin on the right thoracic wall between the 4th and 6th intercostal spaces at the level of the costochondral junction. Connect the ECG leads to the animal. Inject 1–4 ml of 2% lidocaine HCl at the insertion site and down to the pleural surface. Using an 8-French, 9-cm intravenous catheter (Safety Thoracocentesis System, Sherwood Medical, St. Louis), slowly insert the catheter and enter the pericardial space. Aspirate the fluid from the pericardial space.

16. How do you know whether the blood is from the pericardium or a cardiac chamber?
Blood within the pericardial space is defibrinated and will not clot. The first sample should be placed in a redtop collection tube and monitored for clotting. If a clot forms, remove the catheter and begin again.

17. What is the purpose of the ECG during pericardiocentesis?
As the catheter enters the pericardial space, it may touch the epicardium. If it does, the galvanometer in the ECG will detect the contact; you will see a bizarre QRS or even ventricular arrhythmias. These signs require that you back the catheter slightly outward as you continue to aspirate fluid.

18. Do you need to remove all of the fluid from the pericardial space to relieve the symptoms?
No. Removal of a small volume of fluid results in dramatic drops in intrapericardial pressure (see figure at top of following page).

19. What laboratory data help to diagnose the cause of pericardial effusion?
Changes in laboratory data are variable and nonspecific. Recently, pericardial fluid pH has been explored as a test for discriminating between benign (inflammatory) and neoplastic (noninflammatory) origins of pericardial fluid. Inflammatory pericardial fluid has a markedly acidic pH value (6.5), whereas the pH of noninflammatory pericardial fluid is near the value of normal body fluid (7.5). Determination of pericardial fluid pH is inexpensive and simple to interpret but has not been evaluated in a large number of cases and therefore should be interpreted with caution.



When fluid accumulates within the pericardial space *(solid line)*, there is a sigmoid-shaped presssure-volume curve. When fluid is removed from the pericardial space *(dotted line)*, the curve follows the hysteresis of the volume accumulation curve. Thus, when a small volume of fluid is removed, there is a dramatic drop in intrapericardial pressure.

20. Is cytology of the pericardial effusion of diagnostic value?

Cytologic examination of pericardial fluid is diagnostic for effusion due to infectious processes; however, it is of little benefit for differentiating between benign idiopathic and neoplastic effusions.

21. What are the treatment choices available for pericardial effusion?

- Repeated pericardiocentesis
- Pericardiotomy
- Thoracoscopic pericardiotomy
- Percutaneous ultrasound guided balloon pericardiotomy

22. What is the standard approach to treatment in dogs with pericardial effusion?

Historically, there have been multiple therapeutic approaches to dogs with pericardial effusion. Cases of probable idiopathic pericardial effusion are managed initially with repeated pericardiocentesis; surgery is used only if the effusion persists. Fifty percent of benign idiopathic pericardial effusions resolve with multiple pericardiocentesis. Patients with high probability of neoplasia usually undergo surgery for prevention of refractory cardiac tamponade and confirmation of diagnosis. Total pericardiotomy offers no advantage over subtotal pericardiotomy and is more time-consuming. Pericardiectomy is considered palliative for nonresectable cardiac tumors. Postoperative complications associated with pericardiectomy are uncommon.

23. What newer techniques are available?

Thoracoscopic pericardiotomy and percutaneous ultrasound-guided balloon pericardiotomy recently have been described in the veterinary literature. These newer techniques are significantly less invasive than thoracotomy and pericardiotomy. Both rely on the creation of a pericardial window for drainage and therefore may be associated with a higher recurrence rate of the effusion than pericardiotomy. Thoracoscopy has the added advantage of allowing visual inspection and biopsy of the contents of the thoracic cavity. Within human medical literature, ultrasound-guided placement of pigtail catheters is commonly used when extended drainage of malignant pericardial effusion is necessary. Complications described with this technique include infection, pleural effusion, atrial fibrillation, transient pericardial pain, and erratic drainage.

23. What are the prognostic indicators of survival in dogs with pericardial effusion?

Negative prognostic indicators of survival include pulmonary metastasis or a right atrial mass documented on thoracic radiographs and echocardiography. The only positive prognostic indicator of survival is ascites at the time of initial physical examination. Rapid onset of pericardial effusion is characteristic of an aggressive neoplastic process such as hemangiosarcoma bleeding into the pericardial sac, whereas slower rates of accumulation of pericardial fluid are characteristic of less aggressive processes, such as idiopathic pericardial effusion. A slower accumulation rate allows the pericardium to stretch and fill with fluid, eventually presenting with signs consistent with right-sided congestive heart failure such as ascites.

24. What is the prognosis for dogs with pericardial effusion?

The prognosis of pericardial effusion in dogs depends largely on the etiology. Generally, pericardial effusion secondary to neoplasia is reported to carry poor prognosis, whereas benign idiopathic pericardial effusion is thought to carry a better prognosis. A recent study of dogs with idiopathic pericardial effusion treated with surgery revealed 12% mortality rate associated with surgery and 72% survival rate eighteen months post-operatively. Another study analyzing the prognostic indicators for dogs with pericardial effusion reported a median survival time of 15.3 months for dogs with idiopathic pericardial effusion, 15 days for dogs with pericardial effusion due to hemangiosarcoma, and 13.6 months for dogs with pericardial effusion due to mesothelioma.

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56. FELINE MYOCARDIAL DISEASE

Jonathan A. Abbott, D.V.M.

1. What is cardiomyopathy?

Cardiomyopathy is a heart muscle disease that is associated with cardiac dysfunction. In the past, this term was reserved for idiopathic or primary heart muscle diseases. More recently, a task force of the World Health Organization (WHO) adopted the more general definition stated above. This was prompted by the growth of knowledge which has blurred the distinction between idiopathic myocardial disease and what were previously known as specific heart muscle diseases. The current WHO scheme classifies the cardiomyopathies based on pathophysiology and, when it is known, etiology. The following morphopathologic designations are accepted: dilated cardiomyopathy, restrictive cardiomyopathy, hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and unclassified cardiomyopathy. Each of these basic types of heart muscle disease can be described as idiopathic or as a specific cardiomyopathy when the cause is known. However, the use of a functional classification without other qualifiers is often reserved for patients with primary cardiomyopathies. For example, hypertrophic cardiomyopathy usually applies to an idiopathic myocardial disease characterized by hypertrophy of a nondilated ventricle. The term *thyrotoxic heart disease* or *thyroid-induced cardiomyopathy* is appropriate when myocardial disease occurs in the setting of hyperthyroidism.

2. What forms of myocardial disease occur in cats?

Three functional designations of primary myocardial disease are in widespread use:

- Hypertrophic cardiomyopathy
- Dilated cardiomyopathy
- Restrictive cardiomyopathy

Hypertrophic cardiomyopathy is probably the most common. In addition, secondary myocardial diseases, including hypertensive heart disease and thyrotoxic heart disease, are also recognized. In addition, the term *unclassified cardiomyopathy* is gaining acceptance and is used when myocardial diseases share features of the more basic functional designations.

3. What characterizes each form of feline myocardial disease (FMD)?

Dilated cardiomyopathy (DCM) is characterized by ventricular dilation and hypokinesis. Atrial dilation results from atrial myocardial disease, secondary atrioventricular (AV) valve incompetence, and elevation of ventricular filling pressures. The recognition of the association between nutritional taurine deficiency and DCM prompted supplementation of commercial cat food with this amino acid. Supplementation has reduced dramatically the prevalence of DCM in cats. Idiopathic DCM still occurs in cats, albeit uncommonly.

Hypertrophic cardiomyopathy (HCM) is characterized by hypertrophy of a nondilated ventricle in the absence of systemic hypertension, anatomic ventricular outflow tract obstruction, or metabolic derangements. Systolic ventricular performance in HCM is normal or hyperdynamic. Mitral valve regurgitation may complicate HCM because of distortion of the mitral valve apparatus related to hypertrophy, systolic anterior motion of the mitral valve leaflets, or papillary muscle dysfunction. Mitral valve regurgitation, together with elevation of ventricular filling pressures associated with diastolic dysfunction, contributes to the development of left atrial dilation.

Restrictive cardiomyopathy is characterized by atrial dilation and ventricular dimensions that are normal or nearly so and systolic myocardial function that is normal or only mildly diminished.

Expression of myocardial disease in cats is diverse. Although some cats have cardiomyopathies that fit easily into the above categories, in other cases the distinctions are less clear and the nature of the myocardial disease defies currently accepted methods of classification. For example, some

feline cardiomyopathies have features of more than one morphologic or functional designation. Some of these cases may represent an intermediate phase of a progression in which the end result will be more easily classified. The use of the term intermediate or unclassified cardiomyopathy is probably appropriate in this setting. Alternatively, a functional and morphologic description based on echocardiographic findings is appropriate and perhaps superior to the use of a single term that, in a specific instance, may be inaccurate or lack specificity.

Thyrotoxic heart disease. The cardiovascular manifestations of thyrotoxicosis are varied. Some cats with hyperthyroidism develop a secondary myocardial disease that closely resembles idiopathic hypertrophic cardiomyopathy, whereas others have ventricular dilation with apparently preserved systolic function. Yet another subset of the hyperthyroid population is characterized by systolic myocardial dysfunction; dilated cardiomyopathy has been observed in association with hyperthyroidism.

Hypertensive heart disease. Systemic hypertension results in concentric left ventricular hypertrophy in some cats.

4. The various forms of FMD differ in terms of pathophysiology. Contrast the mechanisms by which HCM and DCM result in cardiac dysfunction and congestive heart failure.

DCM is primarily a disorder of systolic myocardial dysfunction. When myocardial contractility is impaired, the stroke volume declines and the end-systolic ventricular volume is increased. This residual volume, augmented by pulmonary venous return, results in ventricular dilation. If ventricular filling pressures become sufficiently high, they are reflected onto the upstream capillary bed, resulting in the development of tissue edema or accumulation of effusions. Usually, the left ventricle is affected in DCM, and pulmonary edema is the expected consequence, although pleural effusions also may occur. Cardiogenic pleural effusion in cats is seldom associated with ascites and may result from diseases that, based on echocardiographic study, seem to affect primarily the left ventricle.

In contrast to DCM, the primary pathophysiologic mechanism in HCM is diastolic dysfunction. Diastolic function is difficult to quantify and perhaps less tangible than systolic function, which has an importance that is easily and intuitively grasped. Diastolic function is determined by the active, energy-requiring process of myocardial relaxation as well as a mechanical property of the ventricle known as compliance. Compliance is the relationship between a change in volume and the associated change in pressure. When primary diastolic dysfunction is present, ventricular filling pressures are elevated when diastolic volumes are normal or small. Congestive signs may result if elevated filling pressures are reflected onto the pulmonary venous circulation. Diastolic dysfunction also may explain signs of low-output failure because impaired ventricular filling reduces stroke volume.

5. What is feline endomyocarditis?

Recently, the clinical characteristics of a series of cats with histologic findings of endomyocarditis were described. A stressful event such as anesthesia for sterilization or declawing was noted in the history of many of these cats. The clinical presentation was characterized by sudden onset of severe dyspnea, radiographic pulmonary opacities, and echocardiographic evidence of minimal atrial enlargement. The echocardiographic finding of an abnormally echogenic endocardium was believed to be distinctive. The dyspnea was apparently associated with interstitial pneumonia. The cause of this syndrome is unknown. Recognition may be important, because the dyspnea is unlikely to be due to cardiogenic pulmonary edema; overly aggressive diuresis probably should be avoided when the diagnosis is suspected.

6. What historical findings are typically associated with FMD?

Clinical signs in FMD are generally related to congestive heart failure (CHF) or systemic thromboembolism. Dyspnea resulting from pulmonary edema or pleural effusion is the clinical sign that most commonly prompts owners to present the cat for veterinary evaluation. Onset of dyspnea in cats with myocardial disease may be surprisingly sudden; the owner may have been unaware of anything untoward in the cat's behavior before development of dyspnea. Possibly this is related to the fact that most cats lead a sedentary existence; they are able to conceal signs referable to the cardiovascular system until such signs are provoked by minimal stress or exertion.

7. What physical findings are expected in cats with FMD?

Vital signs. Often cats with FMD are presented for emergency evaluation of dyspnea. Typically, the respiratory rate is elevated and respiratory effort is increased. The patient may be distressed and anxious. Some cats with FMD and markedly reduced cardiac output become hypothermic. Elevated adrenergic tone is part of the syndrome of CHF; a consequent increase in heart rate is therefore expected. Indeed, tachycardia is evident on physical examination of some patients with FMD. However, even healthy cats have relatively high heart rates in the clinic due to an elevation in adrenergic tone, presumably related to anxiety. As a result, the heart rates of cats with CHF are often comparable to heart rates of healthy cats recorded in the veterinary clinic. Except when pathologic tachycardias such as ventricular tachycardia are present, the heart rate of cats with CHF seldom exceeds the upper limit of the range that is accepted for hospitalized cats. Indeed, bradycardia is sometimes noted on physical examination of cats with CHF. The bradycardia may result from conduction system disease or extracardiac factors.

Auscultation. Auscultation may reveal crackles when pulmonary edema is present. A quiet thorax suggests pleural effusion. A systolic murmur is often but not invariably present. Some cats with FMD develop mitral valve regurgitation secondary to functional or structural changes of the mitral valve apparatus as a consequence of myocardial disease. A subpopulation of cats with HCM develops systolic anterior motion (SAM) of the mitral valve leaflets that may result in a murmur of dynamic outflow tract obstruction. More than one mechanism can explain the presence of a murmur in FMD; consequently, the systolic murmur associated with FMD is variable in intensity and character. The absence of a cardiac murmur should not exclude FMD from the differential diagnosis of cats with dyspnea. Audibility of the third or fourth heart sound or a gallop rhythm suggests myocardial dysfunction in many cats with FMD. The third heart sound (S3) is associated with termination of the rapid ventricular filling phase of early diastole. It becomes audible when transmitral flow is increased, when the passive compliance of the ventricle is reduced, or when the end-systolic volume is high. In small animals, audibility of a third heart sound is most commonly associated with dilated cardiomyopathy. The fourth heart sound (S4) is associated with the atrial contraction phase of diastole; it is accentuated and may be audible when ventricular relaxation is impaired. Distinction between the third and fourth heart sounds is not generally possible when the heart rate exceeds 150 bpm. An auscultated triple rhythm may represent a summation gallop resulting from fusion of the third and fourth heart sounds. The presence of a gallop rhythm in small animals is generally a specific sign of cardiac disease; therefore, recognition of the gallop is of much greater clinical importance than making the distinction between S3 and S4 gallop rhythms.

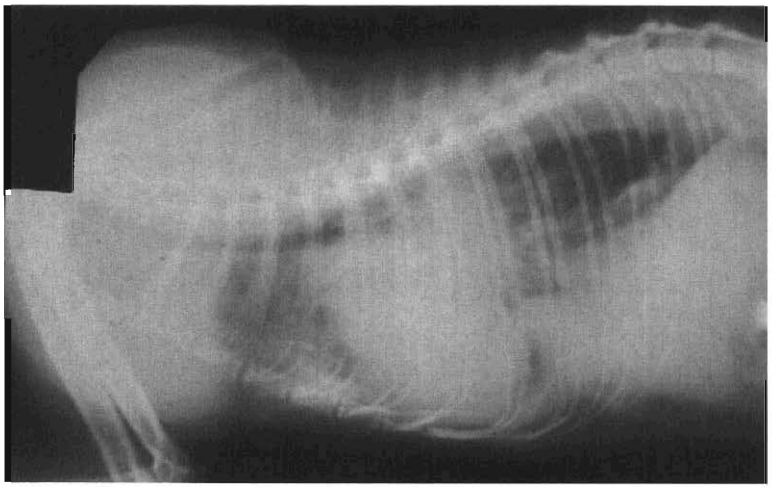
8. What is the role of electrocardiography in the diagnosis and management of FMD?

The electrocardiogram (ECG) provides information about heart rate, rhythm, and size. ECG evidence of ventricular hypertrophy is sometimes present in cats with myocardial disease. However, the primary utility of the ECG in evaluation of FMD is elucidation of disorders of rate and rhythm. Premature ventricular complexes and occasionally ventricular tachycardia may be detected. Because ventricular arrhythmia seldom complicates extracardiac disease in cats, this ECG abnormality provides useful diagnostic information in cats with signs of cardiovascular disease. Supraventricular arrhythmias, including atrial premature complexes, junctional premature complexes, and supraventricular tachycardia, also may occur in FMD. Bradyarrhythmias, including sinus bradycardia and various forms of atrioventricular (AV) dissociation related to AV block, also may complicate the presentation of FMD. AV block may result from structural disease of the conduction system, although sometimes the block is transient and associated with low cardiac output and hypothermia. When AV conduction disturbances are present, the rate of the idiojunctional or idioventricular rhythm often exceeds 100 bpm but is generally less than 150 bpm.

9. What is the role of thoracic radiography in the diagnosis of FMD?

Plain thoracic radiographs are invaluable because they allow assessment of cardiac size in relation to pulmonary vasculature and parenchyma. Usually, some degree of cardiac enlargement

precedes the development of congestive heart failure. Therefore, the chest radiograph provides an indirect assessment of global cardiac performance. Unfortunately, however, thoracic radiography is relatively insensitive in the detection of chamber enlargement; furthermore, the ability to image specific chambers is limited. These shortcomings are particularly acute in feline thoracic radiography. In addition, the stress associated with restraint is poorly tolerated by feline patients in overt CHF. The risk-to-benefit ratio of restraint for diagnostic studies must be carefully assessed before radiographic studies are undertaken.



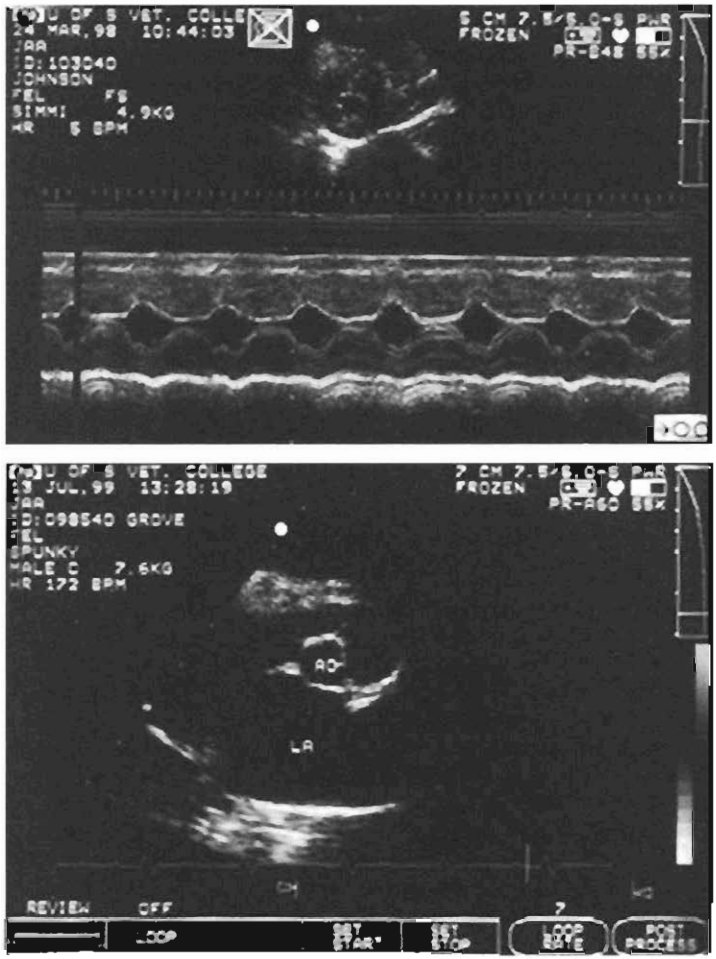
Lateral thoracic radiograph of a 5-year-old, castrated male Siamese cat who developed congestive heart failure due to hypertrophic cardiomyopathy. The cardiac silhouette is enlarged. Alveolar pulmonary opacities reflect the presence of severe edema.

10. What is the role of echocardiography in the diagnosis of FMD?

Echocardiography is a noninvasive means by which to evaluate cardiac chamber dimensions and myocardial function. The cardiac septae can be visualized, allowing relatively precise assessment of specific cardiac chambers. Other diagnostic studies, including thoracic radiography, provide information that is not obtained by echocardiographic examination. However, echocardiography is required for noninvasive antemortem diagnosis of FMD. As stated previously, the expression of myocardial disease in cats is diverse and optimal therapy likely differs in the various forms of FMD. Echocardiography is therefore indicated to obtain a definitive diagnosis, which in turn provides information that guides therapy. (See figures at top of following page.)

11. When should echocardiography be performed in patients suspected of FMD?

Echocardiography is recommended whenever FMD is suspected. In the emergency setting, the relative risk-to-benefit ratio of restraint for echocardiographic study must be carefully considered. When physical findings suggest CHF, it is often advisable to initiate treatment before undertaking diagnostic tests. However, it is sometimes possible to examine cats echocardiographically when they are in sternal recumbency and minimally restrained. Sometimes a cursory echocardiographic examination is better tolerated than restraint for radiographic examination. Cursory examination may be sufficient to establish that the patient has structural cardiac abnormalities that may reasonably have resulted in CHF. Respiratory signs in the absence of echocardiographic atrial enlargement are almost always due to extracardiac disease. As with any diagnostic test, there are limitations to echocardiography; however, if these limitations are understood, echocardiography is an appropriate initial diagnostic test in cats in whom history and physical findings suggest CHF.



Top, M-mode echocardiogram of the left ventricle of a feline patient with hypertrophic cardiomyopathy. M-mode echocardiography provides a unidimensional view of the heart; the ordinate measures distance from the transducer and the abscissa, time. The two-dimensional image from which this M-mode was derived is shown in the inset. The echocardiogram demonstrates moderate and symmetrical left ventricular hypertrophy; systolic left ventricular performance is normal or perhaps, hyperdynamic. *Bottom,* Two-dimensional right-parasternal, short-axis echocardiogram obtained at the level of the heart base. The left atrium (LA) is markedly enlarged. In this patient, hypertrophic cardiomyopathy and associated diastolic dysfunction explained the left atrial enlargement. Ao = aorta.

12. How are congestive signs managed in cats with FMD?

Diuretics are used initially in the treatment of cardiogenic pulmonary edema. Furosemide, a potent loop diuretic, is administered intravenously. The fragility of feline patients with CHF should not be underestimated; if venous access is difficult to obtain, intramuscular administration is suggested. Diuretics act at the level of the nephron to increase urine volume. The consequent decrease in intravascular volume effects a decrease in ventricular filling pressures and favors the resolution of pulmonary edema.

When radiographic, sonographic, or physical findings suggest that signs of dyspnea are caused by pleural effusion, therapeutic thoracocentesis is recommended. Thoracocentesis is suggested

before further diagnostic evaluation in patients with respiratory distress when physical findings indicate the presence of pleural effusion. Diuretics tend to mobilize body cavity effusions poorly, and the use of diuretics does not obviate the need for thoracocentesis when pleural effusion is the primary cause of dyspnea. Aggressive diuretic therapy without thoracocentesis may cause dehydration and signs of low cardiac output before causing a clinically apparent reduction in the volume of pleural effusion.

13. How is contractility manipulated in FMD?

Systolic myocardial dysfunction is seldom the primary cause of CHF in cats. Therefore, inotropic support is rarely indicated. However, catecholamines, including dobutamine, may be administered to cats with echocardiographic confirmation of systolic myocardial dysfunction. Careful monitoring is suggested because some cats develop adverse neurologic and gastrointestinal signs when receiving catecholamines.

14. How is supplemental oxygen administered?

The administration of supplemental oxygen is indicated when patients with FMD present in overt CHF and are short of breath. Cats with CHF are fragile and tolerate manipulation poorly. Usually, confinement in an oxygen cage is beneficial. An oxygen mask is generally tolerated only by moribund patients.

15. How are cats with FMD monitored?

Careful monitoring of body temperature is suggested because some patients with FMD and low cardiac output develop hypothermia. The noninvasive evaluation of blood pressure in cats is potentially challenging, although Doppler or oscillometric techniques may be considered if the patient tolerates the necessary degree of restraint. Cats, perhaps more than dogs, are apt to develop signs of low-output cardiac failure. Diuretics rarely have a salutary effect on cardiac output. In fact, a decrease in preload generally causes a decrease in stroke volume. This is usually well tolerated in patients with systolic dysfunction and dilated ventricles because the relationship between preload and stroke volume in this setting is not linear. When ventricular dilation is present, aA reduction in end-diastolic volume may relieve congestive signs with negligible effects on stroke volume. However, diseases of diastolic dysfunction are currently most prevalent in cats. In this setting, end-diastolic volumes are normal or small, and a relatively minor reduction in ventricular filling pressure may result in a clinically important decrease in stroke volume. Diuresis is certainly indicated when congestive signs are present. However, the adverse effects of excessive diuresis may be particularly acute in diseases characterized by diastolic dysfunction. When ventricular filling is impaired, the decrease in preload resulting from overly aggressive diuresis may have a noticeable and negative effect on cardiac output and result in clinical deterioration. Monitoring of the hematocrit and total protein is sometimes helpful in gauging the degree of hemoconcentration that has resulted from diuretic administration. Similarly, the blood urea nitrogen or, preferably, the creatinine level is monitored in patients with FMD.

16. Should intravenous fluids be administered to cats with FMD? If so, what kind of fluid?

The administration of intravenous fluid increases intravascular volume and, as a consequence, ventricular filling pressures. This has obvious benefit in hypovolemic patients. In CHF, ventricular filling pressures (preload) are already excessive. A clinical diagnosis of CHF means that ventricular filling pressures are elevated; in the setting of overt CHF, infusion of fluid is unlikely to effect an increase in stroke volume but is likely to contribute to the accumulation of edema fluid. The careful administration of maintenance volumes of crystalloid is considered when respiratory distress has resolved but the patient is slow to recover and unwilling or unable to take fluid and food by mouth. The use of a low sodium fluid, such as 5% dextrose in water or 0.45% saline with 2.5% dextrose in water, is recommended.

17. What are the roles of calcium channel blockers in FMD?

Calcium channel antagonists bind to the L-type calcium channels of myocardial and vascular smooth muscle cells. In general, the calcium channel antagonists act as negative inotropes, negative chronotropes, and vasodilators. Evidence also suggests that they increase the rate of myocardial relaxation-that is, they have a positive lusotropic effect. Based largely on the assumption that a positive lusotropic effect is helpful in HCM, they have found favor in treatment of HCM in cats.

Diltiazem is the calcium channel antagonist currently in widespread use for treatment of feline HCM. It is most often administered orally as chronic therapy and is used as an adjunct to diuretic therapy in patients with HCM and clinical signs due to CHF. In cats with HCM but no clinical signs, diltiazem is sometimes used in attempts to delay or prevent the onset of congestive signs. Its efficacy for this purpose is unknown. The author considers the use of diltiazem in cats with occult HCM if there is unequivocal echocardiographic evidence of left ventricular hypertrophy in the presence of left atrial dilation. Diltiazem also has a role as an antiarrhythmic agent when FMD is complicated by supraventricular arrhythmias. It is available in an injectable formulation that can be used in an attempt to terminate supraventricular tachycardia. In addition, injectable diltiazem may have a role in cats with overt CHF and normal or elevated heart rates that are unable to take medications orally.

18. What are the roles of beta-adrenergic antagonists in FMD?

The beta-adrenergic antagonists include propranolol, atenolol, carvedilol, and others. They bind competitively to the beta-adrenergic receptors and have negative inotropic, negative chronotropic, and negative dromotropic effects. Their effect on diastolic function is, for the most part, indirect and results from prolongation of ventricular filling time, although some evidence suggests that beta-adrenergic antagonists may increase ventricular distensibility. The negative inotropic effect may be beneficial in cats with HCM and systolic anterior motion (SAM) of the mitral valve. The results of a clinical trial suggest that diltiazem may be superior to propranolol for the treatment of CHF due to feline HCM. However, it is probably inappropriate to discard the use of beta-adrenergic antagonists completely in this setting. The effect of beta-adrenergic antagonists on heart rate is generally greater than the effect of diltiazem. Therefore, beta-adrenergic antagonists may have advantages over diltiazem in cases in which control of heart rate is an important objective, when SAM is present, or when HCM is complicated by ventricular tachyarrhythmia.

19. Suggest a protocol for the management of severe heart failure due to diastolic dysfunction.

- Cage rest
- Oxygen supplementation
- Furosemide administered based on clinical status and response. Feline patients with diastolic dysfunction are intolerant of overly aggressive diuresis. Monitoring of the blood urea nitrogen, hematocrit and total protein can be used to guide therapy.
- Specific interventions such as diltiazem are usually reserved for chronic management of patients following echocardiographic evaluation.

20. Does empirical therapy have a role? What response is expected when CHF is the cause of dyspnea?

In some patients with severe dyspnea, the risk associated with restraint for diagnostic evaluation cannot be justified, and empiric therapy is reasonable. When physical and historical findings suggest a diagnosis of fulminant CHF, furosemide is administered with careful monitoring of clinical response. The concurrent use of nitroglycerin might be beneficial and can also be considered. In cats, allergic bronchitis can be difficult to distinguish from acute CHF based only on physical and historical findings. While the indiscriminate use of corticosteroids is obviously to be avoided, a single dose of prednisone is usually tolerated and can be justified if diagnostic evaluation is pursued following resolution of respiratory distress.

When cardiogenic pulmonary edema is the cause of dyspnea the response to brisk diuresis is often prompt and dramatic. When patient response is poor, the risk:benefit ratio associated with

diagnostic evaluation may shift so that restraint for diagnostic procedures can be justified. Prolonged and aggressive diuretic therapy can result in clinical deterioration in cases in which respiratory disease is in fact responsible for clinical signs.

CONTROVERSIES

21. Are vasodilators indicated in HCM?

Vasodilators have proven efficacy in the treatment of patients with DCM and primary valvular disease. The rationale for their use is based on the premise that peripheral vascular resistance is inappropriately elevated in these disorders. The decrease in peripheral vascular resistance that results from vasodilation permits an increase in stroke volume, and the effect of judicious vasodilation is clearly beneficial.

Most cats with HCM have normal or hyperdynamic systolic ventricular performance. It is unlikely that a mismatch of systolic function and aortic impedance is present. Conceivably, treatment with vasodilators may result in systemic hypotension. An important hemodynamic consideration relates to the presence of SAM, a valve motion abnormality detected in some cats with HCM. Vasodilation may increase the pressure gradient associated with SAM, and vasodilators are believed to be contraindicated in human patients with HCM.

22. What is the role of angiotensin-converting enzyme (ACE) inhibitors in feline HCM?

The use of the ACE inhibtor enalapril and, more recently, benazepril has been investigated in cats with HCM, and adverse effects related to the hemodynamic effects of the drug were not recognized. Mitral valve regurgitation occurs commonly in cats with HCM. In the setting of HCM complicated by mitral valve regurgitation, a decrease in peripheral vascular resistance may have favorable effects. Furthermore, the results of ACE inhibition are not limited to the mechanical effect of vasodilation. For example, experimental evidence suggests that ACE inhibitors have a positive lusotropic effect. In addition, ACE inhibition reduces aldosterone levels, an effect that is probably helpful in the setting of CHF. In addition, angiotensin II has trophic effects on myocardium. Although the relevance of these observations to spontaneous HCM in cats is unknown, it is possible that some of the neurohumoral effects of ACE inhibition are beneficial.

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57. SYSTEMIC ARTERIAL THROMBOEMBOLISM

Steven L. *Marks*, B.V.Sc., M.S., M.R.C.V.S.

1. Define thromboembolism.

A thrombus is an intravascular deposit of fibrin and formed blood elements. Thromboembolism occurs when the entire thrombus or a piece of thrombus formed at one location travels in the vascular system and lodges in a distant site.

2. What is the basic pathophysiology of thromboembolism?

- Local endothelial or endocardial injury
- Altered blood flow or stasis
- Altered coagulability

3. What is the name given to these three factors?

Virchow's triad.

4. List the factors that determine the clinical consequences of thromboembolism.

- Site of thrombus origin
- Degree of occlusion
- Collateral circulation

5. What are causes of arterial thromboembolism in cats?

The most common cause of thromboembolism in cats is myocardial disease. It may be seen with dilated cardiomyopathy, hypertrophic cardiomyopathy, and restrictive cardiomyopathy. Less common causes of arterial thromboembolism in cats include:

- Bacterial endocarditis
- Neoplasia
- Sepsis
- Heartworm disease
- Idiopathic

6. What are the most common anatomic sites for thromboembolism in cats?

The aorta and iliac bifurcation are the most common sites of thromboembolism in cats. Other sites include:

- Forelimbs
- Kidney
- Brain
- Gastrointestinal tract

7. What are causes of thromboembolism in dogs?

- Heartworm disease
- Hyperadrenocorticism
- Neoplasia
- Fractures

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57. SYSTEMIC ARTERIAL THROMBOEMBOLISM

Steven L. *Marks*, B.V.Sc., M.S., M.R.C.V.S.

1. Define thromboembolism.

A thrombus is an intravascular deposit of fibrin and formed blood elements. Thromboembolism occurs when the entire thrombus or a piece of thrombus formed at one location travels in the vascular system and lodges in a distant site.

2. What is the basic pathophysiology of thromboembolism?

- Local endothelial or endocardial injury
- Altered blood flow or stasis
- Altered coagulability

3. What is the name given to these three factors?

Virchow's triad.

4. List the factors that determine the clinical consequences of thromboembolism.

- Site of thrombus origin
- Degree of occlusion
- Collateral circulation

5. What are causes of arterial thromboembolism in cats?

The most common cause of thromboembolism in cats is myocardial disease. It may be seen with dilated cardiomyopathy, hypertrophic cardiomyopathy, and restrictive cardiomyopathy. Less common causes of arterial thromboembolism in cats include:

- Bacterial endocarditis
- Neoplasia
- Sepsis
- Heartworm disease
- Idiopathic

6. What are the most common anatomic sites for thromboembolism in cats?

The aorta and iliac bifurcation are the most common sites of thromboembolism in cats. Other sites include:

- Forelimbs
- Kidney
- Brain
- Gastrointestinal tract

7. What are causes of thromboembolism in dogs?

- Heartworm disease
- Hyperadrenocorticism
- Neoplasia
- Fractures

- Nephrotic syndrome
- Disseminated intravascular coagulopathy
- Immune-mediated hemolytic anemia
- Sepsis
- Pancreatitis
- Myocardial disease
- Foreign body

8. What are the most common anatomic sites for thromboembolism in dogs?

- Aorta
- Pulmonary artery
- Lungs
- Kidney
- Forelimbs
- Gastrointestinal tract
- Brain

9. Describe the clinical signs of thromboembolism.

Clinical signs associated with thromboembolism are generally related to hypoperfusion of a specific area or organ system. The specific clinical signs are therefore related to the underlying disease or organ system involved. For example, clinical signs of pulmonary thromboembolism include hypoxemia and respiratory distress.

10. List clinical signs specific for thromboembolism of a limb.

- Lack of detectable pulses
- Decreased temperature compared with normal limb
- Cyanosis of nail beds or pads
- Neurologic deficits
- Pain

11. List diagnostic procedures that help to evaluate for the presence of thromboembolism.

The diagnostic tests should be directed toward finding the underlying disease that has led to thromboembolism:

- Complete blood count
- Biochemical profile
- Urinalysis
- Antithrombin III levels
- Adrenocorticotropic hormone stimulation test
- Heartworm antigen test
- Echocardiography
- Doppler ultrasound
- Thyroid profile
- Thoracic radiographs
- Blood gas analysis
- Ventilation/perfusion studies
- Coagulation profile
- Coombs test

12. Which tests are both specific and sensitive for thromboembolism?

- Selective or nonselective angiography
- Ultrasound to visualize thrombus
- Doppler studies to evaluate blood flow

13. What therapeutic options are available for thromboembolism?

Most therapy for arterial thromboembolism is directed toward correcting the underlying disease processes. Other therapy may be divided into supportive, preventive, or thrombolytic.

14. What supportive care is required for thromboembolism?

Supportive care is based on the system involved. For example, with pulmonary thromboembolism oxygen therapy is beneficial. For renal thromboembolism, surgical intervention and fluid therapy are suggested. Cats with arterial thromboembolism often require analgesia.

15. List therapies that may prevent further thromboembolism.

- Heparin
- Warfarin
- Aspirin

16. Which drugs may improve collateral circulation?

- Hydralazine
- Acepromazine

17. Which thrombolytic drugs are currently used?

- Streptokinase
- Urokinase
- Tissue plasminogen activator

18. Can heparin be used as an anticoagulant in all cases of thromboembolism?

No. Animals with protein-losing nephropathy often lose significant amounts of antithrombin III. Heparin requires antithrombin III as a cofactor. In such cases, fresh frozen plasma may be used as an antithrombin III source, or other anticoagulants such as warfarin may be considered.

19. What emergency therapy may be provided for thromboembolism?

Emergency therapy also should be directed toward the underlying disease process. Supportive care, including fluid therapy and analgesia, is generally indicated.

Pulmonary thromboembolism

- Oxygen
- Bronchodilators
- Vasodilators
- Calcium channel blockers
- Corticosteroids
- Thrombolytic drugs

Peripheral thromboembolism

- Vasodilators
- Aspirin
- Heparin
- Thrombolytic drugs

20. What is the prognosis of thromboembolic disease? How long should treatment be continued?

The prognosis for animals with thromboembolic disease is based on the underlying disease and how easily it can be managed. Overall the prognosis is guarded, especially for cats with myocardial disease, because recurrence is high. There is no time limit for medical management. Duration of treatment is usually based on the clinical condition of the animal and finances. Owners can provide good nursing care in their home.

CONTROVERSY

20. Is surgical therapy indicated for thromboembolic disease?

In most cases surgical therapy is not indicated because of instability due to the underlying disease process. If, however, aggressive medical management leads to no improvement, embolectomy may be considered. Unfortunately, recurrence of thromboembolism is nearly 100%.

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VII. Oncologic and Hematologic Emergencies

Section Editor: Gregory K. Ogilvie, D.V.M.

58. NEUTROPENIA, SEPSIS, AND THROMBOCYTOPENIA IN PATIENTS WITH CANCER

Gregory K. Ogilvie, D.V.M.

1. Is sepsis secondary to neutropenia a true oncologic emergency?

Absolutely. Sepsis is the most common cause of death in people with cancer, exceeding all other causes combined. Neutropenia secondary to malignancy or myelosuppressive effects of chemotherapy is a common predisposing factor for development of sepsis in dogs and cats, which, if left untreated, is almost always fatal. The seriousness of this condition cannot be overstated. Because owners are demanding advanced care for their pets with cancer, the use of combination chemotherapy for treatment of a wide variety of malignancies in dogs and cats has increased; therefore, neutropenia and sepsis are emergencies of increasing prevalence and importance. Neutropenia and thrombocytopenia may occur in animals with many other diseases; the treatment is often the same for these patients as for animals with cancer. This condition requires immediate recognition and rapid support.

2. Does the client need support in this type of emergency?

Unquestionably. The only word more feared in the English language than cancer is chemotherapy. Clients are afraid of chemotherapy, and most feel very guilty if complications result from cancer treatment. Therefore, it is just as important to meet the nonmedical needs of the client as it is to meet the medical needs of the patient. The consequence of not understanding and responding to this balance often leads to the euthanasia of the patient.

3. Describe the pathogenesis and consequences of neutropenia and sepsis.

Neutropenia and sepsis may be transient problems that resolve when the animal's white blood cell count returns to normal, or they may progress to transient pyrexia or septic shock. Septic shock is the state of circulatory collapse secondary to overwhelming sepsis and/or endotoxemia. This syndrome frequently is fatal, with a mortality rate of 40–90% in humans. Although no data document the percentage of fatalities in pets with septic shock, it is believed to be at least as high as the percentage reported in people. The profound systemic effects of septic shock include:

- Vasoconstriction leading to multiorgan failure
- Cardiac dysfunction, in part from lactic acidosis
- Increased vascular permeability leading to hyperviscosity and hypovolemia
- Liver dysfunction from splanchnic vascular pooling and tissue ischemia
- Acute renal failure
- Worsening neutropenia and thrombocytopenia
- Coagulopathies
- Severe gastrointestinal damage
- Decreased insulin release
- Initial hyperglycemia followed by hypoglycemia.

4. What kinds of bacteria are most commonly involved in sepsis secondary to neutropenia?

Fortunately, the bacteria that most commonly cause morbidity and mortality in veterinary patients with cancer arise from the animal's own flora. Prolonged hospitalization and antibiotic use result in susceptibility to resistant strains of organisms. The increasing risk for fungal infections is an emerging problem in human oncology and probably will be recognized in the near future in veterinary medicine. Therefore, culturing for fungi will become an important issue.

5. What are the most common causes of neutropenia?

The causes of neutropenia are extensive. Neutropenia may result from leukemia or lymphoma caused by bone marrow destruction or from the myelosuppressive effects of chemotherapy. The myelosuppressive effects of chemotherapeutic agents can be categorized as high, moderate, and mild. These drugs cause a nadir (lowest part of the white blood cell count) at different times after administration. Infection early in the course of neutropenia typically is caused by endogenous bacteria that are relatively nonresistant. Frequent acquisition of blood samples greatly increases the risk of infection in cancerous animals. Other sites of entry of organisms include the skin, oral cavity, colon, and perianal area.

Mature neutropenia

1. Marrow hypoplasia
   - Chemical intoxication
   - Idiosyncratic drug reactions
   - Cancer chemotherapy
   - Viral diseases (FeLV, panleukopenia)
2. Myelophthisis
   - Myeloproliferative disorders
   - Lymphoproliferative disorders
3. Increased margination
   - Endotoxemia
   - Shock
4. Increased removal
   - Immune-mediated
   - Hypersplenism

Predominantly immature neutrophils

1. Acute overwhelming bacterial infection
2. Viral diseases (feline leukemia virus [FeLV], feline immunodeficiency virus [FIV], panleukopenia)

Marrow hypoplasia frequently involves more than one cell line. Bone marrow examination is recommended.

6. Which specific bacteria are commonly associated with sepsis in patients with cancer?

Gram-negative bacteria

- *Escherichia coli*
- *Klebsiella pneumoniae*
- *Pseudomonas* sp.
- *Enterobacteriaceae* sp.

Gram-positive bacteria

- *Staphylococcus epidermitidis*
- *S. aureus*

The increase in the prevalence of gram-positive infection may be due to the chronic use of venous and urinary catheters.

7. What common causes or acquired conditions are associated with sepsis in patients with cancer?

1. **Defects in cellular immunity** are also a cause of sepsis in animals with cancer. Cellular immune dysfunction may be due to an underlying cause or antineoplastic agents and corticosteroids. It results in various bacterial, mycobacterial, fungal, and viral infections. Humoral immune dysfunction also is associated with an increased prevalence of sepsis in human patients with cancer and may cause similar problems in animals with cancer. Agammaglobulinemic or hypogammaglobulinemic animals are susceptible to infections. Multiple myeloma and chronic lymphocytic leukemia are common neoplasms associated with humoral immune dysfunction.

2. **Splenectomized animals** are susceptible to overwhelming sepsis when infected with a strain of encapsulated bacteria against which they have not made antibodies. Dogs that have had routine splenectomy may have decreased long-term survival because they lack an intact immune system.

3. **Indwelling vascular or urinary catheters** have been associated with increased prevalence of sepsis. The longer a catheter is present, the higher the probability for infection, especially in neutropenic patients. The risk of catheter-induced sepsis can be minimized by using aseptic technique and by placing a new catheter in a new site every 2-3 days. Strict aseptic procedures should be used, especially with animals that are myelosuppressed. The use of semipermanent indwelling catheters in patients with cancer may be safe if strict aseptic procedures are followed by owners and health care professionals.
4. **Prolonged hospitalization** can result in serious consequences, in part because the patient is exposed to bacterial strains resistant to the antibiotics most commonly used in that practice.
5. **Malnutrition** is a serious cause of debilitation and secondary resistance to bacterial infection, especially in those patients with neutropenia.
6. **Neurologic dysfunction** or inability to ambulate from any cause.

8. What is the best way to recognize the septic patient?

Obtain an adequate history while performing a physical examination. This approach may reveal either the hyperdynamic or hypodynamic state of shock. In addition, the some of the following may be identified on physical examination in animals with the hyperdynamic state of septic shock:

- Tachycardia
- Short capillary refill time
- Gastrointestinal signs
- Altered mentation
- Decrease in blood pressure.

End-stage signs reflect a hypodynamic state and include:

- Hypothermia
- Mucous membrane pallor
- Marked mental depression
- Bloody diarrhea
- Signs of multiorgan failure

9. What is unusual about the results of diagnostic tests in a neutropenic patient with sepsis?

The absence of circulating neutrophils results in a urinalysis without pyuria and chest radiographs that are normal because of lack of neutrophilic infiltrates. Neutrophils are responsible for the early radiographic changes associated with pneumonia. Therefore, these conditions are often not identifiable by standard diagnostic tests.

10. What should be cultured in neutropenic, septic patients?

Quite simply, everything.

Blood cultures. Two, and preferably four, sets of blood cultures (aerobic and anaerobic) should be acquired. The timing of the sampling intervals is controversial; however, every 20–30 minutes before antibiotic therapy may be adequate. At least 5 ml of blood should be injected into appropriate culture containers.

Catheter cultures. If central venous catheters are present, cultures of the port should be obtained. Ideally, culture bottles that contain an antibiotic-binding resin or other antibiotic-binding substance should be included with each culture for patients on antibiotics.

Urine culture. A cystocentesis specimen for urine culture and analysis should be acquired in each case after the patient has been evaluated to ensure the presence of at least 60,000 platelets/ml.

Cerebrospinal fluid (CSF) culture. When neurologic signs are present, a CSF tap should be obtained and cultured appropriately. CSF should be sent for Gram stain, bacterial culture, cell count and differential, and glucose and protein determination. A cryptococcal antigen titer or India ink preparation should be performed in suspect cases. Acid-fast stains and culture probably are not indicated routinely.

Stool cultures. For animals with diarrhea, appropriate cultures should be done for clostridial bacteria, including appropriate assays for endotoxin.

Lung cultures. Chest radiographs and a transtracheal wash should be taken, especially when the patient shows any sign of respiratory difficulty such as cough.

11. What other diagnostic tests should be considered?

- Complete blood count with differential, biochemical profile, and urinalysis
- Chest and abdominal radiographs to look for signs of infection
- Abdominal ultrasonography looking for pancreatitis, abscesses, abdominal effusion
- Ultrasonography, especially echocardiography, to identify the presence of valvular endocarditis
- Bronchoscopy if pulmonary disease is suspected
- Skin biopsy if deep cutaneous infection is identified
- Bone marrow aspirate or biopsy to determine the source of neutropenia
- Percutaneous liver biopsy or aspirate to evaluate for hepatic infection or abscessation.
- Exploratory laparotomy in select cases when other, less invasive tests are not successful, yet there is clinical evidence of disease in the abdomen. A negative exploratory is better than a positive necropsy result.

12. What are the overall goals of treating septic, neutropenic animals?

- To restore adequate tissue perfusion
- To improve alterations in metabolism
- To control systemic infection

13. What type and how much fluid should be used to restore tissue perfusion?

Standard therapy includes crystalloid solutions and antibiotics. Although hypertonic solutions are currently under investigation for treatment of shock, crystalloid solutions such as lactated Ringer's are cited in most veterinary books as the first line of therapy, with an initial infusion rate for critical animals of 70–90 ml/kg IV for 1 hour, followed by 10–12 ml/kg/hr. The fluid rate should be adjusted to meet the needs of each patient, as directed by monitoring of body weight, heart and respiratory rates, central venous pressure, ongoing losses such as vomiting and diarrhea, and urine output. Lactate-containing fluids may be contraindicated because septic animals are already hyperlactatemic and engaged in futile cycling throughout the course of septic shock. Septic animals with cancer are even more likely to be detrimentally affected by lactate-containing fluids. The administration of lactate-containing fluids to hypermetabolic patients that are septic may further tax this energy-consuming system and result in further debilitation. Therefore, 0.9% sodium chloride or a balanced electrolyte crystalloid solution (e.g., Normosol R) should be used. Dextrose (2.5–5%) should be included in fluids when systemic hypoglycemia is identified during constant monitoring. In states of severe cardiovascular shock, 70–90 ml/kg for the first hour, followed by up to 10 ml/kg/hr, is recommended. When fluids are administered at this rate, the patient must be monitored closely and the rate changed to meet individual needs.

14. What type of antibiotics are used in neutropenic patients, with or without sepsis?

Asymptomatic neutropenic patients. Asymptomatic animals with less than 1,000–1,500 neutrophils/ml should be started on prophylactic antibiotics. Trimethoprim-sulfa (7.5 mg/kg twice daily orally) is often recommended for prophylactic therapy in neutropenic animals.

Symptomatic neutropenic patients. Neutropenic animals in septic shock should be started on IV fluids and IV antibiotic therapy as soon as samples for bacterial cultures are acquired. Reevaluation of an empiric antibiotic regimen is mandatory when the identity and sensitivity pattern of the bacteria become available. When a gram-negative infection is present, the two most effective antibiotics against the isolated organism often are recommended. Bacteremias are associated with gram-negative bacteria in 30–70% of cases, gram-positive isolates in 25–50%, anaerobes in 10–30%, and mixed infections in 10–50%. Broad-spectrum antibiotic therapy—often combinations of aminoglycoside plus penicillin or a second-generation cephalosporin (cefoxitine, cefamandole, cefaclor, cefuroxime, cefonicid, ceforanide, cefotetan, cefetazole)—is a

common initial choice in sepsis. If the infection does not respond within 12–24 hr, the antibiotics should be changed. For gram-negative organisms a different aminoglycoside, quinolone, or aztreonam may be used. Extended-spectrum penicillins (e.g., ticarcillin, carbenicillin, azlocillin, piperacillin sodium, and mezocillin), third-generation cephalosporins (e.g., cefotaxime, moxalactam, cefoperazone, ceftizoxime, ceftriaxone, ceftazidime, cefixime), or imipenam with cilastatin sodium have sufficiently broad spectrums to be used alone.

15. What other treatments can be used now or in the near future?

1. **Corticosteroids** remain controversial in septic shock. Recommended doses in shock are hydrocortisone at 300 mg/kg, methylprednisolone or prednisone at 10–30 mg/kg, or dexamethasone at 4–8 mg/kg. Short-term use (i.e., < 2 days) of massive doses does not result in as many adverse effects as long-term use.

2. **Glucose** (0.25-gm/kg IV bolus) can be given if hypoglycemia is present. The initial bolus should be followed by infusions of 2.5–10% glucose solutions, as needed, to maintain normal blood glucose levels.

3. **Bicarbonate** can be given if severe metabolic acidosis is present. The amount can be calculated (i.e., base deficit × [0.3 × BW in kg]) or estimated (mild, moderate, or severe acidosis is treated with 1, 3, or 5 mEq bicarbonate/kg IV, respectively). Bicarbonate should be given slowly over 20 minutes or more.

4. **Neutrophil-rich transfusions** have not been associated with beneficial responses in controlled trials. In addition, transfusion reactions and allosensitizations to specific antigens of the granulocytes may occur, and increased prevalence of severe pulmonary reactions also may be noted.

5. **Hematopoietic growth factors.** Canine recombinant granulocyte colony-stimulating factor (rcG-CSF, 5 mg/kg/day subcutaneously [SQ]) and canine recombinant granulocyte-macrophage colony-stimulating factor (rcGM-CSF, 10 mg/kg/day SQ) have been associated with an increased rate of myeloid recovery in dogs and cats with neutropenia. These hematopoietic growth factors increase cell numbers and enhance neutrophil function but are not yet available commercially. Human recombinant G-CSF and GM-CSF are commercially available; however, long-term use may induce antibody formation to the protein. Of the two human recombinant proteins, rhG-CSF induces the most profound increase in canine and feline neutrophil numbers before development of antibodies is noted.

6. **Other options.** Tumor necrosis factor antiserum, antibody to tumor necrosis factor, interleukin and interferon therapy, pooled immunoglobulin preparations, and monoclonal antibodies to neutralize endotoxin may be future treatments of choice.

16. Summarize the initial approach to the febrile, neutropenic patient.

1. Identify the site of infection.
   - Perform complete history and physical examination.
   - Acquire complete blood and platelet count, biochemical profile, and urinalysis
   - 2–4 blood cultures, cystocentesis for culture and sensitivity, chest radiographs, and transtracheal wash and culture and sensitivity.
   - If indicated, culture and sensitivity for CSF, catheters, joint fluid, feces.
2. Initiate supportive care.
   - Establish indwelling IV catheter aseptically, and initiate fluid therapy. For shock: 70–90 mg/kg for the first hour, followed by 10–12 mg/kg/hr. Adjust as needed thereafter.
   - Withhold chemotherapeutic agents.
3. Initiate IV antibiotic therapy after cultures.
   - If aminoglycosides are contraindicated (e.g., dehydration, renal disease)—cefoxitin (22 mg/kg 3 times/day).
   - If aminoglycosides are not contraindicated—cefoxitin (22 mg/kg 3 times/day), gentamicin (2–3 mg/kg 3 times/day). Monitor for nephrotoxicity.
   - Granulocyte colony-stimulating factor, if available (5 μg/kg/day SQ for < 14 days if human recombinant product is used)

4. Redefine antibiotic therapy based on culture and sensitivity results.
   - Monitor fever and neutrophil count.
   - Give fluid therapy as needed for shock and support.
5. Discharge for home care (neutrophils > 1,500 µl and afebrile) with appropriate antibiotic therapy (e.g., trimethoprim-sulfasalazine, 15 mg/kg orally 2 times/day).
6. Consider dose reduction with next course of chemotherapy (e.g., decrease by 25%).

From Ogilvie GK, Moore AS: Managing the Veterinary Cancer Patient: A Practice Manual. Veterinary Learning Systems, Trenton, NJ, 1995, with permission.

17. What can be done to prevent sepsis in neutropenic patients?

Sepsis can be prevented by altering the environment and by using surveillance cultures. Typical environmental manipulations include washing hands and changing protective gloves between each patient. This approach may prevent introduction of infections from patient to patient and from veterinarian to animal. Foods, objects, or specific materials (e.g., rectal thermometers) also may harbor bacteria. Prophylactic antibiotic therapy is recommended by some; however, it may result in increased bacterial resistance, especially in areas of high antibiotic use such as university hospitals. In humans, the most common prophylactic antibiotic therapy includes nonabsorbable agents, quinolones, trimethoprim-sulfamethoxazole, antifungal drugs, antiviral drugs, and antiparasitics. Immunization with appropriate viral vaccines may be of value; however, the vaccines must be initiated before starting chemotherapeutic agents.

18. What is the most common cause of thrombocytopenia?

A decreased platelet count is most commonly caused by the cytotoxic effects of chemotherapeutic agents, bone marrow infiltration by a malignant process, or consumption coagulopathy. If a chemotherapeutic agent induces bone marrow suppression that results in cytopenia, thrombocytopenia usually occurs a few days after neutropenia and before a decrease in red blood cells. Other causes include:

- Immune-mediated thrombocytopenia
- Modified live virus vaccine-induced thrombocytopenia
- Drug-related thrombocytopenia (chemotherapeutic agents, cephalosporins, chloramphenicol, cimetidine, estrogen, gold salts, griseofulvin, levamisole hydrochloride, methimazole, metronidazole, nonsteroidal antiinflammatories, penicillins, phenobarbital, phenothiazines, phenylbutazone, procainamide hydrochloride, propylthiouracil, and sulfonamides)
- Microangiopathy
- Disseminated intravascular coagulation (increased platelet consumption)
- Hemolytic uremic syndrome
- Vasculitis
- Splenomegaly and hepatomegaly
- Splenic torsion
- Endotoxemia
- Sepsis
- Acute hepatic necrosis
- Infectious diseases

19. What factors predispose to thrombocytopenia?

Thrombocytopenia may occur in any patient with cancer that receives myelosuppressive chemotherapeutic agents. Drugs such as vincristine, bleomycin, and prednisone do not cause as significant a degree of thrombocytopenia as myelosuppressive agents such as doxorubicin. Compared with other myelosuppressive drugs, cyclophosphamide induces suppression in platelet numbers. Dogs or cats with bone marrow infiltration by a malignant process are more sensitive to the cytotoxic effects of chemotherapeutic agents that may result in thrombocytopenia. Other conditions that affect the bone marrow (e.g., ehrlichiosis, estrogen toxicity from exogenous supplementation or from a productive testicular tumor) are likely to make the marrow

more sensitive to cytotoxic agents. Tumors that are frequently associated with coagulopathies (e.g., hemangiosarcoma, thyroid carcinoma) may cause consumptive thrombocytopenia. In addition, hypersplenism and chronic bleeding of any origin may cause a decrease in platelet numbers.

20. How is thrombocytopenia diagnosed?

Clinical signs include but are not limited to bleeding diatheses, melena, and weakness. The blood loss may occur into any organ and result in clinical signs related to the damaged tissues. An acute decline in platelet numbers may result in development of clinical signs at higher platelet counts than if the decline in platelets is much slower. Diagnosis is confirmed by obtaining platelet counts and doing bone marrow aspirate or biopsy. Bone marrow testing is essential and helps the clinician to determine whether decreased production is the problem. Clotting profiles (e.g., activated partial thromboplastin time, one-step prothrombin time, fibrin degradation products) may help to determine whether thrombocytopenia is due to coagulopathy, such as disseminated coagulopathy.

21. What is the treatment for thrombocytopenic patients?

Thrombocytopenia-related clinical signs may be exacerbated when drugs that affect platelet function are administered during overt or impending thrombocytopenia. Therefore, aspirin and aspirinlike drugs should be withheld. Obviously, the animal with thrombocytopenia should be kept quiet. Tranquilizers may be needed in some patients. In academic settings or large private practices, platelet transfusions may be administered to specific cases that are, or have a high likelihood of, bleeding uncontrollably. The amount of random donor platelet transfusion is generally about 3 U/m2 body surface area or 0.1 U/kg body weight. It is often recommended that each unit be administered with 30-60 ml of plasma per unit of platelets. With acute bleeding that is not responsive to other treatments or procedures, epsilon aminocaproic acid (Amicar) may be given by the intravenous or oral route (250 mg/m2 4 times/day). Vincristine (0.5 mg/m2 body surface area) may be administered IV to induce premature release of platelets from megakaryocytes. Platelet count increases in approximately 4 days after vincristine is given.

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59. ACUTE TUMOR LYSIS SYNDROME

Gregory K. *Ogilvie*, D.V.M.

1. Is acute tumor lysis syndrome a life threatening emergency?

Absolutely, although it is uncommon. Acute tumor lysis syndrome (ATLS) is a condition of acute collapse that may lead to death soon after administration of a chemotherapeutic agent to an animal with a chemosensitive tumor. In short, chemotherapy results in the acute death of large amounts of tumor and release of cellular contents that may be acutely toxic. This emergency situation is underrecognized in veterinary patients and is becoming more common with the widespread use of chemotherapeutic agents. Therefore, when a case is suspected, a complete history and physical examination is taken as an intravenous catheter is placed and blood samples are obtained for subsequent analysis.

ATLS has been documented in humans with lymphoma, leukemia, and small cell lung cancer; in dogs and cats it has been associated with lymphoma and leukemia. ATLS may occur after effective chemotherapy in animals with rapidly growing, bulky, chemosensitive tumors. The patient often presents with a history of acute decompensation over a short time, sometimes to the point of imminent death. Rapid diagnosis and therapy are essential to reduce mortality rates.

2. What factors predispose animals to ATLS?

In humans and animals, rapid tumor lysis may cause acute release of intracellular phosphate and potassium. This release of electrolytes causes hypocalcemia, hyperkalemia, and hyperphosphatemia. In humans with ATLS, hyperuricemia is also seen, but this is not a concern in veterinary patients. As noted earlier, ATLS is most common in patients with lymphoma or leukemia, partly because the intracellular concentration of phosphorus in human lymphoma and leukemic cells is 4-6 times higher than in normal cells.

ATLS is most common in animals with some degree of volume contraction and a large tumor mass that responds rapidly to cytolytic therapy. In addition, septic animals or animals with extensive neoplastic disease that infiltrates the parenchyma are predisposed to ATLS. Veterinary patients at highest risk are volume-contracted dogs with stage IV or V lymphoma that are treated with chemotherapy and undergo rapid remission. ATLS is most often identified within 48 hours after the first treatment.

3. How is ATLS diagnosed?

When ATLS is suspected, the history should document the recent administration of chemotherapy to a pet with lymphoma, leukemia or other chemoresponsive tumor. A rapid, thorough, complete, physical examination should be performed to identify tell-tale signs of cardiovascular collapse, vomiting, diarrhea, and ensuing shock. The accompanying hyperkalemia may result in a bradycardia and diminished P-wave amplitude, increased PR and QRS intervals, and, rarely, spiked T-waves on electrocardiogram. Biochemical analysis of blood may confirm the presence of hypocalcemia, hyperkalemia, and hyperphosphatemia. In the presence of elevated serum phosphate levels, hypocalcemia develops as a result of calcium and phosphate precipitation. Without effective treatment, renal failure may occur; therefore, concentrations of blood urea nitrogen and creatinine should be monitored closely. Fluid therapy should be initiated as soon as an intravenous catheter is placed.

4. What is the treatment for ATLS?

The ideal treatment is prevention. Identify predisposed patients that have heavy tumor burden, a chemoresponsive tumor, and volume contraction. Because the kidney is the main source of electrolyte excretion, metabolic abnormalities may be exacerbated in the presence of

renal dysfunction. Identification of patients at risk and correction of volume depletion or azotemia may effectively reduce the risk of ATLS; chemotherapy should be delayed until metabolic disturbances such as azotemia are corrected.

If ATLS is identified, the animal should be treated with aggressive crystalloid fluid therapy. Further chemotherapy should be withheld until the animal is clinically normal and all biochemical parameters are within normal limits. Crystalloid solutions such as lactated Ringer's solution are cited in most veterinary books as the first line of therapy, with an initial infusion rate for critical animals of 70–90 ml/kg IV for 1 hour, then 10–12 ml/kg/hr thereafter. The fluid rate then should be adjusted to meet the needs of each patient, as directed by monitoring of body weight, heart and respiratory rates, central venous pressure, ongoing losses such as vomiting and diarrhea, and urine output.

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60. COAGULATION DISORDERS

Gregory K. *Ogilvie*, D.V.M.

1. Are coagulation disorders an important oncologic emergency and a common cause of death in animals with cancer?

Absolutely. Disorders of hemostasis are a common cause of morbidity and mortality in animals and humans with cancer and may be loosely categorized as follows:

- Disseminated intravascular coagulopathy (DIC)
- Malignancy-associated fibrinolysis
- Platelet abnormalities
- Clinical syndrome of the hypercoagulable state of malignancy (e.g., hemangiosarcoma, mast cell tumor)
- Chemotherapy-associated thromboembolism (e.g., l-asparaginase, prednisone)

2. What is disseminated intravascular coagulation?

DIC is a consumptive coagulopathy that often is life-threatening. It should be considered an emergency and must be diagnosed and treated as soon as possible. Obtain a history while doing a physical examination; at the same time, a catheter should be placed to obtain blood for appropriate diagnostic steps. DIC has been associated with several of the parameters noted above and occurs with many malignancies. The malignancy sometimes induces DIC when clotting factors are activated by tumor-induced procoagulants or when the tumor directly or indirectly stimulates platelet aggregation. The resultant formation of clots in the circulation consumes clotting factors and platelets and subsequently leads to widespread bleeding. In addition, deposition of fibrin throughout the body may result in concurrent microangiographic hemolytic anemia. To reduce morbidity

renal dysfunction. Identification of patients at risk and correction of volume depletion or azotemia may effectively reduce the risk of ATLS; chemotherapy should be delayed until metabolic disturbances such as azotemia are corrected.

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and mortality, DIC must be identified and treated early. Best results are seen when at-risk patients are identified and supported with fluids and monitored for clotting coagulation disorders.

3. What factors predispose to coagulation defects?

DIC occurs with a wide variety of malignant conditions, including:

- Hemangiosarcoma
- Inflammatory carcinoma
- Lymphoma
- Mast cell tumors
- Thyroid carcinoma

Treatment with chemotherapeutic agents or surgery or concurrent infection may induce or exacerbate DIC. Renal failure and loss of low-molecular-weight coagulation factors through glomeruli also may increase the risk of coagulation abnormalities. Thrombosis with or without DIC has been identified in dogs with hyperadrenocorticism and in dogs treated with high doses of glucocorticoids. The syndrome has been identified in dogs more often than in cats.

4. What is the best way to diagnose DIC?

Clinical signs supportive of a diagnosis of DIC include but are not limited to oozing from venipuncture sites, nosebleeds, oral bleeding, melena, ecchymoses and petechial hemorrhages anywhere on the body, and hematuria. Widespread thrombosis may cause multiorgan failure that results in various clinical signs, such as acute renal failure and acute onset of respiratory distress. A diagnosis is best made by fulfilling at least three of the following criteria:

1. Abnormal activated partial thromboplastin time (APTT), prothrombin time (PT), thrombin clotting time (TCT)
2. Low plasma fibrinogen concentration
3. Low plasma antithrombin III activity
4. High serum concentration of fibrinogen-related antigens (FRAs)
5. Low platelet count

The key is to identify the problem early in an emergency setting and to initiate therapy while the condition is clinically silent or before clinical signs become serious.

5. What laboratory abnormalities are associated with DIC?

Laboratory abnormalities associated with DIC vary, depending on the organs involved and whether the DIC is acute or chronic; the chronic form of DIC is rarely associated with clinical signs. In addition, red blood cell fragmentation may result from microangiographic events that are seen in DIC. Diagnosis is based on clinical findings and an elevated PT or aPTT, thrombocytopenia, prolonged activated clotting time (ACT), decreased antithrombin III concentrations, hypofibrinogenemia, and increased fibrin degradation products (FDPs). Many emergency facilities routinely screen patients for DIC by performing ACTs.

Clinical and Laboratory Parameters Used to Diagnose Disseminated Intravascular Coagulopathy (DIC)

TESTS/OBSERVATIONS	ACUTE DIC	CHRONIC DIC
Clinical signs	Clinically evident coagulopathies	Few clinical signs evident
Onset and duration	Rapid onset, quick progression	Insidious, prolonged
PT, APTT, ACT	Prolonged	Normal to slightly decreased
Platelets	Decreased	Often normal
Fibrin degradation products	Very high	High
Fibrinogen	Decreased to normal	Normal
Antithrombin III	Reduced	Normal
Prognosis	Grave	Good

PT = prothrombin time, APTT = activated partial thromboplastin time, ACT = activated clotting time.
From Ogilvie GK, Moore AS: Managing the Veterinary Cancer Patient: A Practice Manual. Veterinary Learning Systems, Trenton, NJ, 1995, with permission.

6. What are the differential diagnoses for altered coagulation parameters?
See figure on following page.

7. What are the causes of the coagulation disorders associated with DIC?

There are many causes for DIC-associated abnormalities. In each patient, identifying and specifically treating the underlying cause are the keys to successful treatment. Decreased platelet count may be caused by bone marrow failure, increased platelet consumption, or splenic pooling of platelets. Prolonged PT may be due to lack of one or more of the following clotting factors: X, VII, V, II (prothrombin), and I (fibrinogen). Increased APTT may be caused by a deficiency in one or more of the following clotting factors: XII, XI, IX, X, VIII, V, II, and I. Heparin and oral anticoagulant therapy prolong the APTT. Low fibrinogen levels are associated with decreased production or increased consumption of this protein.

8. What is the best treatment for DIC?

Specific treatment for DIC is controversial, but certain procedures are uniformly accepted despite the fact that few data document their efficacy. Treatment revolves around the following:

1. **Underlying cause.** The most important therapy for DIC is treatment of the underlying cause.

2. **Fluids.** Fluid therapy is essential to correct volume contraction and to reduce the possibility of ensuring renal failure and acid-base abnormalities. Increases in body weight, heart and respiratory rates, and central venous pressure may suggest volume overload. Volume overload is especially threatening when the patient is anuric secondary to acute renal shutdown.

3. **Transfusion support.** In animals with a severe bleeding diathesis, fresh blood or plasma with clotting factors and platelets may be useful for replacing components of the blood that are consumed.

4. **Heparin therapy.** If thrombosis appears to be the most clinically evident problem, heparin therapy may reduce the formation of thrombi. The amount of heparin to be used is controversial. One method is to administer heparin by intermittent subcutaneous or intravenous dosages or by constant-rate infusion to prolong the APTT by 1.5–2 times. Minidose heparin therapy (5–10 IU/kg/hr by constant-rate infusion or 75 IU/kg every 8 hours subcutaneously) may be helpful in some cases. Ten IU/kg SQ daily is also used by some.

5. **Discontinuation of chemotherapy.** Chemotherapeutic agents, including prednisone, should be withheld until all evidence of DIC is eliminated and the patient has recovered completely. Dogs and possibly cats that receive glucocorticoid therapy are at major risk for thromboembolic events that can initiate or perpetuate DIC.

Animals with acute DIC have a poor prognosis; therefore, identification of patients at high risk and prophylactic treatment are of great value. Routine monitoring of ACTs and platelet counts can identify animals in the early phases of DIC.

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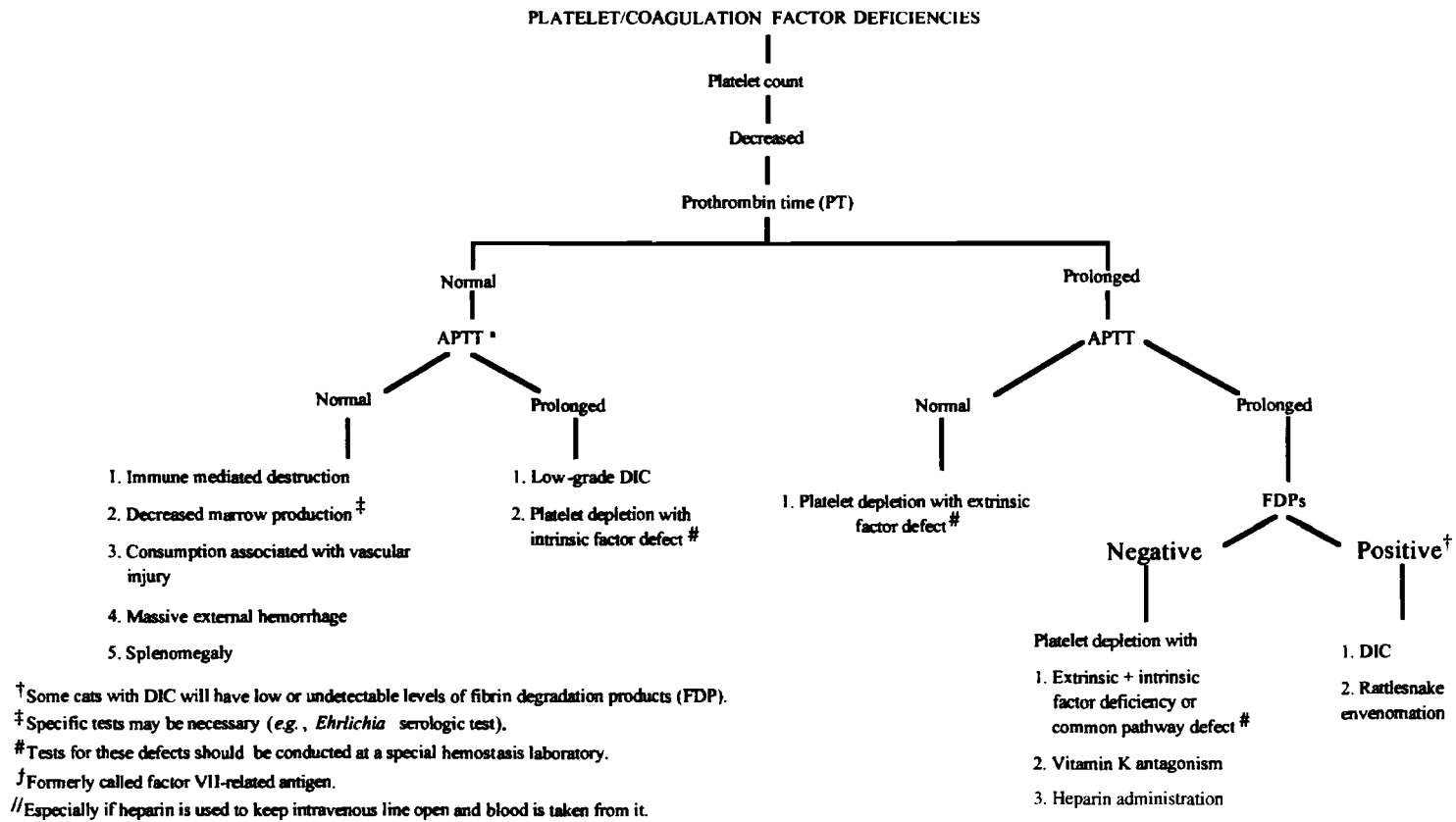

Differential diagnoses for abnormal coagulation parameters. APTT = activated partial thromboplastin time, DOC = dissesminated interavascular coagulation.

61. METABOLIC EMERGENCIES IN PATIENTS WITH CANCER

Gregory K. *Ogilvie*, D.V.M.

1. What are the most common metabolic emergencies in patients with cancer?

- Hypercalcemia (most common)
- Hypoglycemia (may result in nonspecific clinical signs and delayed diagnosis)
- Hyponatremia (underrecognized emergency)
- Hypercalcemia

2. What are the most common cancers associated with hypercalcemia of malignancy?

- Lymphoma is the number-one cause of hypercalcemia in dogs and should be eliminated as a diagnosis if a more obvious cause is not apparent.
- Apocrine gland/anal sac adenocarcinoma
- Mammary adenocarcinoma
- Primary hyperparathyroidism
- Parathyroid carcinomas and adenomas are rare malignancies, but intractable hypercalcemia may be caused by elevated parathormone levels.

3. What is the most common mechanism associated with hypercalcemia of nonparathyroid malignancies?

Parathormone-related peptide (PTH-rp) is most commonly associated with hypercalcemia of malignancy in dogs. Although it has been suggested that bone metastases may be associated with hypercalcemia, this mechanism is rare in veterinary medicine.

4. What are the most common clinical findings in animals with hypercalcemia of malignancy?

The oncologic emergency secondary to hypercalcemia of malignancy revolves around clinical signs associated with decreased sensitivity of the distal convoluted tubules and collecting ducts to antidiuretic hormone (ADH) and the vasoconstrictive properties of calcium, with decreases in renal blood flow and glomerular filtration rate. The epithelium undergoes degenerative changes, necrosis, and calcification. Progressive renal disease is noted clinically as polyuria and polydipsia, followed by vomiting, hyposthenuria, and dehydration. Calcium also may affect the gastrointestinal, cardiovascular, and neurologic systems directly and cause anorexia, vomiting, constipation, bradycardia, hypertension, skeletal muscle weakness, depression, stupor, coma, and seizures.

5. What other differential diagnoses must be considered in dogs with hypercalcemia?

Other diagnoses that must be considered when an animal is evaluated for true hypercalcemia (Ca^{2+} > 12 mg/dl) include laboratory error, error in interpretation (e.g., young growing dogs), hyperproteinemia from dehydration, acute renal failure, vitamin D and calcium toxicosis, granulomatous disorders, nonneoplastic disorders of bone, hypoadrenocorticism, true hyperparathyroidism, and chronic disuse osteoporosis.

6. Does serum protein or albumin influence serum calcium values?

Yes, in both cases. It is important to interpret calcium in relation to serum albumin and blood pH. The following correction formula for dogs takes albumin into account:

$$\text{Adjusted calcium (mg/dl)} = [\text{calcium (mg/dl)} - \text{albumin (gm/dl)}] + 3.5$$

Acidosis results in an increase in the free, ionized fraction of calcium and may magnify the observed clinical signs associated with hypocalcemia. Whenever possible, an ionized calcium value

should be obtained so that the biologically active form of calcium can be assessed. The serum sample is taken anaerobically with a heparinized syringe. The blood in the heparinized syringe can then be placed on ice for subsequent analysis. An ionized calcium value does not have to be corrected for albumin or protein.

7. What is the ideal diagnostic plan for hypercalcemic animals?

All hypercalcemic patients should have serial serum calcium measurements and assessment of electrolytes, blood urea nitrogen, and creatinine levels. Elevated immunoreactive parathormone levels in association with hyperphosphatemia may suggest ectopic hormone production. Patients with multiple myeloma may have elevated calcium levels secondary to abnormal calcium binding to a paraprotein without elevation of ionized calcium, and malnourished patients with hypoalbuminemia may have symptoms of hypercalcemia with normal serum calcium levels.

8. What intravenous fluids should be used to treat hypercalcemic animals?

Treatment of an emergency secondary to hypercalcemia depends on the severity of clinical signs and presence of renal disease. Treatment entails intravenous 0.9% saline in volumes that exceed daily maintenance requirements. Many sources suggest that this amount of fluid is ≥ 132 ml/kg/day (or approximately > 66 ml/kg/day plus exogenous losses from vomiting and diarrhea) plus replacement fluids for dehydration. More recent data suggest that the correct amount of fluid is more conservative (30 kg + 70). Potassium depletion should be prevented by addition of potassium chloride (KCl) to fluids based on serum potassium levels.

9. How should potassium depletion be treated?

When potassium is administered intravenously, the rate should not exceed 0.5 mEq/kg/hr. In addition, the patient should be watched carefully for signs consistent with overhydration and congestive heart failure, and effective antitumor therapy should be initiated as soon as possible.

Intravenous Potassium Supplementation to Correct Hypokalemia

SERUM POTASSIUM (mEq/L)	KCl ADDED TO EACH LITER OF FLUID (mEq)	MAXIMAL RATE OF INFUSION (ml/kg/hr)
< 2	80	6
21.–2.5	60	8
2.6–3.0	40	12
3.1–3.5	28	16

10. How can drugs be used to treat patients with hypercalcemia?

- Furosemide (1–4 mg/kg 2 times/day, IV or orally) and intravenous biphosphonates (e.g., etidronate, disodium palmidroate) also may be used in addition to saline diuresis.
- Intravenous or oral biphosphonates have rapid hypocalcemic effects; they inhibit osteoclast activity.
- Gallium nitrate produces concentration-dependent reduction in osteolytic response to parathormone and certain other types of lymphokines that cause hypercalcemia. Gallium nitrate infused at doses of approximately 100 mg/m^2 daily for 5 consecutive days successfully reduces high calcium levels in 86% of human patients.
- Mithramycin, a chemotherapeutic agent that decreases bone resorption by reducing osteoclast number and activity, also has been shown to be effective in people. Because mithramycin is a sclerosing agent, it must be given as a bolus (25 mg/kg IV once or twice weekly) through a newly placed intravenous line. If extravasation occurs, ulceration and fibrosis will develop. Mithramycin has not been used extensively in dogs or cats; in refractory patients, it may require twice-weekly dosing.
- Salmon calcitonin (4–8 MRC U/kg SQ) also may be used in refractory patients. Calcitonin inhibits bone resorption and thus causes a fall in serum calcium levels within

hours of administration. When administered at approximately 40 U/kg, salmon calcitonin may result in hypocalcemia for several days.

- Corticosteroids are effective for treatment of hypercalcemia. Corticosteroids block bone resorption caused by osteoclast-activating factor, increase urinary calcium excretion, inhibit vitamin D metabolism, and increase calcium absorption after long-term use. To be effective, high doses are generally required for several days. Steroids should not be used until tissue diagnosis is made, primarily because lymphomas are the primary cause of malignancy-associated hypercalcemia.

Most patients are effectively managed with hydration, mobilization, antitumor therapy, and treatment with hypocalcemia-inducing agents such as mithramycin, calcitonin, or corticosteroids. Serum calcium should be monitored at least twice weekly.

11. What drugs or vitamins are contraindicated in hypercalcemic animals?

Thiazide diuretics or vitamin A and D (which may elevate calcium levels) should not be used in hypercalcemic animals.

HYPOGLYCEMIA

12. What tumors are most commonly associated with hypoglycemia?

Fasting hypoglycemia in the face of hyperinsulinemia occurs most commonly with insulinomas; however, other tumors of the liver (e.g., hepatomas, carcinomas) also have been associated with hypoglycemia.

13. What other diagnoses are associated with hypoglycemia?

Liver disease (including glycogen storage diseases and sepsis) may mimic hypoglycemia of malignancy. In addition, because red blood cells metabolize glucose rapidly, delay in separating red blood cells from the serum may lead to spurious results.

14. What are the most common clinical signs associated with malignancy-induced hypoglycemia?

Before presenting with seizures, coma, and impending death, most animals have a history of fatigue, weakness, dizziness, and confusion associated with paroxysmal lowering of the blood glucose levels. Hypoglycemic dogs with neurologic signs present like any other patient with a central nervous system abnormality, such as brain tumor, brain trauma, meningitis, or metabolic encephalopathy.

15. What is the best diagnostic plan to confirm the presence of malignancy-associated hypoglycemia and to identify the underlying cause?

Hypoglycemia

1. Idiopathic
2. Starvation
3. Hepatic enzyme deficiency (glycogen storage disease)
4. Septicemia
5. Insulin treatment
6. Extrapancreatic tumors
7. Artifact: serum not separated from red blood cells
8. Liver insufficiency (severe)

1. Increased insulin
2. Functional islet cell neoplasm

Insulin-producing tumors can be diagnosed by identifying elevated insulin levels in association with low blood glucose concentrations. In some cases, the identification of malignancy-associated hypoglycemia may require periodic sampling during a 72-hour fast. The diagnosis is made

when the blood glucose is dramatically reduced but insulin levels are elevated. Although controversial, the amended insulin:glucose ratio is controversial but has been advocated by some as a method to help diagnose insulin-producing tumors in domestic animals:

$$\frac{\text{Serum insulin } (\mu U/ml \times 100)}{\text{Serum glucose } (mg/dl) - 30} = \text{amended insulin:glucose ratio}$$

Values above 30 suggest a diagnosis of insulinoma or other insulin-producing tumor.

16. What is the treatment plan for animals with hypoglycemia of malignancy?

In an emergency setting, medical management is often necessary before, during, and after definitive therapy, especially in cases of insulinomas, which have a high metastatic rate. Glucose-containing fluids (2.5–5% dextrose in 0.9% NaCl or other isotonic crystalloid solution) should be administered to meet fluid requirements and to maintain blood glucose concentrations within acceptable limits. The administration of glucose, however, may trigger the tumor to release more insulin; therefore, a constant infusion of glucose to maintain normal serum glucose levels is preferred to intermittent high-dose bolusing.

Prednisone (0.5–2 mg/kg divided into 2 oral doses/day) is often effective in elevating blood glucose levels by inducing hepatic gluconeogenesis and decreasing peripheral utilization of glucose.

Diazoxide (10–40 mg/kg divided into 2 oral doses/day) may be effective in elevating blood glucose levels by directly inhibiting pancreatic insulin secretion and glucose uptake by tissues, enhancing epinephrine-induced glycogenolysis, and increasing the rate of mobilization of fatty acids. The hyperglycemic effects of diazoxide can be potentiated by concurrent administration of hydrochlorothiazide (2–4 mg/kg/day orally)

Propranolol (10–40 mg/kg 3 times/day orally), a β-adrenergic blocking agent, also may be effective in increasing blood glucose levels by inhibition of insulin release through the blockade of β-adrenergic receptors at the level of the pancreatic beta cell, inhibition of insulin release by membrane stabilization, and alteration of peripheral insulin receptor affinity.

Combined surgical and medical management of pancreatic tumors has been associated with remission times of 1 year or more. Once the patient is stable, surgical extirpation may be the treatment of choice for tumors that cause hypoglycemia. Because many tumors (including insulinomas) that induce hypoglycemia as a paraneoplastic syndrome are malignant, surgery alone often is not curative. In the case of insulinomas, partial pancreatectomy may be indicated; iatrogenic pancreatitis and diabetes mellitus are recognized complications. Streptazotazin has been advocated by some as a viable treatment for this tumor.

HYPONATREMIA

17. What is the most common cause of hyponatremia that leads to an emergency?

An emergency condition related to the syndrome of inappropriate antidiuretic hormone secretion (SIADH) is a rare but underrecognized cause of true hyponatremia in patients with cancer.

18. What is SIADH?

SIADH is the presence of excessive quantities of antidiuretic hormone secondary to malignancy. The affected animal has low plasma osmolality despite inappropriate urine concentration (high sodium). Because this situation also may occur in renal disease, hypothyroidism, and adrenal insufficiency, these disorders must be excluded to confirm the diagnosis of SIADH.

19. What factors predispose an animal to hyponatremia due to SIADH?

The condition may be caused by a cancer or a drug that results in renal activation or enhanced release of antidiuretic hormone. SIADH has been identified in dogs with lymphoma. Drugs in veterinary medicine that may cause SIADH include but are not limited to the following:

- Chlorpropamide
- Vincristine
- Vinblastine
- Cyclophosphamide
- Opiates
- Thiazide diuretics
- Barbiturates
- Isoproterenol

20. What clinical signs are most commonly seen in animals with SIADH and hyponatremia?

When hyponatremia develops rapidly or sodium falls below 115 mg/dl, patients may develop mental status abnormalities, confusion, or coma. With profound hyponatremia, seizures also may occur. Serum and urine electrolytes, osmolality, and creatinine should be measured in suspect cases.

21. What is the best diagnostic plan to confirm SIADH?

The diagnosis of SIADH is initially made by the combination of hyponatremia on the biochemical profile and clinical signs. The diagnosis of SIADH is often missed. SIADH is associated with inappropriate sodium concentration in the urine for the level of hyponatremia in the serum. Urine osmolality is greater than plasma osmolality, but the urine specific gravity is not maximally dilute. With SIADH the urea nitrogen values in the serum are usually low because of volume expansion. Hypophosphatemia also may be noted. Adrenal and thyroid function should be normal.

22. What is the best treatment for animals with SIADH?

Initial treatment should be directed at resolution of the hyponatremia in an emergency setting:

1. Fluids should be restricted to ensure that the patient receives only the amount needed to maintain normal hydration and to keep serum sodium concentration within normal levels.
2. Demeclocycline may correct hyponatremia to reduce ADH stimulus for free water reabsorption at the collecting ducts in an emergency setting. The most common side effects of demeclocycline are nausea and vomiting.
3. Lithium carbonate and phenytoin also have some use in treatment of SIADH.
4. Hypertonic sodium chloride (3–5%) also may be used in an emergency situation; however, if not used carefully, it may result in fluid and circulatory overload.
5. Furosemide may be used concurrently with the hypertonic saline to reduce volume overload. Rapid correction of hyponatremia may lead to neurologic damage. The following formula may help to determine approximate amounts of sodium to administer for correction of hyponatremia:

$$\text{Na for replacement (mEq)} = [\text{desired serum sodium (mEq/L)} - \text{observed serum sodium (mEq/L)}] \times \text{observed serum sodium (mEq/L)} \times \text{body weight (kg)} \times 0.6$$

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62. CANCER TREATMENT-INDUCED CONGESTIVE HEART FAILURE

Gregory K. *Ogilvie*, D.V.M.

1. What chemotherapeutic agent is most commonly associated with development of cardiac disease and can chemotherapy-induced heart disease result in a life threatening emergency?

Cardiac disease secondary to anthracycline or anthracycline-like drugs is relatively common in dogs and may be life-threatening. Doxorubicin is the anthracycline commonly associated with development of cardiac disease. Tachyarrhythmias and cardiomyopathy are more common in pets that receive more than 8 standard doses of doxorubicin. Doxorubicin-induced cardiomyopathy is uncommon in cats.

2. What are the most common cardiac abnormalities associated with doxorubicin-induced heart disease?

Doxorubicin is associated with development of tachyarrhythmias and dilatative cardiomyopathy. Cardiomyopathy may occur in response to administration of any number of doses of doxorubicin, but the risk increases significantly after a dog receives a total cumulative dose exceeding 240 mg/m^2. The risk in cats appears to be minimal; however, histologic abnormalities have been found in cats that were given total cumulative doses between 130–320 mg/m^2.

3. Can radiation induce heart disease?

Unquestionably, but the degree of heart disease is related to the number of fractions of radiation treatment, the dose per fraction, the type of radiation (photons vs electrons) and the total dosage. Radiation also can induce cardiomyopathy if the heart is in the radiation therapy field and if high enough doses are used. Histologic and clinically significant pericardial effusion develops approximately 3 months after completion of a 3-week radiation schedule. Radiation may include thinning of the myocardium and significant amounts of fibrosis 1 year after treatment.

4. What predisposing factors are associated with development of doxorubicin-induced cardiac disease?

Doxorubicin-induced cardiac disease may occur more frequently in animals with preexisting cardiac disease and in animals that cannot metabolize or eliminate the drug adequately after administration. Similarly, rapid infusion of the drug, which establishes high serum concentrations, may increase the prevalence of cardiac disease. Therefore, increased time for infusion of a dose of doxorubicin may reduce the prevalence of acute and chronic cardiac disease.

5. What are the most common clinical signs of doxorubicin-induced cardiomyopathy?

In an animal with cardiomyopathy and fulminant congestive heart failure, clinical signs vary from anorexia, lethargy, and weakness to more common signs associated specifically with decreased

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62. CANCER TREATMENT-INDUCED CONGESTIVE HEART FAILURE

Gregory K. *Ogilvie*, D.V.M.

1. What chemotherapeutic agent is most commonly associated with development of cardiac disease and can chemotherapy-induced heart disease result in a life threatening emergency?

Cardiac disease secondary to anthracycline or anthracycline-like drugs is relatively common in dogs and may be life-threatening. Doxorubicin is the anthracycline commonly associated with development of cardiac disease. Tachyarrhythmias and cardiomyopathy are more common in pets that receive more than 8 standard doses of doxorubicin. Doxorubicin-induced cardiomyopathy is uncommon in cats.

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4. What predisposing factors are associated with development of doxorubicin-induced cardiac disease?

Doxorubicin-induced cardiac disease may occur more frequently in animals with preexisting cardiac disease and in animals that cannot metabolize or eliminate the drug adequately after administration. Similarly, rapid infusion of the drug, which establishes high serum concentrations, may increase the prevalence of cardiac disease. Therefore, increased time for infusion of a dose of doxorubicin may reduce the prevalence of acute and chronic cardiac disease.

5. What are the most common clinical signs of doxorubicin-induced cardiomyopathy?

In an animal with cardiomyopathy and fulminant congestive heart failure, clinical signs vary from anorexia, lethargy, and weakness to more common signs associated specifically with decreased

cardiac output and ensuing congestive heart failure. Owners may complain that their pet has exercise intolerance; coughing spells late at night, which may develop into a persistent cough at all times of day; abdominal distention; increased respiratory effort and rate; and generalized malaise.

The physical examination is helpful and may include identification of a jugular pulse, rapid heart and respiratory rates, ascites, cool extremities, cyanotic mucous membranes, delayed capillary refill, pitting edema of lower extremities, enlarged liver and spleen, and rapid, weak pulses. The chest may sound dull because of pleural effusion, or pulmonary edema may cause crackling lung sounds. Heart murmurs or an abnormal rhythm is frequently auscultated; the heart sounds in dogs with atrial fibrillation may sound like jungle drums (i.e., irregularly irregular) on auscultation. Electrocardiography may suggest heart chamber enlargement or reveal arrhythmias, which may be supraventricular or ventricular in origin.

6. What are the most rewarding tests for diagnosis of doxorubicin-induced cardiac disease?

In a recent study, 32 of 175 dogs treated with doxorubicin developed clinically evident cardiac disease. Thirty-one had electrocardiographic abnormalities, including arrhythmias (premature atrial complexes, atrial fibrillation, paroxysmal atrial and sinus tachycardia, ventricular arrhythmias, bundle branch blocks, atrioventricular dissociation) and nonspecific alterations in R wave, ST segment, or QRS durations. Seven dogs had overt congestive heart failure that resulted in death within 90 days despite supportive therapy. Arrhythmias may occur at the time of treatment or within a variable period after treatment is complete. In people with doxorubicin-induced cardiac diseases, significant dysrhythmias often are present without other physical or historical abnormalities. Other important clinical tests include:

- Chest and abdominal radiographs are valuable in identifying evidence of cardiac disease, including pericardial or pleural effusions; enlargement of the heart, liver, spleen, and pulmonary veins; and pulmonary edema, which usually is first noted around the hilar region.
- Echocardiography is extremely valuable for confirmation of pericardial effusion and documentation of chamber size, myocardial wall thickness, and parameters such as ejection fraction, cardiac output, and contractility.
- Blood pressure measurements may assist in documentation of hyper- or hypotension. An elevated central venous pressure aids diagnosis of cardiac insufficiency.
- Fluid analysis of thoracic or abdominal effusion (usually a modified transudate with reactive mesothelial cells and macrophages)
- Contrast radiography can assist when echocardiography is not available.

Unfortunately, no evaluation can be performed routinely in veterinary practice to predict whether cardiotoxicity will occur in dogs that receive anthracycline agents or radiation therapy. This precludes withdrawal of therapy before overt signs of cardiac insufficiency occur. In people, nuclear medicine imaging techniques may be able to predict the development of doxorubicin cardiomyopathy before it becomes clinically evident.

7. If doxorubicin-induced cardiomyopathy is identified, can doxorubicin treatment be reinitiated in the future?

The simple answer is no. Work at Colorado State University suggests that development of cardiomyopathy may be associated with a profound decrease in contractility without substantial alterations in quality of life. Once alterations in cardiovascular performance are documented, the administration of doxorubicin should be discontinued indefinitely. The important lesson from these data is that the animal's quality of life rather than results of diagnostic tests should dictate whether therapy should be initiated.

8. How does one prevent doxorubicin-induced cardiac disease (other than not giving the drug)?

Liposomal encapsulation has been effective at reducing systemic toxicity. Doxil, a pegylated liposome formulation of doxorubicin, is less cardiotoxic. Doxil has been used successfully

to treat a number of people with cancer without inducing significant toxicity. David Vail at the University of Wisconsin has taken the lead to understand how doxil can be used in veterinary patients. His work showed the ability to escalate the dosage with few side effects. The drug was preferentially concentrated in the skin which resulted in significant toxicoses in dogs and cats.

Dexrazoxane (ICRF 187) is the most effective blocking agent to prevent cardiotoxicity from the administration of doxorubicin. Dexrazoxane is a bisdioxopiperazine which is hydrolyzed intracellularly to a bidentrate chelator, similar in structure to EDTA. The drug actually has anticancer effects on its own and may act via topoisomerase II inhibition. The putative mechanism by which dexrazoxane prevents cardiac toxicity is by chelating intracellular iron. Dexrazoxane can strip iron from the doxorubicin:iron complex which catalyzes the generation of free radicals, thus preventing free-radical generation. This cardioprotectant has been shown to be effective in a number of human cancer trials. Work done in the dog has shown it is very effective at preventing doxorubicin cardiotoxicity. One study in people with cancer suggested that dextrazoxane may decrease doxorubicin's anticancer effect, although others have not confirmed this concern. Evidence suggests that the cardioprotection of dexrazoxane can be extended to other anthracyclines such as epirubicin.

9. What is the preferred treatment for dogs with anthracycline-induced cardiomyopathy?

Treatment of cardiomyopathy begins with: Indefinite discontinuation of the inciting cause (e.g., radiation or doxorubicin). Evidence suggests that in some humans with doxorubicin-induced cardiomyopathy clinical signs gradually resolve and cardiac function improves. Studies are needed to determine whether this is also true in pets. Diuretics, a low salt diet, rest, oxygen therapy, positive inotropes, and vasodilators should be used as dictated by the clinical status of the patient. For example, furosemide may be used 2–3 times/day in a compensated animal, whereas in a patient in respiratory distress from severe, fulminant pulmonary edema, it may be used every few hours, if necessary. Digoxin, a positive inotrope, may be given orally or parenterally in combination with a preload or afterload reducer; therapeutic levels of digoxin, when given orally, are generally not achieved for a few days, which may be adequate for an animal that is relatively stable. Factors such as dehydration and electrolyte disturbances may promote development of digoxin toxicoses. Because digoxin toxicity is a serious problem that occurs frequently, intravenous loading doses should not be used unless absolutely necessary. Regardless of the method of digitalization, periodic determination of serum digoxin concentrations is essential for adjustment of drug dosage to maintain therapeutic levels.

In an acutely decompensated, dying dog with cardiomyopathy, a constant-rate infusion of dobutamine combined with intravenous furosemide and an intravenous (e.g., nitroprusside) or transdermal (e.g., 2% nitroglycerin, enalapril) pre- or afterload reducer may be more logical than oral treatment. The dobutamine may increase cardiac output within minutes to hours compared with days before improvement of cardiac output with oral digoxin therapy. More detailed treatment of cardiomyopathy is outlined in the table below.

Therapeutic Approach to Dog or Cat with Drug- or Radiation-induced Dilatative Cardiomyopathy

GENERAL PRINCIPLE	SPECIFIC DETAILS, DRUG DOSAGES, AND TOXICITIES
1. Discontinue cardiotoxic agents.	All cardiotoxic drugs should be discontinued indefinitely. Additional radiation therapy to the heart should be avoided.
2. Enforce complete rest.	Avoidance of excitement is essential. Consider cage rest in or out of an oxygen-enriched environment.
3. Oxygenate.	Acquire and maintain a patent airway. Provide supplemental oxygen if needed; 50% oxygen should not be used for more than 24 hr to avoid pulmonary toxicity. Perform thoracocentesis to reduce pleural effusion. Initiate diuretic therapy for pulmonary edema (see below).

Table continued on following page.

Therapeutic Approach to Dog or Cat with Drug- or Radiation-induced Dilatative Cardiomyopathy (Continued)

GENERAL PRINCIPLE	SPECIFIC DETAILS, DRUG DOSAGES, AND TOXICITIES
4. Reduce pulmonary edema.	Furosemide (drug of choice; monitor for dehydration, hypokalemia) Dogs: 2–4 mg/kg IV or IM every 2–12 hr, depending on severity of edema; decrease to 1–4 mg/kg 1–3 times/day orally for maintenance therapy. Cats: 1–2 mg/kg IV or IM every 4–12 hr, depending on severity of edema; decrease to 1–2 mg/kg 1–3 times/day orally for maintenance therapy. Hydrochlorothiazide/spironolactone combination (use with furosemide or as maintenance therapy; monitor for dehydration, electrolyte abnormalities) Dogs: 2–4 mg/kg orally twice daily. Cats: 1–2 mg/kg orally twice daily.
5. Increase contractility.	Perform pericardiocentesis if pericardial effusion is present in significant amounts to reduce contractility Digoxin (monitor blood levels to acquire and maintain therapeutic blood levels [1–2 ng/ml]; watch for anorexia, vomiting, diarrhea, and ECG abnormalities suggestive of digoxin toxicity): Dogs: < 22 kg, 0.011 mg/kg orally twice daily; > 22 kg, 0.22 mg/m^2 orally twice daily. Cats: < 3 kg, ¼ of 0.125 tablet every other day; 3–6 kg, ¼ of 0.125 tablet daily. Dobutamine (monitor for tachycardia and arrhythmias): Dogs and cats: 1–10 μg/kg/min constant-rate infusion, usually in combination with pre- or afterload reducer and furosemide in severe, fulminant congestive heart failure. Milrinone (monitor for GI toxicity, hypotension): Dogs and cats: 0.5–1 mg/kg orally twice daily.
6. Redistribute blood volume	Vasodilators 2% nitroglycerin ointment; watch for hypotension. Dogs: ¼ inch on skin or in ear 4 times/day Cats: ⅛ inch on skin or in ear 4 times/day Sodium nitroprusside (5–20 μg/kg/min constant-rate infusion); watch for hypotension; prolonged use may result in cyanide toxicity. Miscellaneous: Morphine for dogs only (0.05–2 mg/kg IV, IM, or SQ) to reduce apprehension and to redistribute blood volume.
7. Reduce afterload.	Enalapril: dogs and cats: 0.25–0.5 mg/kg orally once or twice daily (do not use in conjunction with nitroprusside; monitor for hypotension) Hydralazine: dogs: 0.5–2 mg/kg orally twice daily (do not use in conjunction with nitroprusside; monitor for hypotension).
8. Control arrhythmias.	See following table.
9. Monitor response to therapy.	Pulse, respiratory urine output, hydration, electrolytes, blood urea nitrogen, creatinine, blood gases, quality of life. Adjust therapy as indicated.

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Arrhythmias may occur during infusion of a chemotherapeutic agent. If they persist, interfere with an animal's quality of life, or serve as a serious threat to survival, therapy should be instituted and the underlying cause identified and eliminated. In each case, the potential adverse effects of the antiarrhythmic agents must be evaluated and considered before therapy is initiated.

Drugs Used to Treat Supraventricular and Ventricular Arrhythmias Induced by Anthracycline Antibiotics or Radiation Therapy

DRUG	SPECIFIC DETAILS, DRUG DOSAGES, AND TOXICITIES
Bradyarrhythmias	
Atropine (sinus bradycardia, sinoatrial arrest, atrioventricular [AV] block)	Dogs and cats: 0.01–0.02 mg/kg IV; 0.02–0.04 mg/kg SQ; short-acting (Monitor for sinus tachycardia, paradoxic vagomimetic effects.)
Glycopyrrolate (sinus bradycardia, sinoatrial arrest)	Dogs and cats: 0.005–0.01 mg/kg IV; 0.01–0.02 mg/kg SQ (Monitor for sinus tachycardia, paradoxic vagomimetic effects.)
Isoproterenol (sinus bradycardia, sinoatrial arrest, complete AV block)	Dogs: 1 mg in 250 ml 5% dextrose; administer IV at rate of 0.01 µg/kg/min. Cats: 0.5 mg in 250 ml 5% dextrose; administer IV to effect. (Monitor for CNS stimulation, arrhythmias, emesis.)
Tachyarrhythmias	
Digoxin (supraventricular premature complexes, supraventricular tachycardia, atrial fibrillation)	Dogs: < 22 kg, 0.011 mg/kg orally twice daily; > 22 kg, 0.22 mg/m^2 orally twice daily. Cats: < 3 kg, ¼ of 0.125 tablet every other day; 3–6 kg, ¼ of 0.125 tablet daily. (Monitor blood levels to acquire and maintain therapeutic blood levels [1–2 ng/m;]; watch for anorexia, vomiting, diarrhea, and ECG abnormalities suggestive of digoxin toxicity.)
Lidocaine (premature ventricular contractions, ventricular tachycardia)	Dogs: 2–4 mg/kg IV slowly as bolus (maximum of 8 mg/kg) followed by 25–75 mg/kg/min constant-rate infusion. Cats: 0.25–1 mg/kg IV over 4–5 minutes. (Monitor for CNS excitation, seizures, vomiting, emesis, lethargy, arrhythmias.)
Tocainide (premature ventricular contractions, ventricular tachycardia)	Dogs: 5–20 mg/kg 3 or 4 times/day orally. (Monitor for CNS signs or GI toxicity.)
Procainamide (premature ventricular contractions, ventricular tachycardia)	Dogs: 20–40 mg/kg 4 times/day orally, IM; 8–20 mg/kg IV, 25–30 µg/kg/min constant-rate infusion.
Propranolol (supraventricular premature complexes and tachyarrhytymias, atrial fibrillation, ventricular premature complexes)	Dogs and cats: 0.04–0.06 mg/kg IV slowly or 0.2–1.0 mg/kg orally 2–3 times/day, often in combination with digoxin for supraventricular arrhythmias. (Monitor for decreased contractility, bronchoconstriction.)
Diltiazem (supraventricular premature complexes and tachyarrhythmias, atrial fibrillation)	Dogs: 0.5–1.5 mg/kg 3 times/day orally. Cats: 1.75–2.4 mg/kg 2 or 3 times/day orally. (Monitor for bradyarrhythmias and hypotension.)

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63. CHEMOTHERAPY-INDUCED ANAPHYLAXIS

Gregory K. Ogilvie, D.V.M.

1. What chemotherapeutic agent is most commonly associated with development of anaphylaxis?

L-Asparaginase is the drug most commonly associated with development of anaphylaxis, although anaphylaxis or an anaphylaxis-like reaction may occur after administration of any drug. Anaphylaxis most commonly occurs within minutes to a few hours after administration of the inciting drug. Hypersensitivity reactions may occur with any drug, but they occur most commonly with doxorubicin, paclitaxel, and etoposide.

2. How common is anaphylaxis in dogs or cats receiving L-asparaginase?

L-Asparaginase is well known for inducing anaphylaxis, hemorrhagic pancreatitis, diabetes mellitus, and coagulopathies in dogs and people. In one study, 48% of dogs given L-asparaginase intraperitoneally developed adverse effects; 30% of these dogs exhibited signs of anaphylaxis, similar to reports in children that were given L-asparaginase intravenously. The same study showed that intramuscular administration completely eliminated signs associated with anaphylaxis but did not reduce remission rates. Dogs given L-asparaginase subcutaneously had a longer time until remission compared with dogs given the drug intramuscularly. Until more information is known, the drug should be given intramuscularly to minimize adverse effects and to maximize efficacy.

3. What is the mechanism of L-asparaginase-induced anaphylaxis?

L-Asparaginase-induced anaphylaxis and hypersensitivity are common because of enzyme immunogenicity. Anaphylaxis usually is caused by IgE-mediated mast cell degranulation; however, certain substances (e.g., bacterial and fungal cell walls) may trigger anaphylaxis by activating the alternate complement pathway. During activation of this alternate pathway, C3a and C5a are formed; both are potent anaphylatoxins capable of degranulating mast cells and basophils. Although the exact mechanism of L-asparaginase-induced anaphylaxis is largely unexplored in dogs, anaphylaxis in children with acute lymphoblastic leukemia is thought to be induced by complement activation due to formation of immune complexes of L-asparaginase and specific antibodies. Anaphylaxis usually occurs within seconds to minutes after administration of L-asparaginase.

4. What is the mechanism of action associated with anaphylaxis due to other chemotherapeutic agents?

The hypersensitivity reaction secondary to doxorubicin is thought to be related to mast cell degranulation. Cremophor El and polysorbate 80 carriers are responsible for the hypersensitivity reaction induced by paclitaxel and etoposide, respectively.

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5. What predisposing factors are associated with chemotherapy-induced anaphylaxis?

One predisposing factor related to anaphylaxis secondary to L-asparaginase or other drug therapy is a history of prior exposure. Because L-asparaginase is a bacterial product that is ubiquitous in mammalian systems, prior exposure may be an uncontrollable risk factor. In addition, anaphylactic and hypersensitivity reactions are worse in animals with a prior condition such as atopy, which results in a build-up of mast cells and eosinophils before drug treatment. As mentioned earlier, the route of administration also may be a contributing factor to development of an anaphylactic or hypersensitivity reaction.

6. What are the best diagnostic methods for identifying chemotherapy-induced anaphylaxis?

The most common clinical signs of drug-induced anaphylaxis are acute collapse and cardiovascular failure, which lead to shock and death. The event usually occurs within minutes after parenteral injection of the offending drug, although some anaphylactic reactions have been reported hours to days after drug therapy. The patient generally is pale and weak, with bradycardia or tachycardia and rapid, thready pulse. Mucous membranes are generally pale to cyanotic. Peripheral extremities are often cool to the touch, and blood pressure is low.

Hypersensitivity reactions may result in profound pruritus during and after administration of the drug. Pruritus may result in head shaking and swelling of the ears, lips, paws, or near the vein or area being treated. The erythematous reaction usually lasts for the duration of treatment. Occasionally, the edematous and erythematous reaction may last for hours after treatment is finished.

7. Can chemotherapy-induced anaphylaxis be prevented?

Yes. For example, 81 dogs with histologically confirmed, measurable malignant tumors were used in a prospective study to determine the prevalence of anaphylaxis associated with intramuscular administration of 232 doses of L-asparaginase (10,000 U/m^2). None of the dogs exhibited clinical signs associated with anaphylaxis. Therefore, to reduce the probability of anaphylaxis, L-asparaginase should be given IM rather than IV or interperitoneally. In addition, because L-asparaginase is a potent inducer of anaphylaxis, administration of a test dose is advised.

Hypersensitivity reactions secondary to the administration of doxorubicin can be eliminated almost completely by dilution in 250–500 ml of 0.9% NaCl and administration over 20–40 minutes. Hundreds of doses of doxorubicin have been administered at the Comparative Oncology Unit at Colorado State University, and only 1–3 dogs have shown hypersensitivity reactions. Some advocate pretreatment with diphenhydramine and glucocorticoids to reduce the prevalence of hypersensitivity reactions.

The reactions secondary to the carriers in paclitaxel and etoposide can be reduced by slowing the rate of infusion and by pretreatment with dexamethasone (1–2 mg/kg IV), diphenhydramine (2–4 mg/kg IM), and cimetidine (2–4 mg/kg IV slowly) 1 hour before infusion of the chemotherapeutic agent. If a reaction is noted, the infusion can be discontinued temporarily until the animal is more comfortable.

8. What is the treatment of chemotherapy-induced anaphylaxis?

Anaphylaxis is a potentially fatal condition and should be treated immediately with supportive care, fluids, glucocorticoids, H1 receptor antagonists, and epinephrine. Treatment is detailed in the table below.

General Approach to Treatment of an Animal with Drug-induced Anaphylaxis

GENERAL PRINCIPLE	SPECIFIC DETAILS
1. Evaluate the patient.	Do physical examination; ascertain temporal relationship to drug treatment; discontinue drug infusion or injection indefinitely.
2. Ensure a patent airway and cardiac output.	Initiate CPR if indicated; establish airway; breathe for patient after endotracheal intubation; initiate cardiac compressions; initiate drug therapy.

Table continued on following page.

General Approach to Treatment of an Animal with Drug-induced Anaphylaxis (Continued)

GENERAL PRINCIPLE	SPECIFIC DETAILS
3. Establish vascular access; initiate fluid and drug therapy	Establish indwelling IV catheter aseptically; initiate fluid therapy. For shock: ≤ 70–90 ml/kg for first hour followed by 10–12 ml/kg/hr; adjust as needed thereafter. Concurrently, initiate drug therapy: Dexamethasone $NaPO_4$ (2 mg/kg IV) Diphenhydramine (2–4 mg/kg IM; watch for toxicoses, especially in cats) Epinephrine (0.1–0.3 ml of 1:1000 solution IV or IM for severe reactions)

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Hypersensitivity reactions are treated by terminating drug therapy. Reactions usually subside within minutes. The patient can then be treated with H1 receptor antagonists (see table) before reinitiating drug treatment at a much slower rate.

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64. EXTRAVASATION OF CHEMOTHERAPEUTIC DRUGS

Gregory K. Ogilvie, D.V.M.

1. What chemotherapy agents may cause a perivascular reaction or slough and is this truly an oncologic emergency?

Many chemotherapeutic agents are known to induce significant tissue injury after extravasation. Some are severe, irreversible vesicants; others are irritants. Immediate treatment of this condition can result in reduction of dramatic morbidity and in some cases, mortality. The agents commonly used in veterinary medicine include the following:

Actinomycin D	Etoposide	Vincristine
Daunorubicin	Mithramycin	Mitoxantrone
Doxorubicin	Vinblastine	Cisplatin
Epirubicin		

General Approach to Treatment of an Animal with Drug-induced Anaphylaxis (Continued)

GENERAL PRINCIPLE	SPECIFIC DETAILS
3. Establish vascular access; initiate fluid and drug therapy	Establish indwelling IV catheter aseptically; initiate fluid therapy. For shock: ≤ 70–90 ml/kg for first hour followed by 10–12 ml/kg/hr; adjust as needed thereafter. Concurrently, initiate drug therapy: Dexamethasone $NaPO_4$ (2 mg/kg IV) Diphenhydramine (2–4 mg/kg IM; watch for toxicoses, especially in cats) Epinephrine (0.1–0.3 ml of 1:1000 solution IV or IM for severe reactions)

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Hypersensitivity reactions are treated by terminating drug therapy. Reactions usually subside within minutes. The patient can then be treated with H1 receptor antagonists (see table) before reinitiating drug treatment at a much slower rate.

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64. EXTRAVASATION OF CHEMOTHERAPEUTIC DRUGS

Gregory K. Ogilvie, D.V.M.

1. What chemotherapy agents may cause a perivascular reaction or slough and is this truly an oncologic emergency?

Many chemotherapeutic agents are known to induce significant tissue injury after extravasation. Some are severe, irreversible vesicants; others are irritants. Immediate treatment of this condition can result in reduction of dramatic morbidity and in some cases, mortality. The agents commonly used in veterinary medicine include the following:

Actinomycin D	Etoposide	Vincristine
Daunorubicin	Mithramycin	Mitoxantrone
Doxorubicin	Vinblastine	Cisplatin
Epirubicin		

Management of extravasation in human and veterinary medicine is anecdotal and extremely controversial. Despite this controversy, guidelines have been established for clinical use (see question 4).

2. How can perivascular reactions or slough be prevented?

As expected, accurate and secure first-stick catheter placement is absolutely essential in administering drugs that can cause tissue damage if extravasated perivascularly. Generally, only small (22–23 gauge) indwelling intravenous catheters should be used when treatment volumes exceed 1 ml; 23–25-gauge butterfly needles are used for administering small volumes of drugs such as vincristine. All persons involved in patient care should note when and where blood samples are taken by venipuncture and where catheters have been placed previously. This practice prevents administration of chemotherapeutic agents through veins that may leak because of previous procedures. Only recently placed catheters should be used for administration of chemotherapeutic agents. Extreme care should be taken in administering drugs to animals with fragile veins (e.g., diabetics and some aged animals). The catheter should be checked for patency with a large injection of saline (e.g., 12–15 ml) before and after administration of the drug. In addition, the catheter must be checked for patency during infusion, and the injection site must be checked during treatment.

3. What is the best method to diagnose a chemotherapy-induced extravasation?

Usually there is no doubt whether an extravasation has occurred. It should be noted, however, that some drugs will go perivascularly without any reaction from the patient. Some agents are highly caustic if given perivascularly; animals may vocalize or physically react to pain at the injection site. Treatment for extravasation must begin immediately. Evidence of tissue necrosis generally does not appear for 1–10 days after injection and may progress for 3–4 weeks. Lesions may start as mild erythema and progress to an open, draining wound that will not heal without extensive debridement and plastic surgery weeks to months after the perivascular slough begins when all damage is evident. The lesions occur early with vinca alkaloids and late with anthracycline antibiotics such as doxorubicin.

4. What is the treatment of choice for perivascular injection of a chemotherapeutic agent?

Every person involved with the administration of chemotherapeutic agents should be aware of procedures for treatment of extravasation. The procedures should be posted in a common area, and all materials needed to treat extravasation should be readily accessible. Because of extensive use in veterinary practice, doxorubicin and vinca alkaloids are the most common cause of perivascular sloughs. Unfortunately, no method effectively eliminates tissue necrosis. The following procedure is currently believed to be helpful:

- Once extravasation is noted, stop the infusion or injection.
- Do *not* remove the catheter.
- Aspirate back as much fluid and blood as possible from the perivascular space.
- For doxorubicin, apply ice packs continually for 3–4 hours to reduce spread of the drug into adjacent tissue. Treatments that have not been consistently helpful include sodium bicarbonate, corticosteroids, dimethyl sulfide (DMSO), alpha tocopherol, N-acetylcysteine, glutathione, lidocaine, diphenhydramine, cimetidine, propranolol, and isoproterenol.
- For vincristine and vinblastine, apply hot compresses for at least 3–4 hours and inject saline subcutaneously to disperse the drug from the local site.
- Once tissue damage is identified, an Elizabethan collar and bandages with a nonstick pad are essential to allow the area to heal without self-trauma. The bandage should be changed daily as long as the area is draining or has the potential for infection. If a bacterial infection is noted, culture and sensitivity testing and appropriate use of antimicrobials are essential. Frequent cleansing and debridement may be necessary. In some cases, reconstructive surgical repair is essential.

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65. CHEMOTHERAPY-INDUCED ACUTE RENAL FAILURE

Gregory K. *Ogilvie*, D.V.M.

1. Can anticancer drugs cause an emergency condition by inducing renal failure?

Absolutely. Cisplatin, piroxicam, and methotrexate are commonly associated with renal failure in veterinary patients. Cisplatin, when administered intravenously to the cat causes a rapidly fatal pulmonary edema and pleural effusion and is contraindicated in that species. Doxorubicin has been shown to induce renal disease in some dogs and cats. In addition, renal failure is induced by a wide variety of malignant conditions, including transitional cell carcinoma. If left untreated or if not recognized immediately, a fatal outcome can occur.

2. How does cisplatin induce renal damage?

The most nephrotoxic chemotherapeutic agent is cis-diamminedichloroplatinum II (cisplatin), a heavy metal coordination compound that has antineoplastic activity against various malignant tumors in dogs. In dogs, 80–90% of the drug is eliminated in the urine within 48 hours. Nephrotoxicosis, characterized by reduced glomerular filtration rate and tubular injury, is the major dose-limiting toxicosis. Renal toxicosis may range from brief increases in serum urea nitrogen and creatinine concentrations to irreversible renal failure. However, renal damage generally is not a clinical problem if adequate hydration is maintained. Various administration protocols have been suggested to limit or eliminate cisplatin nephrotoxicosis in dogs. Each protocol includes the use of intravenous saline solution during the 1- to 24-hour diuresis period (see question 8).

3. Do other chemotherapeutic agents induce renal disease?

Doxorubicin also induces acute and chronic renal failure in dogs and cats. One study suggests that the renal damage in cats is dose-dependent; however, this observation has not been repeated. Renal failure in dogs also has been induced with variable cumulative doses of doxorubicin. Another unrelated drug, methotrexate, is eliminated primarily from the kidneys and also has been associated with development of nephrotoxicity. Piroxicam, a nonsteroidal antiinflammatory agent, has been shown to be effective for treating dogs with transitional cell carcinoma of the bladder and squamous cell carcinomas of the head and neck.

4. Can the physical presence of a tumor result in kidney damage?

Dogs with transitional cell carcinoma of the bladder, urethra, or prostate commonly have urethral obstruction that may lead to hydroureter and hydronephrosis. The concurrent septic cystitis seen in most patients with bladder tumors may induce secondary pyelonephritis. The end result is acute and chronic renal failure.

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5. What factors predispose to development of chemotherapy-induced kidney damage?

In veterinary medicine, two of the most common predisposing factors associated with development of acute renal failure are cancer and nephrotoxic drugs, including chemotherapeutic agents. Therefore, when chemotherapeutic agents are used in veterinary patients, other nephrotoxic drugs such as aminoglycosides should be avoided. Other risk factors associated with development of acute and chronic renal failure in dogs and cats are as follows:

- Decreased cardiac output
- Urinary tract infection
- Sepsis
- Preexisting renal disease
- Advanced age
- Dehydration
- Fever
- Liver disease
- Hypokalemia
- Hypercalcemia

Several studies have shown that preexisting renal disease may be one of the most important predisposing factors for development of cisplatin-induced acute renal failure.

6. What are the best ways to diagnose kidney damage induced by chemotherapeutic agents?

Acute or chronic renal failure results from decreased glomerular filtration rate with or without tubular damage; therefore, the parameters used for diagnosis are related to damage to these structures. Renal disease may have been significant for variable periods before clinical, hematologic, and biochemical abnormalities were identified, because at least two-thirds of kidney function must be abnormal before overt evidence of renal disease develops.

Acute renal failure may occur with nonoliguria, oliguria, or anuria. Regardless of the amount of urine, it is usually isothenuric or minimally concentrated with a high sodium content (> 40 mEq/L). Glucose, protein, and renal epithelial cells also may be noted in the urine, along with an acute rise in serum urea nitrogen, creatinine, and phosphorus concentration. In oliguric or anuric renal failure, body weight, heart rate, and central venous pressure may increase if fluids are administered before urine flow is reestablished.

7. What is the best treatment for dogs with chemotherapy-induced renal failure?

The best treatment for acute or chronic renal failure is prevention. Substantial data show that cisplatin nephrotoxicity can be reduced and almost eliminated with adequate hydration. The incidence of doxorubicin- and methotrexate-induced renal failure can be reduced by eliminating dogs with preexisting renal disease and by increasing the duration of time the drug is administered. Because cisplatin is a profound nephrotoxin, a brief discussion of hydration schemes to reduce kidney damage is followed by a review of treatment for acute renal failure.

8. How does the method of administering cisplatin influence the induction of renal failure?

The duration of saline diuresis may influence the induction of renal failure in dogs. For example, 24-, 6-, and 4-hour diuresis protocols have been shown to be effective for administering cisplatin with a low probability of inducing renal failure. Shorter diuresis protocols have been shown to be detrimental. For example, a 1-hour diuresis protocol was evaluated for safety and effectiveness. Four doses of cisplatin (70 mg/m^2 of body surface every 3 wk) were administered intravenously to 6 healthy dogs over a 20-minute period after 0.9% NaCl solution (saline) was administered intravenously for 1 hour at a volume of 132 ml (kg)$^{0.75}$. Each dog vomited at least once within 8 hours after each treatment. Clinical status, body weight, and food consumption were normal throughout the 12-week study for 5 of the 6 dogs. The sixth dog developed acute renal failure and became acutely blind and deaf within 3 days after the fourth dose of cisplatin. Electrolyte, creatinine, and serum urea nitrogen values remained within normal limits in all dogs immediately before each treatment and in 5 of 6 dogs evaluated 3 weeks after the final treatment. The serum creatinine value (3.3 mg/dl) obtained from the beagle euthanized 2 weeks after the fourth treatment was above normal. Despite the normality of all but one of the creatinine values, the serum creatinine concentrations obtained 3 weeks after the final treatment with cisplatin were higher than pretreatment values. Glomerular filtration rate, as determined by exogenous and endogenous creatinine clearance tests, was significantly decreased 3 weeks after the fourth treatment of cisplatin compared with data from all other

evaluation periods. Neutrophil counts decreased below pretreatment values at the third, fourth, and fifth evaluation periods. Therefore, this protocol cannot be recommended.

9. What is the best treatment for chemotherapy-induced renal failure?

The initial goals for treating drug- and tumor-related acute renal failure in dogs and cats are to discontinue all drugs that may be nephrotoxic, to document prerenal or postrenal abnormalities, and to initiate fluid therapy. The primary objectives of fluid therapy are to correct deficits such as dehydration and excesses such as volume overload, as seen in oliguric renal failure; to supply maintenance needs; and to supplement ongoing losses, such as those due to vomiting and diarrhea. Each patient must be assessed carefully, and a treatment plan must be based on hydration status, cardiovascular performance, and biochemical data. Maintenance requirements vary from 44–110 ml/kg body weight; smaller animals require the larger amount. A simpler formula is to use 66 ml/kg/day. The amount of fluid that is needed daily for maintenance must be supplemented by an amount equal to external losses due to vomiting and diarrhea. In patients with renal failure, 1.5–3 times this amount of fluid is administered daily to achieve diuresis. The success of diuresis can be monitored by documenting adequate urine output (> 2 ml/kg/hr). Fluid therapy should meet daily needs, replace excessive losses, and correct dehydration. The percentage of dehydration should be determined; approximately 75% of the fluids needed to correct dehydration should be administered during the first 24 hours. Fluid therapy should be altered to correct electrolyte and acid-base abnormalities. In acute renal failure, potassium-containing fluids generally are not ideal because systemic hyperkalemia is often present. Until more is known about the systemic effects of sepsis, lactate-containing fluids should be avoided because sepsis and cancer are associated with hyperlactatemia, which worsens with administration of lactate-containing fluids.

Fluid Therapy for a 10-kg Dog with 5% Dehydration and Diarrhea

TASK	CALCULATION
1. Correct dehydration.	5% (0.05) × 10 kg body weight = 0.5 kg of water needed to correct dehydration. 1000 mk/kg of water × 0.5 kg = 500 ml of water needed to correct dehydration. 75% (0.75) × 500 ml = 375 ml of fluid should be adminstered to replace 75% of dehydration.
2. Administer fluids to meet daily needs.	66 ml/kg (daily requirement) × 10 kg body weight = 660 ml needed on daily basis. Other believe that daily requirements are best estimated as [30 (kg) + 70].
3. Replace ongoing losses.	Estimated losses through diarrhea = 200 ml.
4. Fluids needed, first 24 hr.	375 ml + 660 ml + 200 ml = 1235 ml; increase fluid therapy judiciously to increase urine output to sustain mild-to-moderate diuresis.

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General Approach for a Dog in Renal Failure

GENERAL PRINCIPLE	SPECIFIC DETAILS
1. Stop administration of nephrotoxins.	Discontinue cisplatin, methotrexate, doxorubicin, and aminoglycosides; avoid anesthesia.
2. Assess patient status.	Complete blood count, blood chemistry profile Specifically determine: % dehydration Amount of ongoing losses (e.g., vomiting, diarrhea, blood loss) Maintenance of fluid requirements Electrolyte and biochemical abnormalities Cardiovascular performance Urine output

Table continued on following page.

General Approach for a Dog in Renal Failure (Continued)

GENERAL PRINCIPLE	SPECIFIC DETAILS
3. Select and administer specific fluids.	Tailor therapy to needs of each patient. Isotonic polyionic fluid initially, preferably potassium-free (e.g., NaCl). Correct dehydration first over 6–8 hr to prevent further renal ischemia while watching carefully for pathologic oliguria and subsequent volume overload. Meet maintenance requirements (approximately 66 ml/kg/day). Meet ongoing losses (vomiting, diarrhea) Induce mild-to-moderate diuresis.
4. Monitor urine output, ensure adequate output.	Metabolism cage or indwelling catheter. For inadequate output (< 0.5–2 ml/kg/hr): Mannitol or dextrose, 0.5–1.0 gm/kg in slow IV bolus Furosemide, 2–4 mg/kg IV every 1–3 hr as needed Dopamine, 1–3 µg/kg/min IV (50 mg dopamine in 500 ml of 5% dextrose = 100 µg/ml solution)
5. Correct acid–base and electrolyte abnormalities.	Rule out hypercalcemia of malignancy; treat specifically for that if identified.
6. Provide mild-to-moderate diuresis.	Urine output: 2–5 ml/kg/hr; monitor body weight, heart and respiratory rate, and central venous pressure for signs of overhydration.
7. Consider peritoneal dialysis if not responsive.	Temporary or chronic ambulatory peritoneal dialysis with specific dialysate solution may be helpful.
8. Initiate long-term plans.	Continue diuresis until blood urea nitrogen and creatinine normalize or until values stop improving despite aggressive therapy and clinically stable patient; then gradually taper fluids. Control hyperphosphatemia if indicated (e.g., aluminum hydroxide, 500 mg at each feeding). Treat gastric hyperacidity if indicated (cimetidine, 5–10 mg/kg every 6 hr IV or orally).

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If oliguric renal failure is present, a diligent and aggressive approach should be made to increase urine output, first by increasing glomerular filtration rate and renal blood flow. In addition, osmotic diuresis can be used to increase urine flow. If urine output is less than 0.5–2 ml/kg/hr despite aggressive fluid therapy, furosemide should be administered every 1–3 hours. Furosemide increases glomerular filtration rate and enhances diuresis in many patients. If furosemide is not effective, mannitol or 50% dextrose may be used as an osmotic diuretic to enhance urine production. The advantage of dextrose over mannitol is that dextrose can be detected on a urine glucose test strip. If furosemide and osmotic diuretics are not effective, dopamine may be administered as a constant-rate infusion. Dopamine enhances renal blood flow and increases urine output secondarily.

Treatment for acute renal failure should be continued until the patient is substantially improved and until abnormal biochemical parameters have been corrected or at least stabilized. Therapy then should be tapered over several days and a home treatment plan developed, including avoidance of nephrotoxic drugs, high-quality, low-quantity protein diet, maintenance of a low stress environment, and provision of fresh, clean water at will.

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66. ANEMIA, THROMBOCYTOPENIA, AND HYPOPROTEINEMIA

Gregory K. *Ogilvie*, D.V.M.

1. Are transfusions essential in an emergency situation?

Absolutely. Transfusions are frequently needed for veterinary patients as a result of various emergency situations, including blood loss, disseminated intravascular coagulation (DIC), clinical syndromes associated with the hypocoagulable state of malignancy and other diseases, and other hematologic abnormalities. In general, transfusions and specific blood components should be given only when specifically indicated. Other emergency support procedures, such as fluid therapy, should be used concurrently. The recent availability of blood components commercially makes this form of therapy practical for general practitioners. Finally, bovine hemoglobin is a viable option in an emergency situation when blood is not available.

2. When should blood component therapy be used? How long can blood components be stored?

Blood components should be administered when clinically indicated to either dogs or cats, especially in an emergency setting. Because blood component therapy takes time to prepare and to administer, forethought is essential. Blood component therapy should be initiated early in the management of critical patients but only when indicated. Whole blood or packed red blood cells may be administered immediately or stored for at least 21 days. Fresh frozen plasma has adequate levels of clotting factors for up to 1 year. Frozen plasma stored for longer than 1 year may have a diminished amount of clotting factors V and VII and von Willebrand's factor. Dog blood can be drawn into human unit bags, holding approximately 450 ml of blood and 50 ml of anticoagulant. The plasma can be decanted to make packed cells. In cats a unit is frequently defined as 50 ml, which is the maximal amount that can be drawn safely from average adult cats.

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3. What type of blood should be used to transfuse dogs or cats with acute blood loss?

Although there is a theoretical advantage to transfusing fresh whole blood, packed red blood cells may be administered with excellent results. Red blood cells stored for more than 2 weeks may have a depletion of 2,3 DPG (diphosphoglycerate), which may diminish red blood cell oxygen-carrying capacity. Transfusion should be performed to keep the hematocrit above 15% in dogs and above 10% in cats, when possible. In each case, the patient's response to transfusion should be just as important a determinant as the hematocrit or amount to be transfused. Dogs and cats with acute blood loss are less tolerant of low hematocrit values, whereas those with a gradual reduction in red blood cell numbers are able to adapt to extremely low red blood cell numbers, especially cats.

4. What is bovine hemoglobin (Oxyglobin)? When should it be used in an emergency situation instead of blood?

Oxyglobin is the brand name of one product derived from bovine hemoglobin that acts to increase hemoglobin and arterial oxygen. Emergency treatment of the following conditions generally results in clinical improvement in up to 95% of the patients.

- Immune-mediated hemolysis
- Blood loss (rodenticide, trauma, surgery, gastrointestinal bleeding)
- Ineffective erythropoiesis (red cell aplasia, ehrlichiosis)

Treatment success was defined as dogs in which no further oxygen support (e.g., transfusion), was necessary 24 hours after Oxyglobin treatment. The success rate in the treatment goup was 95% vs. 32% in controls.

5. What are the indications to transfuse a dog with immune-mediated hemolytic anemia?

Immune-mediated hemolytic anemia may require the administration of red blood cells, even if it results in lysis in some of the transfused blood. An immune-mediated hemolytic event may result in acute or gradual onset of a low hematocrit. Therefore, the patient may present like an animal with either acute or chronic blood loss. Adjunctive therapy with glucocorticoids, azathioprine, and cyclosporine is often essential to treat the underlying disease. Dogs and cats with hemolytic anemia cannot be cross-matched adequately because of the presence of antibodies. Frequent evaluation of packed cell volume is essential.

6. What are the indications to transfuse a dog with nonregenerative anemia?

Generally nonregenerative anemia is relatively mild and often does not require transfusion. However, in some cases nonregenerative anemia is quite severe and requires either fresh whole blood or packed red blood cells. Some dogs and cats with nonregenerative anemia do quite well clinically until they are stressed for any reason. Stresses include but are not limited to unexpected confinement or kenneling, disease of any kind, or presentation to the veterinarian for routine evaluation. In addition, the administration of erythropoietin may be of value; however, antibodies directed to the erythropoietin are possible.

7. How should oxyglobin be administered?

Oxyglobin is given to dogs at 30 mL/kg IV at a rate of up to 10 ml/kg/hr. The product can be warmed to 37°C before administration. The half-life is between 30 and 40 hours.

8. What adverse effects are associated with the administration of Oxyglobin?

- Anaphylactic reactions
- Circulatory overload in cases of overdose, (>10 ml/kg/hr), or in patients with preexisting cardiac disease. Monitor central venous pressure and clinical signs for circulatory overload
- Discoloration of skin (yellow-orange), feces (red to dark green), and urine (brown-black)
- Vomiting
- Diarrhea and decreased skin elasticity (may occur within 48 hours of transfusion)

9. What are the indications to treat a patient with thrombocytopenia?

Platelet counts greater than 30,000–40,000 are rarely associated with bleeding disorders. Indeed, a gradual reduction in platelet counts may result in healthy-appearing patients with only 2000–3000 platelets. Recently released platelets have much greater function than older platelets. Platelet transfusion should be used only in dogs or cats that exhibit clinical signs. Platelet-rich plasma may be considered in such patients; however, the half-life of platelets may last for only days or weeks or less, especially in the presence of immune-mediated conditions. One unit per 20 kg body weight of platelet-rich plasma or fresh whole blood should be administered and repeated every hour until an adequate platelet count is reached.

10. What drug can be used to increase platelet numbers, assuming adequate megakaryocytes are present?

Vincristine (0.5 mg/m^2 IV every 1–3 weeks) may be administered to induce premature release of platelets from the bone marrow at other sites during this time. The platelet count usually increases 3–5 days after vincristine is administered.

11. What is disseminated intravascular coagulation (DIC)?

DIC is a syndrome with severe bleeding and consumption of clotting factors and platelets.

12. How is DIC treated?

Approximately one unit of fresh frozen plasma can be used and repeated as needed to maintain prothrombin and partial thromboplastin time at 1–1.5 times the normal bleeding time. Use of heparin is controversial; however, if used in conjunction with platelets, it may have beneficial results. When all cell lines (red blood cells and platelets) are decreased, fresh whole blood also can be used.

13. When are plasma transfusions used to treat dogs with hypoproteinemia?

Plasma transfusions may be of value in patients with decreased albumin levels. Administration of protein may cause a slow increase in plasma proteins because only 40% of the body albumin is in the intravascular space, whereas 60% resides within the interstitial space. Therefore, the administration of fresh frozen plasma must increase the albumin not only within the circulating space but also within the interstitial spaces, which may require repeated administration of proteins. Obviously, the administration of fresh frozen plasma from various donors may result in the development of antibodies. Colloidal solutions such as dextrans or hetastarch also may be useful despite the fact that their half-life may be quite short.

14. How do you determine how much blood or blood components to administer?

Animals with significant acute blood loss should be treated first for shock with crystalloid solutions. Hypertonic saline is also a reasonable choice in select patients. Packed red blood cells may be given with crystalloid fluids or whole blood. As a general rule, one unit of packed red blood cells is administered per 20 kg body weight with close adjustments to maintain the hematocrit above 15%. Dogs that require whole blood for either acute or chronic anemias should be transfused using the general guidelines below:

General rule: amount to transfuse

$$\text{ml donor blood} = [(2.2 \times \text{wt}_{\text{kg}}) \times (40_{\text{dog}} \text{ or } 30_{\text{cat}}) \times \text{PCV}_{\text{desired}} - \text{PCV}_{\text{recipient}})]\text{PCV}_{\text{donor}}$$

where PCV = packed cell volume; 2.2 ml of blood/kg raises PCV by 1% when transfused blood has a PCV of 40.

General rule: rate of transfusion

Dogs: 0.25 ml/kg/30 min or faster (22 ml/kg/day) with close patient monitoring

Cats: 40 ml/30 min with close patient monitoring

Whenever plasma transfusions are considered, it should be remembered that 60% of the blood volume is plasma. In addition, only 40% of the albumin in an animal is in the plasma. Therefore, it takes half a dozen units of plasma to raise the albumin of a 66-pound dog from 1.8 gm/dl to 3 gm/dl.

15. What are the possible complications after transfusion?

Hemolysis is probably the most serious adverse effect; however, it is relatively rare. An acute hemolytic reaction may result in elevated temperature, heart rate, and respiration rate; tremors; vomiting; and collapse. When this occurs, blood component transfusion should be stopped, and the patient's plasma should be checked for hemoglobinemia. Crystalloid fluids should be initiated, and urine output should be monitored. Delayed hemolysis is also possible in some patients.

Fever that develops during transfusion may indicate bacterial contamination of the blood, or the fever may be related to leukocyte antigens that cause an elevation of endogenous pyrogens. Elevation in body temperature is more commonly seen in cats than in dogs.

Allergic reactions may manifest as urticaria and angioneurotic edema. If such signs are noted, the transfusion should be discontinued, and glucocorticoids should be administered.

When large volumes of blood are administered, **volume overload** should be monitored and treated appropriately.

Citrate toxicity, another possible complication of stored blood transfusion, may cause an acute decrease in serum ionized calcium. Citrate toxicity may induce muscle tremors, facial twitches, and seizures as a result of hypocalcemia. Intravenous calcium gluconate and cessation of transfusion are the treatments of choice.

Rarely, **blood ammonia levels** may rise and cause associated clinical signs, such as mental dullness or seizures. This is usually seen in blood that is stored over a prolonged period and is usually associated with packed red blood cells. Treatment should be the same as for hepatoencephalopathy.

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VIII. Neurologic Emergencies

Section Editor: *Wayne* E. *Wingfield*, M.S., D.V.M.

67. INTERVERTEBRAL DISK DISEASE

Wayne E. *Wingfield*, M.S., D.V.M.

1. Describe the anatomy of an intervertebral disk.

Intervertebral disks are circular gelatinous cushions located between each pair of vertebral bodies, with the exception of the first and second cervical vertebrae. Each disk consists of two parts:

- Nucleus pulposus: a central gelatinous area
- Annulus fibrosus: an outer fibrous ring

From the second to the tenth thoracic vertebrae, each disk is overlaid by a band of ligamentous tissue known as the intercapital ligament.

2. How does the anatomy of the intervertebral disk relate to disk extrusions?

Most disk extrusions occur in a dorsal direction (the thinner part of the annulus fibrosus), and the presence of the intercapital ligament explains the relative paucity of dorsal disk herniations in all but the cervical, caudal thoracic, and lumbar vertebrae.

3. What is the difference between extrusion and protrusion of intervertebral disk displacement?

Extrusion. The annulus fibrosus is ruptured, and all or part of the nucleus pulposus is displaced into the vertebral canal.

Protrusion. The annulus fibrosus is intact, but the nucleus pulposus causes a dorsal displacement into the vertebral canal.

4. Describe Hansen's classification of intervertebral disk herniation.

Hansen's type 1	Degenerative changes (premature chondroid metaplasia associated with mineralization, necrosis, and desiccation) leading to a rapid expulsion of a nucleus pulposus through a weakened dorsal annulus fibrosus.
Hansen's type 2	Gradual protrusion of disk material contained within an intact but degenerate (fibroid metaplasia) annulus.

5. Which breeds are associated with the two classes of intervertebral disk herniation?

Hansen's type 1	Chondrodystrophoid breeds (e.g., dachshund, Lhasa apso, Shih Tzu, Welsh corgi, beagle, cocker spaniel, Pekinese) with disk extrusion
Hansen's type 2	Nonchondrodystrophoid breeds (e.g., German shepherd, Labrador retrievers) with disk protrusion

6. What is a type 3 intervertebral disk lesion?

The type 3 disk lesion also has been called a "gunshot" disk lesion. A small fragment of nucleus pulposus is ejected into the vertebral canal with high velocity. Often there is direct penetration of the spinal cord, which results in peracute or acute onset of rapidly progressive paralysis, frequently with loss of pain sensation.

7. What accounts for the predilection of different breeds for intervertebral disk disease?
Most likely, genetic predisposition.

8. Describe the pathogenesis of spinal injury subsequent to intervertebral disk extrusion or protrusion.
The spinal cord injury is due to a combination of vascular and mechanical effects. The contribution of each is controversial.

Mechanical effects. Spinal cord compression results from disk fragments and extradural hemorrhage caused by tearing of the venous sinuses (acute disk extrusions). Both vascular occlusion and mechanical distortion result.

Vascular effects. Acute disk extrusion is associated with an assortment of vascular changes that may progress to central hemorrhagic necrosis and myelomalacia. Vascular changes include vasospasm, endothelial cell swelling, thrombi, and vascular tears. Implicated endogenous chemicals include norepinephrine, dopamine, endorphins, prostaglandins, oxygen free radicals, and calcium. The resultant central hemorrhagic necrosis is most pronounced in the gray matter, because its blood supply is 5 times that of white matter.

9. Identify the neurologic signs associated with an intervertebral lesion in each of the following spinal cord segments:

C1–C5	Upper motor neuron (UMN) to all limbs
C6–T2	Lower motor neuron (LMN) to thoracic limbs and UMN to pelvic limbs
T3–L3	Normal thoracic limbs, UMN to pelvic limbs
L4–S2	Normal thoracic limbs, LMN to pelvic limbs
S1–S3	Partial LMN to pelvic limbs, absent perineal reflex, atonic bladder
Caudal nerves	Atonic tail

10. Which anatomic structures in the spinal cord are pain sensitive?
Pain sensitive stuctures include the meninges, nerve roots, disks, joints, bones, and muscles.

11. What are some of the differential diagnoses in cervical spinal cord hyperesthesia?
Differential diagnoses include degenerative disease (intervertebral disk disease, cervical vertebral malformation-malarticulation, osteoarthritis), neoplasia (bone or extradural and intradural-extramedullary masses), inflammatory disease (infectious-noninfectious meningomyelitis and diskospondylitis), and trauma.

12. Is cervical spinal hyperesthesia associated with intracranial disorders?
Yes! Cervical spinal hyperesthesia is a clinical sign of intracranial disease in dogs and cats. Most frequently it is spoken of as a "headache" and is applied to dogs and cats with brain tumors. In cases that involve concurrent cervical pain and intracranial signs, brain imaging is the primary diagnostic procedure to establish the presence of an intracranial lesion.

13. What radiographic signs are associated with intervertebral disk protrusion or extrusion?
- Narrowing and dorsal wedging of the intervertebral disk space
- Reduction in size and opacification of the intervertebral foramen
- Narrowing of the interarticular facet space

14. Is the calcified disk in situ the likely site of the offending lesion?
No. Calcified disks in situ are rarely the cause of paresis or paralysis.

15. What is the role of myelography in intervertebral disk disease?
If surgery is contemplated, myelography helps to select the appropriate surgical procedure. The contrast column usually deviates at the site of the disk lesion. When spinal cord edema is present, compression often extends over several segments, but the lesion is usually centered in the area of the myelographic column impingement.

16. Describe the treatment of animals with intervertebral disk disease.

Few prospective studies assess the benefits of medical vs. surgical therapy. In addition, questions remain about fenestration, hemilaminectomy, dorsal laminectomy, and combinations of these surgical procedures. Usually the decision is based on the following factors:

- Patient's neurologic status
- Experience of the veterinarian
- Available surgical expertise
- Financial considerations and concerns of the pet owner.

17. What are the indications for medical management of intervertebral disk disease?

- First episode of ataxia, pain, or mild paresis
- Paralysis for more than 24 hours with no deep pain perception
- Owner's refusal of surgical option

18. Should corticosteroids be administered to patients with intervertebral disk disease?

Corticosteroids given to animals with intervertebral disk disease are most beneficial during the first 12–24 hours; their effect wanes thereafter.

19. What benefits do corticosteroids offer to patients with intervertebral disk disease?

- Antiinflammatory effects
- Inhibition of lipid peroxidation by oxygen free radicals
- Increase in blood flow
- Enhancement of neuronal excitability
- Preservation of neurofilament proteins

20. Which corticosteroid should be used to treat intervertebral disk disease?

Currently two corticosteroids are used:

- **Methylprednisolone.** Studies in humans and cats showed improved outcome after spinal injury. Response appears to be biphasic. Doses of 15 mg/kg show a suboptimal response, whereas at 60 mg/kg deleterious effects result from decreased spinal blood flow. Currently no studies in dogs show benefits of this drug. The positive results do not restore the ability to walk in tetraplegic patients, and in chronic studies the effects may not be sustained.
- **Dexamethasone.** Although less expensive, dexamethasone causes significant gastrointestinal complications.

21. When is surgery indicated in animals with intervertebral disk disease?

- More than one episode of pain, ataxia, or mild paraparesis
- Severe paraparesis or paraplegia with intact deep pain perception
- Deterioration of neurologic status with medical therapy
- Paralysis without perception of deep pain for less than 24 hours

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68. SEIZURES

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is a seizure?

A seizure is a paroxysmal, transitory disturbance of brain function that has sudden onset, ceases spontaneously, and is likely to recur. Although most veterinarians call the resulting effects (e.g., jerky movements, staring) a "seizure," the seizure is the neuronal event itself. The observable manifestation is called "seizure activity."

2. Why are seizures an important emergency?

Something is interfering with normal functioning of a group of neurons. The hyperactivity of the neurons causes a build-up of metabolic byproducts, resulting in a harmful effect on the neurons. Neurons depend on aerobic metabolism. When the need for oxygen outstrips the availability, the neuron is injured. If this situation is prolonged, cell death results.

3. Describe the general pathophysiology of seizures.

Seizures are the result of disturbances in normal electrical activity in the brain. Anything that alters neuronal function may lead to a lower threshold of excitability and spontaneous depolarization. If the depolarization wave spreads to other areas of the brain or the entire nervous system, seizures result. The basic pathophysiologic processes that result in seizures are excessive cellular excitation and loss of cellular inhibition.

4. How are seizures classified?

In a study of nonreferral seizures, 53 etiologic diagnoses were found. The seizures were classified as follows:

Primary epileptic seizure (idiopathic or without a definable cause)	44%
Secondary epileptic seizure (identifiable intracranial cause)	46%

5. What is the difference between focal and generalized seizures?

Focal seizures remain localized to one body region. They may become generalized and are more often associated with structural brain disease.

Generalized seizures affect the entire body simultaneously.

6. What is the most common seizure in animals?

Generalized, tonic-clonic seizures.

7. Define status epilepticus.

Status epilepticus is a condition characterized by an epileptic seizure that is so frequent or so prolonged as to create a fixed or lasting condition. In veterinary medicine, status epilepticus traditionally has been defined as a seizure lasting 30 minutes or longer. This does not mean that one waits 30 minutes to institute therapy! A practical, operational definition for veterinarians for status epilepticus is either continuous seizure activity lasting at least 5 minutes or 2 or more seizures with poor or incomplete recovery between seizures.

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8. Give examples of bizarre behaviors that may be manifestations of seizure disorders in animals.

- Fly-biting
- Tail-biting
- Flank-sucking

9. What are the common causes of seizures?

1. Idiopathic epilepsy
2. Metabolic disease
   - Hypoglycemia
   - Hypocalcemia
   - Hyperkalemia
   - Hypoxia
   - Renal or hepatic disease
3. Infection
   - Feline infectious peritonitis
   - Canine distemper
   - Toxoplasmosis
   - Rabies
   - Other fungal or bacterial causes
4. Inflammation (noninfectious)
   - Trauma
   - Granulomatous meningoencephalitis
5. Neoplasia
6. Malformation
   - Hydrocephalus
   - Lissencephaly
   - Lysosomal storage disorders
7. Toxicities

10. How can the signalment aid in the initial diagnosis of seizures?

1. Age
   - < 1 year
     Congenital: hydrocephalus, lissencephaly
     Inflammatory: meningitis
     Metabolic: portosystemic shunts
     Toxic: lead, ethylene glycol, organophosphates
   - 1–5 years: primary epilepsy
   - > 5 years
     Neoplasia
     Metabolic: hepatic or renal dysfunction, hyperadrenocorticism, hypoadrenocorticism
2. Breed
   - Beagle, German shepherd, Keeshond, collie, Belgian Tervuren: genetic or inherited primary epilepsy
   - Miniature/toy breeds: hypoglycemia
   - Yorkshire terrier, schnauzer: portosystemic shunts
3. Sex: epilepsy affects males more often than females.

11. Is a neurologic examination helpful in animals with seizures?

Certainly. You need to examine carefully the cranial nerves, comparing right with left and completing the examination with assessment of motor function and reflexes of the extremities. Idiopathic seizures are not commonly associated with interictal neurologic deficits. The caveat is that some dogs may have neurologic deficits in the postictal period that last for days after the seizure. Metabolic causes of seizures may be associated with persistent neurologic deficits, which are most commonly symmetrical.

12. What diagnostic testing should be done to localize the lesion?

- Laboratory studies: complete blood count, serum biochemical profile, urinalysis, and heartworm or FELV/FIV testing

- Electrocardiogram
- Specialized testing: blood lead, ethylene glycol
- Radiography: thoracic, abdominal
- Computed tomography and magnetic resonance imaging

13. How should status epilepticus be treated initially?

Status epilepticus is a true emergency and must be managed quickly. The ABCs (airway, breathing, circulation) must be attended to immediately. Supplemental oxygen should be supplied. If the airway and breathing are compromised, an endotracheal tube is inserted and ventilation is assisted. Venous access should be established and crystalloid fluids administered. If the severity of the seizure or the size of the animal prevents quick venous access, diazepam may be administered rectally at 0.5–2 mg/kg. Intravenous diazepam is delivered to effect (up to 2 mg/kg). If diazepam is not effective, phenobarbital is administered intravenously up to to 16 mg/kg. You may not see an effect with phenobarbital for 20 minutes if the animal has not taken the drug previously. Constant-rate infusions of phenobarbital may be given at 2–4 mg/kg/hr. Body temperature may be quite high if the patient has been seizing for more than 10 minutes. Seizure control and intravenous fluids are usually adequate to correct hyperthermia. Use caution if cold water bathing is necessary (temperature > 105°F after 10 min); hypothermia is frequently a problem in patients requiring long-term sedation.

14. What are the advantages of using per rectum diazepam to control seizures at home?

Advantages include the ability to reduce the number of cluster seizure events, improved overall success in therapeutic control of idiopathic epilepsy, and fostering of a better home environment for the epileptic dog and its owner through the reduction of total seizure activity, yearly emergency clinic costs, and owner anxiety.

15. How are seizures treated pharmacologically?

DRUG	HALF-LIFE	METABOLISM	DOSAGE	INTERACTIONS SIDE EFFECTS, TOXICITY
Diazepam	3.2 hr	Hepatic	0.5–2 mg/kg IV or rectally	CNS depression
Phenobarbital	47–74 hr (dogs) 34–43 hr (cats)	Renal excretion	Up to 16 mg/kg IV; 2–4 mg/kg orally 2 times/day	CNS depression/excitability; PU, PD, PP
Primidone	10–14 hr	Hepatic	15–30 mg/kg/day divided into 3 doses	Sedation, PU, PD, nystagmus, anorexia, hepatotoxicity, dermatitis
Phenytoin	4 hr	Hepatic	35–50 mg/kg 3 times/day	Sedation, PU, PD, nystagmus, tachycardia, hepatopathy, coagulation defects; toxic to cats
Clonazepam	1.4 hr	Hepatic	0.5 mg/kg orally 2 or 3 times/day	Sedation: after prolonged treatment may see withdrawal signs
Cloazepate	41 hr (humans)	—	2 mg/kg orally 2 times/day	?
Potassium bromide	25 days	Renal excretion	Loading dose = 400–600 mg/kg orally over 30–60 min; 20–60 mg/kg/day orally or divided into 2 doses	Vomiting, sedation, diarrhea, constipation

CNS = central nervous system, PU = polyuria, PD = polydipsia, PP = polyphagia.

16. What is a toxic blood level of phenobarbital?

40 mg/ml.

16. What are the complications of status epilepticus?

Hyperthermia, neurologic deficits (inability to walk normally, central blindness, and tremors), hypoglycemia, rhabdomyolysis, acidosis, hypertension, cardiac dysrhythmias, and death.

17. Which causes of seizure activity result in the poorest prognosis for dogs?

Granulomatous meningoencephalitis, loss of seizure control after 6 hours of hospitalization, or the development of partial status epilepticus.

18. Other than intravenous and intrarectal, what other route may be used for administration of diazepam during seizure?

Diazepam is absorbed rapidly and efficiently following intranasal administration. Plasma concentrations match or exceed the therapeutic concentration (300 μg/L). This technique may be useful when seizures in dogs are treated by owners or when IV access is not readily available. Be careful! You can receive a severe bite wound from the dog during this procedure.

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69. MENINGITIS AND ENCEPHALITIS

Michael S. *Lagutchik*, D.V.M., M.S.

1. Define meningitis and encephalitis.

Meningitis and encephalitis refer to inflammatory conditions of the meninges and brain parenchyma, respectively. Meningitis is characterized by inflammation of the meninges with involvement of the subarachnoid space—by strict definition, inflammation of nonneural tissue. Because of the close association of structures in the cranium, meningitis and encephalitis often occur simultaneously, a condition termed meningoencephalitis.

2. What are the causes of meningitis and encephalitis?

Inflammatory diseases of the central nervous system (CNS) are usually divided into infectious and noninfectious causes. Infectious causes include bacterial, fungal, protozoal, parasitic, rickettsial, and viral organisms. Noninfectious causes include steroid-responsive meningitis, granulomatous meningoencephalitis/reticulosis (GME), polioencephalomyelitis of cats, and several breed-specific disorders.

16. What is a toxic blood level of phenobarbital?

40 mg/ml.

16. What are the complications of status epilepticus?

Hyperthermia, neurologic deficits (inability to walk normally, central blindness, and tremors), hypoglycemia, rhabdomyolysis, acidosis, hypertension, cardiac dysrhythmias, and death.

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69. MENINGITIS AND ENCEPHALITIS

Michael S. *Lagutchik*, D.V.M., M.S.

1. Define meningitis and encephalitis.

Meningitis and encephalitis refer to inflammatory conditions of the meninges and brain parenchyma, respectively. Meningitis is characterized by inflammation of the meninges with involvement of the subarachnoid space—by strict definition, inflammation of nonneural tissue. Because of the close association of structures in the cranium, meningitis and encephalitis often occur simultaneously, a condition termed meningoencephalitis.

2. What are the causes of meningitis and encephalitis?

Inflammatory diseases of the central nervous system (CNS) are usually divided into infectious and noninfectious causes. Infectious causes include bacterial, fungal, protozoal, parasitic, rickettsial, and viral organisms. Noninfectious causes include steroid-responsive meningitis, granulomatous meningoencephalitis/reticulosis (GME), polioencephalomyelitis of cats, and several breed-specific disorders.

3. How common is infectious meningitis?

In general, infectious meningitis, regardless of the exact agent involved, is extremely uncommon in dogs and cats.

4. If infectious meningitis is not common, why bother with rapid recognition and treatment?

In general, very high mortality rates are common if meningitis or encephalitis is not recognized rapidly, diagnosed definitively, and treated appropriately. In fact, in people with suspected acute meningitis, intravenous antibiotic therapy is indicated even before culture and sensitivity testing of a cerebrospinal fluid (CSF) sample.

5. What is a brain abscess?

A brain abscess is a focal accumulation of pus in the CNS. Clinical signs reflect a steadily progressive mass lesion that usually presents subacutely. Brain abscesses are uncommon and usually focal, with signs referable to the affected site in the CNS. Most patients have a history of recent ear, respiratory, or oral infection, which is the usual source of CNS infection. Most abscesses are cerebellopontine, from otic infections, and thus are usually unilateral. Abscesses progress steadily and are usually fatal unless (and even if) prompt treatment is initiated. Diagnosis is made by CSF analysis and enhanced imaging (computed tomography [CT]/magnetic resonance imaging [MRI]) to differentiate from neoplasms or GME. Treatment involves appropriate antibiotic therapy, surgical drainage (ideal, but not practical in most cases), and supportive care.

6. List the most common agents that cause infectious meningitis.

- Bacterial: *Staphylococcus* spp., *Pasteurella multocida*, *Actinomyces* spp., *Nocardia* spp., *Listeria monocytogenes*
- Fungal: *Cryptococcus neoformans*, *Aspergillus* spp.
- Parasitic: *Dirofilaria immitis*, *Cutereba* spp., *Toxascaris* spp., *Ancylostoma* spp., *Taenia* spp., and *Angiostrongylus* spp.
- Viral: rabies virus, feline infectious peritonitis (FIP), canine distemper virus, pseudorabies, and parvovirus and herpes viruses in puppies
- Rickettsial: *Ehrlichia* spp., *Rickettsia ricketsii* (RMSF), *Neorickettsia helminthoeca* (salmon-poisoning fluke), *Borrelia burgdorferi* (Lyme disease)
- Protozoal: *Toxoplasma gondii*, *Neospora caninum*, *Babesia* spp.

Viral, protozoal, and parasitic infections usually cause parenchymal signs (encephalitis), whereas bacterial infections usually cause meningeal signs (meningitis). Fungal and rickettsial agents may cause either meningeal or parenchymal signs or both.

7. Describe the most common noninfectious cause of meningitis.

The most common noninfectious cause of meningitis is termed **steroid-responsive meningitis**, which is a breed-related (see question 9) and non–breed-associated multisystemic polyarteritis and necrotizing vasculitis involving the meninges. Affected breeds include the Weimaraner, German short-haired pointer, boxer, Bernese mountain dog, beagle, and Japanese akita. It is rarely reported in cats. Animals display classic signs of pyrexia, pain, and cervical rigidity. Most dogs are young. An immune-mediated cause is suspected, because most dogs respond to some degree to immunosuppressive doses of glucocorticoids. CSF analysis reveals a neutrophilic pleocytosis and elevated protein count.

8. Describe the most common noninfectious cause of encephalitis.

Granulomatous meningoencephalitis (GME) is a nonsuppurative inflammatory disease with focal or diffuse CNS lesions. Three forms are recognized: (1) focal GME usually involves the brainstem; (2) disseminated GME is widespread, involving the cerebrum, lower brainstem, cerebellum, and cervical cord; and (3) ocular GME involves the eyes and optic nerves. The cause of GME is unknown, although an immunologic basis is suspected. Signs are nonspecific but usually resemble typical signs of encephalitis. The disease may have acute and chronic presentations. CSF

analysis usually shows mild-to-moderate increases in protein (40–110 mg/dl) and moderate-to-marked pleocytosis, primarily mononuclear cells (50–660 WBC/cm^3). Treatment usually consists of immunosuppressive doses of steroids; success is variable, especially in the long term.

9. Are meningitis and encephalitis associated with specific breeds of dogs?

Yes. Three breed-specific conditions are reported:

1. The so-called beagle pain syndrome is a severe form of steroid-responsive meningitis with polyarthritis causing cervical pain. A genetic disposition is assumed, and an immunologic basis is suspected. Prednisone therapy is associated with complete remission.

2. Bernese mountain dogs are reported to be susceptible to severe necrotizing vasculitis and polyarteritis (Bernese mountain dog aseptic meningitis). Although the cause is undetermined, clinical signs in most dogs resolve with steroid therapy.

3. Pug meningoencephalitis is common, and affected dogs usually present with sudden onset of seizures and signs referable to meningitis and cerebral involvement. In contrast to the first two disorders, therapy with steroids and anticonvulsants is usually unrewarding.

10. Describe the onset and progression of meningitis or encephalitis.

Most CNS inflammatory diseases present in an acute manner, but some are chronic and insidious (GME, fungal infections). Meningitis and encephalitis should be considered whenever the clinician is presented with rapidly developing and spreading CNS dysfunction. Clinical signs are highly variable, depending on the site and degree of involvement; signs may be focal, multifocal, or diffuse and may spread rapidly from focal to diffuse.

11. Describe the clinical signs of encephalitis.

Signs of encephalitis usually suggest diffuse parenchymal involvement, often slightly asymmetric. Hallmark findings are altered state of consciousness (e.g., depression, stupor, coma), behavioral changes, visual impairment despite normal pupillary light reflexes, incoordination, voluntary motor dysfunction, CNS dysfunction, and seizures. If encephalomyelitis is present, sensory ataxia, postural deficits, motor dysfunction, and cranial nerve dysfunction may be seen.

12. Describe the clinical signs of meningitis.

Classic findings in meningitic patients are pain (usually cervical) and fever. Animals are reluctant to be handled around the neck and show cervical hyperesthesia and muscle rigidity. In severe cases, opisthotonus and forelimb hyperextension may be present. Animals also may have generalized hyperesthesia and signs of encephalitis.

13. If you think a patient has either meningitis or encephalitis, what diagnostic tests should be considered?

The most important diagnostic test is analysis of cerebrospinal fluid, including measurement of opening pressure, gross visual examination, cytologic and biochemical analyses, microbial culture and sensitivity testing, and serologic testing. Other tests that should be performed include a minimal database and otic and ophthalmic examinations. Tests that may be required include blood and urine cultures, skull radiographs, electroencephalography, and enhanced imaging procedures (CT/MRI).

14. What are the risks of CSF collection in patients with meningitis and encephalitis?

1. Although always potentially dangerous, anesthesia presents added risk because of the underlying degree of altered states of consciousness and potential involvement of the midbrain, especially the respiratory center.

2. Encephalitic patients have some degree of cerebral edema. When CSF is removed, further parenchymal swelling may result, with the risk of midbrain and medullary brainstem compression (tentorial herniation).

3. Alterations in CSF flow dynamics increase the risk of spread of infection.

15. What results on CSF analysis support a diagnosis of meningitis or encephalitis?

The pressure reading first measured on tapping the CSF space (opening pressure) is usually moderately to severely elevated in inflammatory diseases secondary to impaired CSF resorption. Brain tumors are the primary differential diagnosis for increased CSF pressure and typically have massive pressure increases. On gross CSF evaluation, turbidity and an off-white to grayish color suggest meningitis due to increased cell and protein contents.

16. What cytologic findings are consistent with meningitis or encephalitis?

The characteristic cytologic finding in meningitis and encephalitis is increased total cell count. The differential count helps to identify the underlying cause. Suppurative meningitis reveals elevated polymorphonuclear neutrophil (PMN) counts (> 5 neutrophils/hpf), typically seen in bacterial infections. Mixed cell types (macrophages, lymphocytes, PMNs, and plasma cells) suggest mixed inflammation characteristic of fungal, protozoal, and idiopathic meningitis and encephalitis. Predominantly mononuclear cells, especially lymphocytes, suggest viral and rickettsial infections and neoplasms. Increased eosinophils suggest parasitic infection.

17. What biochemical findings are consistent with encephalitis or meningitis?

The characteristic biochemical finding in meningitis and encephalitis is an increased total protein count. Protein electrophoresis usually shows this increase to be due predominantly to an increase in globulin count. Albumin is increased in most cases of CNS disease, but globulin is typically increased only in inflammatory diseases.

18. What is the appropriate therapy for bacterial meningitis?

Obviously, the ideal therapy consists of antibiotic administration based on CSF culture and susceptibility testing. However, empirical therapy should be instituted immediately if bacterial meningitis is suspected. Antibiotics with good penetration of CNS barriers—and thus good first choices—include chloramphenicol, isoniazid, metronidazole, trimethoprim-sulfamethoxazole, and rifampin. Acceptable choices with intermediate penetration that is probably improved in the face of inflammation include amoxicillin, ampicillin, and penicillin G. Drugs to avoid because of poor penetration include cephalosporins and aminoglycosides.

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70. COMA

Tim Hackett, D.V.M., M.S.

1. Define coma. How is it different from stupor or obtundation?

Coma is a disorder of consciousness defined by absence of awareness. The comatose animal appears asleep but is unable to respond to external stimuli or physiologic needs except by reflex activity. **Stupor** implies a state of depressed consciousness responsive to some stimuli, even though it may lapse back into unconsciousness when the stimulus is withdrawn. An animal is considered **obtunded** when it is not alert, when it is disinterested in its environment, or when it has a less than normal response to external stimuli.

2. What parts of the brain must be affected to produce coma?

Consciousness is maintained by sensory stimuli passing through the ascending reticular activating system (ARAS) from the rostral brainstem to the cerebral cortex. Decreased consciousness results from global lesions of both central hemispheres or a lesion affecting the ARAS.

3. How does coma change emergency management?

With any emergency, ensuring a patent airway, providing adequate ventilation, and restoring circulating blood volume are necessary to prevent irreversible organ damage. The danger with animals suffering coma from increased intracranial pressure is that any therapeutic maneuver or drugs that increase brain blood volume may lead to irreversible brainstem herniation. In administering fluids and analgesics and in handling such patients, care must be taken to prevent iatrogenic increases in intracranial pressure.

4. Describe the initial treatment of comatose patients.

1. Check for a patent airway and ensure that ventilation is adequate. The partial pressure of carbon dioxide in arterial blood ($PaCO_2$) should be kept below 35 mmHg to reduce cerebral blood flow and minimize cerebral edema.
2. Ensure adequate perfusion and cardiovascular function. Fluid therapy should be individualized because supernormal blood volume and pressure contribute to increased intracranial pressure.
3. Elevate the head and avoid compressing the jugular veins with catheters, bandages, or positioning.
4. Maintain body temperature between 99°F and 102°F.
5. Control seizures with diazepam and, if necessary, phenobarbital.
6. Supply glucose as needed to maintain blood levels between 100 and 200 mg/dl.
7. Supplemental oxygen is important to ensure that the partial pressure of oxygen in arterial blood (PaO_2) is above 60 mmHg. To avoid handling the animal's head, an oxygen cage is preferable to face mask or nasal insufflation. Supplemental oxygen is not a substitute for ventilatory support and does not prevent hypercarbia. If the animal becomes hypercarbic, ventilatory support may be necessary to prevent increased intracranial pressure.

5. How does a history of trauma affect emergency management of coma?

Trauma causes structural damage to the brain through contusion, laceration, and hemorrhage. The presence of hemorrhage within the calvarium complicates therapy because aggressive fluid administration and oncotic agents such as mannitol may worsen intracranial hemorrhage. Patients with head trauma should be evaluated carefully for signs of focal neurologic deficits, which may indicate a space-occupying hemorrhage. The therapeutic goals in cases of head trauma include normalizing blood pressure by carefully titrating crystalloid fluid therapy; and maintaining tissue oxygenation through supplemental oxygen. Hyperventilation of head trauma patients is no longer recommended as the reduced blood flow may worsen ischemic injury.

6. When should mannitol be used in patients with increased intracranial pressure? What are the contraindications?

Mannitol, an osmotic diuretic, dehydrates tissues and is effective in reducing brain tissue volume. In the presence of diffuse cerebral edema, it is the most effective agent to decrease intracranial hypertension. Its effects depend on an intact blood–brain barrier. Mannitol may cause a dramatic elevation in intracranial pressure before it exerts its action and reduces tissue volume. Mannitol is contraindicated in patients with hypovolemic shock, active bleeding, or cardiovascular compromise. It may lead to volume overload and continued hemorrhage. If mannitol leaks into tissues, it may draw excessive fluids with it. This is a major concern with space-occupying intracranial hemorrhage. Mannitol may leak into the hematoma, bringing with it more fluid and further compressing the cerebrum.

7. What are the general pathophysiologic categories of coma?

- Bilateral, diffuse cerebral disease
- Compression of the rostral brainstem (midbrain, pons)
- Destructive lesions of the rostral brainstem
- Metabolic or toxic encephalopathies

8. Describe the diagnostic approach to comatose patients.

Potential brain disease first should be classified according to location of the lesion and clinical course over time. History, physical examination, and serial neurologic examinations are the most useful tools. The clinician should assume increased intracranial pressure (ICP) in any animal with altered consciousness. Care should be taken to avoid anything that would further increase ICP. Neurologic examination of the comatose patient should determine whether the lesion is focal, multifocal, or diffuse. The examination should be repeated frequently to determine whether the patient is improving, unchanged, or worsening. Primary CNS disease causing coma and stupor should be considered when lateralizing signs or cranial nerve deficits are noted. Generalized disease of the cortex, cerebellum, or brainstem suggests a primary process outside the central nervous system. Diagnostic tests to look for evidence of toxic or metabolic disease or organ dysfunction help to differentiate primary CNS disease from other causes.

9. What initial laboratory evaluations should be performed in comatose patients?

Acute coma without a history of trauma suggests a toxic or metabolic disorder. Owners should be questioned about access to various drugs and poisons, including antidepressants, tranquilizers, alcohol, and ethylene glycol. Blood should be drawn immediately for serum chemistries, looking for evidence of organ dysfunction. Blood glucose can be tested easily on admission. Hypoglycemia may be treated quickly while its cause is investigated. A complete blood count may reveal signs of systemic infectious disease or thrombocytopenia. Urinalysis may reveal calcium oxalate crystals in cases of ethylene glycol intoxication, ammonium biurate crystals with hepatic insufficiency or casts and isosthenuria with acute renal failure. Activated clotting time (ACT) can be tested quickly to assess the intrinsic and common coagulation pathways; ACT is markedly prolonged in patients with acquired coagulopathies. Once the results of the screening tests have ruled out organ dysfunction and metabolic disease, cerebral spinal fluid analysis and either computed tomography or magnetic resonance imaging should be performed.

10. What are the major causes of coma?

Trauma
Intracranial mass lesions
  Abscess
  Granuloma
  Neoplasia

Metabolic diseases
  Diabetic mellitus
  Hypoglycemia
  Hepatic encephalopathy
  Myxedema coma
  Uremic encephalopathy

- Hemorrhage
  - Vascular disease
  - Coagulopathy
  - Hypertension
  - Embolism
- Inflammatory diseases
  - Canine distemper
  - Granulomatous meningoencephalitis
  - Bacterial and fungal meningitis
  - Protozoal infections
- Drugs
  - Barbiturates
  - Opiates
  - Alcohol
  - Tranquilizers
  - Bromides
- Toxins
  - Ethylene glycol
  - Lead
  - Carbon monoxide
  - Arsenic

11. Describe changes in pupil size, position, and reaction to light that help to determine location and severity of disease.

Symmetric pupils with normal direct and consensual response to light require a functional ventrorostral brainstem, optic chiasm, optic nerves, and retinas. Increased intracranial pressure and herniation of the cerebellum under the tentorium cerebelli stimulate the nuclei of the oculomotor (third cranial) nerve, causing brief miosis of both pupils. As the pressure increases and the nuclei are irreversibly damaged, the pupils become fixed and dilated.

Anisocoria suggests primary CNS disease. If the pupils are unequal at rest but both respond normally to light and darkness, a unilateral cerebrocortical lesion contralateral to the larger pupil is likely. If the dilated pupil does not respond to light or darkness, a unilateral oculomotor nerve III lesion is present.

Metabolic diseases may cause symmetric miosis, whereas increased sympathetic tone may cause symmetric mydriasis. However, both respond normally to light and darkness. Symmetric miosis with no response to light or darkness is seen with damage to the pons, iridospasm, or bilateral sympathetic denervation (Horner's syndrome).

12. What abnormal breathing patterns may be seen in comatose patients?

Lesions of the medulla may damage the basic rhythmic control of inspiration and expiration. Functional transection of the brainstem cranial to the medulla allows ventilation to continue but in gasps rather than smooth inspiration and expiration. Damage to the midpons cranial to the apneustic area results in apneustic respiration, characterized by prolonged inspiration and short expiration. Cheyne-Stokes respiration is characterized by deep breathing followed by periods of apnea or shallow respirations and indicates that normal feedback mechanisms no longer function. With normal control of ventilation impaired, the deep breathing causes a drop in CO_2 of arterial blood. This drop is detected by the respiratory center in the brainstem, and respiration is inhibited. Progressive deterioration or compression of the brainstem often causes a slowing of respirations associated with rapid progression toward death.

13. What is the oculovestibular reflex? How can it be used to assess comatose patients?

Infusion of cold water into an ear canal normally induces horizontal nystagmus with the fast phase opposite the direction of the infused ear. Infusion of warm water induces horizontal nystagmus with the fast phase toward the infused ear. This caloric test of the oculovestibular reflex requires integrity of the brainstem, medial longitudinal fasciculus, and cranial nerves III, IV, VI, and VIII.

14. What is hepatic encephalopathy?

Hepatic encephalopathy is a clinical syndrome characterized by abnormal mentation, altered consciousness, and impaired neurologic function in patients with advanced liver disease and severe portosystemic vascular shunts. Hepatic encephalopathy results when the liver fails to remove toxic products of gut metabolism from the portal blood. Ammonia, mercaptans, short-chain fatty acids, and gamma-aminobutyric acid (GABA) agonists have been implicated in the pathogenesis of hepatic encephalopathy.

15. How is hepatic encephalopathy diagnosed?

Hepatic encephalopathy is suspected in patients with bizarre behavior after eating or with altered mentation and elevated liver enzymes. With hepatocellular damage both alanine transferase (ALT) and aspartate transferase (AST) are elevated. With congenital portosystemic shunts or end-stage liver failure, ALT and AST may be normal. Chemical parameters that suggest poor liver function include low blood urea nitrogen, low blood glucose, low albumin, lower serum cholesterol, and elevated serum bilirubin. Fasting and postprandial serum bile acids are markedly abnormal. Blood ammonia levels may be normal or elevated. Nuclear scintigraphy may be used to quantitate blood flow around the liver with portosystemic shunts.

16. What treatments are available for patients with hepatic encephalopathy?

Withdrawal of dietary protein is necessary to prevent production of intestinal ammonia. A 10% povidone iodine enema solution rapidly suppresses colonic bacteria and impairs ammonia production. Lactulose (1-4-beta-galactosidofructose; Cephulac, Merrell-Dow) is hydrolyzed by intestinal bacteria to lactic, acetic, and formic acid. With the lower intestinal pH, ammonia (NH_3) accepts an additional H+ proton to form the less diffusible ammonium ion (NH_4), effectively trapping ammonium within the colon. Lactulose is an unabsorbed solute and also causes an osmotic diarrhea, decreasing intestinal transit time and absorption. Lactulose may be given orally but should be given rectally in patients with altered mentation. Patients with chronic intractable portosystemic encephalopathies may benefit from the benzodiazepine antagonist flumazenil.

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71. ACUTE PROGRESSIVE LOWER MOTOR NEURON DISEASE

Ronald S. *Walton*, D.V.M., M.S.

1. What are the four primary differential diagnoses for acute progressive lower motor neuron disease in dogs?

- Tick paralysis
- Botulism
- Acute idiopathic polyradiculoneuritis (coon hound paralysis)
- Aminoglycoside toxicity

2. Coonhound paralysis (CHP) is similar to which acute polyneuritis in humans?

Guillain-Barré syndrome.

3. Do all dogs that develop CHP have some form of contact or exposure to raccoons?

No. Many patients with CHP have no known contact with a raccoon. The disease has been reported most commonly in hunting breed dogs with known or suspected exposure to raccoons. Raccoon saliva has been incriminated as the source of the possible causative antigen or agent, but the exact etiology and pathogenesis of CHP are unknown.

15. How is hepatic encephalopathy diagnosed?

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3. Describe the pathophysiology of CHP.

CHP is the most commonly recognized peripheral neuropathy in dogs. It is a rare peripheral neurologic disorder that attacks primarily the ventral nerve roots and spinal nerves of any breed and either sex. The primary features are immune-mediated segmental demyelination and axonal preservation or degeneration. The neurologic signs are due to failure of motor impulse conduction from the spinal cord to the muscle fiber. Pain perception is usually normal because the dorsal root structures are affected only mildly.

4. Describe the clinical signs of CHP.

The neurologic signs develop suddenly. The onset of clinical signs has been associated with exposure to a raccoon 7–14 days previously. However, CHP also is seen in dogs with no known raccoon exposure. The neurologic signs typically begin as pelvic limb paresis and hyporeflexia, which quickly progress to tetraparesis in 24–48 hours after the first neurologic signs develop. The patients are otherwise alert and afebrile.

5. What are the treatments and prognosis for CHP?

No specific treatment is available for CHP. The underlying pathophysiology supports an immune-mediated reaction; however, no evidence currently supports the use of glucocorticoid therapy. The only therapy is supportive with good general nursing care. The prognosis is usually good.

6. What would you expect to see in a typical sample of cerebrospinal fluid (CSF) from a dog with CHP?

Typical findings range from normal or increased level of total protein to pleocytosis. CSF findings are not a reliable discriminator in cases of CHP.

7. What two species are implicated primarily in tick paralysis in the United States?

Dermacentor andersoni and *D. virabilis.*

8. Describe the pathophysiology of tick paralysis.

A salivary neurotoxin secreted by the engorged female tick acts at the neuromuscular junction. This toxin either blocks the release of acetylcholine or inhibits depolarization at the terminal portion of the motor nerve. The toxin may alter the ionic flux that mediates action potential production in both motor and sensory nerves.

9. Describe the typical clinical signs of tick paralysis.

Neurologic signs develop 7–10 days after attachment of the tick. The early signs manifest as ataxia, which rapidly progresses to paresis. Paralysis soon follows, with areflexia and hypotonus as prominent features. In cases in the United States, cranial nerve involvement is rare. Respiratory paralysis may occur if the tick is not removed. In Australia, a more severe form of tick paralysis is seen, with autonomic nervous system and respiratory dysfunction or failure as common features.

10. Are dogs and cats equally affected by tick paralysis?

No. Cats appear to be resistant to tick paralysis as it is seen in the United States. However, in Australia, where cases of tick paralysis are much more severe, cats and dogs appear to be equally affected. Respiratory failure and autonomic dysfunction occur much more frequently with the *Ixodes holocyclus*-induced paralysis seen in Australia. In addition, the symptoms often persist with tick removal.

11. How do you treat a case of tick paralysis?

In the United States removal of the tick causes rapid improvement in the clinical signs. The typical patient shows complete recovery within 72 hours. The tick must be removed carefully. Failure to remove the entire head may actually worsen the clinical signs. The entire animal should be checked carefully, paying particular attention to the interdigital spaces and ear canal. A topical insecticide solution should be applied to the entire surface of the animal's body. In the more severe Australian form, clinical signs may worsen even when the tick is removed. The use

of mechanical ventilation and hyperimmune serum has been advocated in such cases to treat profound respiratory failure.

12. Which North American snake's venom can induce acute progressive and diffuse lower motor neuron signs?

Coral snake.

13. In an acutely tetraparetic dog or cat, which system should you monitor most closely while you are determining an etiologic diagnosis?

The respiratory system should be monitored closely. Acute lower motor neuron disorders may progress to the respiratory musculature and respiratory insufficiency. Severe cases may require mechanical ventilation. Respiratory function is evaluated with arterial blood gas measurement.

14. Which class of antibiotics may induce signs of acute diffuse lower motor neuron disorders? What is the underlying mechanism?

Aminoglycoside antibiotics can induce neuromuscular paralysis secondary to their neuromuscular blocking action. The effects are similar to those of curare. The aminoglycosides may show dramatic effects, particularly if injected into a body cavity (e.g., the thorax). Intrathoracic administration of gentamicin has been associated with paralysis of the diaphragm secondary to blockade of the phrenic nerves. These signs typically resolve rapidly when the drug is withdrawn.

15. Describe the pathophysiology of botulism.

The clinical signs of botulism develop after ingestion of preformed exotoxin (type C) of *Clostridium botulinum*. The exotoxin produces a neuromuscular blockade inhibiting the release of acetylcholine from the terminals of cholinergic fibers. Nerve conduction velocities may be slowed in some patients, indicating an interference with impulse transmission as well. The clinical signs develop after an incubation period of 6 days or less.

16. Describe the typical clinical signs of botulism.

The signs indicate an acute progressive lower motor neuron disorder; they vary with the amount of toxin ingested from vague generalized weakness to tetraplegia and respiratory failure. A patient with botulism may show involvement of both spinal and cranial nerves. Cranial nerve involvement (dysphagia, dysphonia, mydriasis, and facial weakness) is typically not seen with either tick paralysis or CHP.

17. What is the typical duration of clinical signs in a botulism case?

Generally signs resolve in 1–2 weeks; occasionally recovery takes longer

18. How can electromyographic (EMG) studies help to differentiate an acute lower motor neuron disorder?

In **polyradiculoneuritis** EMG findings include diffuse denervation of affected muscles. Fibrillation potentials and positive sharp waves are the prominent features. The evoked potentials are slightly reduced in amplitude and may even be polyphasic. However, they are not as severely affected as in cases of botulism or tick paralysis.

Tick paralysis shows no signs of denervation. However, there is marked reduction in amplitude of evoked motor potentials. The nerve conduction velocities may be slightly slower than normal, and the terminal conduction times also may be prolonged.

Botulism shows signs of spontaneous activity, including fibrillation waves and positive sharp waves. The typical case also shows a small muscle action potential in response to a single supramaximal stimulus. Nerve conduction velocities range from normal to slightly slowed.

19. Which of the three–polyradiculoneuritis, tick paralysis, or botulism—typically has cranial nerve involvement as a clinical feature?

Botulism.

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72. BRAIN DEATH

Wayne E. *Wingfield*, D.V.M., M.S.

1. How is death defined?

In humans, death is defined as (1) the irreversible cessation of circulatory and respiratory functions or (2) the irreversible cessation of all functions of the entire brain, including the brainstem. In animals, consciousness characterizes an animal's existence, and the irreversible loss of consciousness defines death. Consciousness is the most integrative function in the body and results in the functioning of the animal as a whole.

2. Define brain death.

Brain death is the irreversible cessation of all functions of the brain, including the brainstem.

3. What are the current guidelines for determination of brain death?

1. **Cessation of cerebral function** requires evidence of a state of deep coma. The patient must be unreceptive and unresponsive to noxious stimuli.

2. **Cessation of brainstem function** requires the lack of brainstem reflexes, together with the persistence of apnea despite stimulus to breathe ($PCO_2 > 60$ mmHg).

3. **Demonstrated irreversibility** requires that the cause of coma is established and sufficient to account for the loss of brain function.

4. When can a patient be declared brain dead?

Currently there are three requirements:

1. The cause of the brain injury must be known.
2. Metabolic and toxic central nervous system depression must be excluded.
3. There must be no demonstrable brain function.

5. Why is brain death important in veterinary emergency and critical care medicine?

For centuries animals were deemed dead when they stopped breathing and their hearts stopped beating. With the era of critical care, cessation of brain functions began to be considered

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5. Why is brain death important in veterinary emergency and critical care medicine?

For centuries animals were deemed dead when they stopped breathing and their hearts stopped beating. With the era of critical care, cessation of brain functions began to be considered

the main reason for diagnosing death. Medical concern over making safe and appropriate diagnosis of brain death in respirator-supported animals led to elaboration of criteria.

6. What combination of factors has been shown to result in inability to survive?

- Irreversible coma with apnea
- Absence of brainstem reflexes
- No blood flow above the foramen magnum
- Isoelectric electroencephalogram 6 hours after onset of coma and apnea

7. What are common synonyms for brain death?

- Cerebral death
- Irreversible coma
- Persistent vegetative state
- Death

8. What are the possible contributing factors to brain death?

- Hypothermia (core temperature < 32.2°C [90°F])
- Electrolyte disturbances (hyperkalemia, hyponatremia)
- Metabolic and acid–base disturbances (hypoglycemia, metabolic acidosis)
- Continuing neuromuscular blockade after administration of neuromuscular blocking drugs
- Central nervous system depressant drugs (barbiturates, narcotics, benzodiazepines)

9. How do you check for lack of cerebral function?

- No spontaneous movements, seizures, or motor posturing (remember: spinal reflexes may persist after death)
- No response of any kind in the cranial nerve distribution to painful stimuli
- Isoelectric electroencephalogram

10. How do you check for absence of brainstem reflexes?

1. Fixed, dilated pupils with no direct or consensual response to light
2. Pupils are mid-sized to larger (make sure that no atropine or catecholamines are blocking the pupillary response to light)
3. No corneal reflex
4. No vestibulo-ocular responses to cold water stimulation
5. No gag reflexes
6. No response to suction catheter placed down the endotracheal tube into the trachea
7. No "doll's eye" phenomena

11. How is the apnea test performed?

1. Place an arterial line, connect a pulse oximeter, and have at hand facilities for blood gas measurement.
2. Adjust the ventilator to an FiO_2 of 1.0 (100% oxygen).
3. Adjust the ventilator, if necessary, to achieve a PaO_2 of 40–50 mmHg.
4. Draw an arterial blood gas sample.
5. Start a stopwatch, disconnect the ventilator, and insufflate at 2–6 L/min through the tracheal catheter to help prevent hypoxemia. Watch for any movements suggestive of respiratory effort.
6. After the animal is disconnected from the ventilator for 10 minutes, draw a second arterial blood gas sample, and reconnect the ventilator.
7. Compute the rise in $PaCO_2$ during the apneic period. The rise should exceed 10 mmHg, and no respiratory effort should be present for the apnea test to indicate that no spontaneous respiratory activity is present.

12. How is doxapram hydrochloride used to verify apnea?

Doxapram HCl is a central respiratory stimulant. We have used it to verify apnea in animals after cardiopulmonary arrest. If an animal does not respond to the injection, the electroencephalogram is consistently isoelectric.

13. What are the two determinants of consciousness?

Arousal and awareness.

14. What are the cardiac manifestations of brain death?

Human patients determined to be brain dead progress to cardiovascular collapse within 1 week. Most die within 2 days of the diagnosis of brain death. The electrocardiographic signs of brain death include widening of the QRS complexes, prolongation of the QT segment, and nonspecific ST changes. In more advanced stages of brain death, bradycardia, atrioventricular blocks and interventricular conduction delays, and atrial fibrillation are seen.

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IX. Metabolic Emergencies

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73. DIABETES MELLITUS

Lynda D. Melendez, D.V.M, MS, Diplomate ACVIM

1. What are the most common medical emergencies associated with diabetes mellitus?

The most common medical emergencies associated with diabetes mellitus are diabetic ketoacidosis (DKA), hyperosmolar diabetes mellitus (HDM), and insulin overdose causing severe hypoglycemia. These three syndromes may present in much the same manner but are distinguishable with initial blood work. Often they are precipitated by underlying disease processes such as pyelonephritis, pancreatitis, pyometra, prostatitis, hyperadrenocorticism, renal failure, and heart failure.

2. List the primary metabolic abnormalities that characterize DKA.

- Hyperglycemia/glucosuria
- Metabolic acidosis
- Ketonemia/ketonuria
- Dehydration
- Electrolyte deficiencies

3. What is the pathogenesis of DKA?

DKA results from an imbalance in concentrations of insulin and its counterregulatory hormones, glucagon, catecholamines, cortisol, and growth hormone. An absolute insulin deficiency or a relative deficiency caused by insulin antagonism is accompanied by a relative excess of counterregulatory hormones, especially glucagon. This shift in the glucagon:insulin ratio eventually results in hyperglycemia because of increased hepatic glycogenolysis and gluconeogenesis as well as decreased uptake of serum glucose by insulin-dependent tissues. Once serum glucose concentration exceeds the renal threshold of 180–220 mg/dl (dogs) or 260–310 mg/dl (cats), glucosuria ensues, resulting in osmotic diuresis, significant calorie loss, and polyuria with compensatory polydipsia.

The loss of calories and the lack of availability of glucose for insulin-dependent tissues stimulate the mobilization of adipose for an energy source. Mobilization of adipose is mediated by hormone-sensitive lipase, which is activated by the increased glucagon:insulin ratio. Fat is transported to the liver in the form of long-chain free fatty acids (FFAs); in the liver ketone formation is favored over esterification into triglycerides because of increased glucagon. The ketone bodies produced by oxidation of FFAs include β-hydroxybutyrate, some of which undergoes decarboxylation into acetone, and acetoacetate. In normal animals, ketones are metabolized by peripheral tissues and form carbon dioxide and water, which in turn are used to produce bicarbonate; in diabetics, the production of ketones exceeds utilization. Ketones are acids that are generally buffered by bicarbonate in the extracellular fluid. Decreased production of bicarbonate and excessive production of ketones result in the development of ketonuria and metabolic acidosis.

4. What causes the dehydration and electrolyte disturbances in DKA?

Osmotic diuresis causes a secondary medullary wash-out and significant loss of water and electrolytes, primarily sodium and potassium. Additional sodium and potassium ions are excreted in the urine in combination with the negatively charged ketone bodies in order to maintain electrical neutrality. In addition, sodium is lost through the kidney, primarily from lack of insulin. Vomiting and diarrhea occur in some animals with DKA and contribute to fluid and electrolyte

deficits. Total body water is significantly decreased as water moves from intracellular into extracellular space in response to the increased serum osmolality created by hyperglycemia and then is lost through the renal and gastrointestinal systems.

If severe enough, dehydration results in decreased renal perfusion and prerenal azotemia and increases the severity of hyperglycemia. Total body potassium is often deficient, although the animal may have normal or even elevated serum potassium concentrations. Metabolic acidosis results in the exchange of hydrogen ions for intracellular potassium (see chapter 78). Because insulin is required to drive potassium into the intracellular compartment, the net effect of acidosis and lack of insulin is an efflux of potassium from its intracellular stores to the extracellular space. Because serum biochemistry profiles measure only extracellular potassium, total body concentrations are usually underestimated.

5. What are the common clinical signs and physical findings in an animal with DKA?

Clinical signs are often nonspecific but include lethargy, weakness, anorexia, vomiting, and diarrhea. Polyuria, polydipsia, and weight loss with ravenous appetite often precede the development of presenting signs. Dehydration, hepatomegaly, cataracts, hyperventilation, and a fruity odor to the breath may be detected on physical examination.

6. Which laboratory tests are useful in assessing an animal with DKA?

Serum biochemistry profile, complete blood count, and urinalysis are the minimal diagnostic procedures to confirm DKA and to evaluate other potentiating problems. However, while you are waiting for these results, determination of blood glucose by using a glucose reagent strip or glucometer helps to distinguish a hyperglycemic diabetic crisis from hypoglycemia. Urinalysis reagent strips identify glucosuria and often ketonuria. However, β-hydroxybutyrate, which predominates in dehydrated patients, does not react well with reagent strips, often giving weak positive or negative results. A few drops of hydrogen peroxide added to urine catalyze the formation of acetone, which is detected on urinalysis strips, from β-hydroxybutyrate. Packed cell volume and total protein give quick information about hydration status. If available, venous or arterial blood gases rapidly detect acid base derangements, and serum osmolality rules HDM in or out.

7. How can acid–base balance and serum osmolality be assessed without access to blood gas analyzers or freezing point osmometers?

Acid–base balance can be evaluated by calculating the anion gap:

$$\text{Anion gap} = (\text{Na} + \text{K}) - (\text{Cl} + \text{TCO}_2)$$

where Na = sodium, K = potassium, Cl = chloride, and TCO_2 = total carbon dioxide. Normal values range from 15–25 mEq/L. An increased anion gap is compatible with metabolic acidosis.

Serum osmolality is calculated as follows:

$$\text{Serum osmolality} = 2(\text{Na} + \text{K}) + \text{glucose}/18 + \text{BUN}/2.8$$

where N = sodium, K = potassium, and BUN = blood urea nitrogen. Normal values range from 285–310 mOsm.

8. What are the goals in treating DKA?

- To identify and manage the underlying diseases
- To replace body fluids
- To restore electrolyte and acid–base balance
- To reduce blood glucose and provide insulin required to normalize metabolism

9. How are the underlying diseases assessed?

The diseases that most frequently precipitate a DKA crisis include pyelonephritis, pancreatitis, pyometra, hyperadrenocorticism, renal failure, and heart failure. Information gleaned from the physical examination and minimum database should lead the clinician to pursue other diagnostic procedures, including urine culture and sensitivity testing, abdominal and/or thoracic imaging, serum amylase and lipase concentrations, and adrenocorticotropic hormone stimulation test. Once the condition is identified, therapy must be initiated to treat the diabetic crisis effectively.

10. What is the fluid of choice for treatment of DKA?

The initial fluid of choice is 0.9% saline, which has the highest concentration of sodium among commercially available isotonic crystalloid fluids; thus it is ideal for correcting the hyponatremia in patients with DKA. Hypotonic fluids should be avoided initially because cerebral edema may develop if serum osmolality is decreased too rapidly. Lactated Ringer's solution should be avoided because the hepatic metabolic pathways necessary to generate bicarbonate from lactate are the same pathways necessary to metabolize ketones. Therefore, the ability of the liver to metabolize lactate is often reduced. Poor perfusion may result in retention of lactate and lactic acidosis; in addition, because lactate is negatively charged, more sodium and potassium may be lost by renal excretion to maintain electrical neutrality.

11. How quickly should fluid deficits be replaced?

Addressing the fluid deficit in these patients is often the most crucial aspect of initial therapy. Fluid requirements should be calculated to restore hydration in 10–12 hours, supply maintenance fluids, and replace ongoing losses as they occur. In the severely dehydrated patient with a competent cardiovascular system, an initial bolus of 15–30 ml/kg given in the first 20–30 minutes of fluid therapy, prior to initiating insulin, can help restore perfusion to peripheral tissues. Central venous pressure (CVP) should be monitored along with body weight, packed cell volume, and total protein to prevent volume overload. Serum electrolytes should be reevaluated in 12–24 hours with appropriate adjustments in choice of fluid and rate of delivery.

12. Should potassium be added to fluids?

A normal or elevated serum potassium level does not imply that body potassium stores are normal or increased. Decreased insulin and acidosis result in an extracellular shift of potassium. Once insulin therapy is instituted and metabolic acidosis begins to correct, extracellular potassium moves quickly into the intracellular space and may result in severe hypokalemia. If oliguria and anuria have been ruled out, 20–40 mEq should be added to each liter of fluid. Potassium concentrations should be monitored every 2–4 hours during initial therapy. The amount of potassium added to the fluids should be adjusted accordingly. (See chapter 78 for further information). Because this protocol is not always practical, careful monitoring of the patient for clinical signs of hypokalemia is crucial. Signs include severe muscle weakness, cervical ventroflexion, ileus, and arrhythmias. Electrocardiograms can be evaluated serially for abnormalities associated with hypokalemia.

13. What role does magnesium play in patients with DKA?

Magnesium is a predominantly intracellular cation that is important in maintaining cell membrane gradients and in the synthesis of proteins and nucleic acids. Hypomagnesemia, which has been found to occur in humans and cats with DKA, results in insulin antagonism, weakness, and hypokalemia. Measurement of ionized magnesium in patients with DKA may be warranted, especially in those whose hypokalemia does not respond to fluid supplementation. Correction of hypomagnesemia may improve the hypokalemic state as well as expedite the therapy of ketoacidosis.

14. Is bicarbonate therapy necessary for correction of metabolic acidosis?

Once insulin therapy has been initiated, ketoacids are metabolized to bicarbonate, which results in fairly rapid normalization of pH. Administration of exogenous bicarbonate in addition to this newly generated source may lead to iatrogenic metabolic alkalosis. Bicarbonate increases the affinity of oxygen for hemoglobin, decreases oxygen delivery to tissues, and, because it is hyperosmolar, contributes to the hyperosmolar state of DKA. Because of these considerations and the danger of paradoxical central nervous system acidosis, bicarbonate therapy is not recommended unless serum bicarbonate is < 12 mEq/L, TCO_2 < 12 or pH is < 7.1. Administration of bicarbonate should be done conservatively with the goal to correct the patient's bicarbonate to 12 mEq/L. Calculation of the bicarbonate dose to meet this goal is as follows:

$$\text{mEq } HCO_3^- + \text{body weight (kg)} \times 0.4 \times (12 - \text{patient's bicarbonate}) \times 0.5$$

This dose is added to the IV fluids and administered over 4–6 hours. It is repeated only if the patient's bicarbonate remains less than 12 mEq after 6 hours of appropriate therapy for DKA.

15. What type of insulin and insulin delivery methods should I consider?

Regular crystalline insulin is the insulin of choice for critically ill patients with DKA. Subcutaneous (SQ) administration should be avoided in dehydrated patients because poor perfusion leads to unpredictable absorption. Once the animal is rehydrated, a large amount of insulin that was deposited in subcutaneous tissue may be absorbed quickly, leading to profound hypoglycemia.

Insulin can be administered with repeated intramuscular (IM) injections by giving 0.2 U/kg initially, then 0.1 U/kg every 1–2 hours until the blood glucose concentration is ≤ 250 mg/dl. Blood glucose determinations must be made before each injection of insulin. At this point, frequency of injection should be decreased to every 4–6 hours IM, or, if the animal is rehydrated, insulin may be given SQ every 6–8 hours. The dose of insulin may have to be adjusted at this point, depending on serial blood glucose concentrations. The recommended range is 0.1–0.4 U/kg. Close communication between the clinician in charge of the case and hospital staff is crucial. One way to ensure that proper treatment intervals and dosages are followed is to make a chart with treatment guidelines.

Constant-rate intravenous infusion (CRI) of insulin is used routinely in humans and is becoming popular for treatment of DKA in small animals. This technique alleviates the need for hourly injections and allows easy adjustments in insulin dosing as glucose concentrations fall. A 24-hour dose of 2.2 U/kg (dogs) or 1.1 U/kg (cats) is calculated for each patient and added to 0.9% saline. Because insulin binds to plastic IV tubing, the first 50 ml of the solution is allowed to flow through the tubing and is discarded. The drip should be administered with an infusion pump. If an infusion pump is used to administer maintenance fluids, the insulin can be "piggy-backed" to the other line. Otherwise, a separate catheter should be placed for insulin infusion. Because periodic adjustments need to be made, the insulin should not be placed in the rehydration/maintenance fluids.

To prevent development of cerebral edema, which occurs with rapid reduction in blood glucose, especially when the reduction in glucose exceeds replacement of lost sodium, blood glucose concentration should be maintained above 250 mg/dl for the first 4–6 hours. When the blood glucose falls below this level, insulin delivery should be adjusted.

Regardless of the route of administration of insulin, blood glucose should be monitored hourly during initial therapy. Once it falls below 250 mg/dl, 2.5% or 5% dextrose should be added to the fluids. Once the animal is eating on its own, a longer-acting insulin, such as NPH or Lente, may be given subcutaneously and the dextrose can be discontinued.

Example of Hospital Chart for 10-kg Dog with DKA †*

GLUCOSE	INSULIN DOSE/ROUTE	DOSING FREQUENCY	FLUID TYPE
>250	1 U IM	1 hr	0.9% saline
200–250	1 U IM	2 hr	0.9% saline + 2.5% dextrose
150–199	1 U IM	2 hr	0.9% saline + 5% dextrose
100–149	1 U IM	4 hr	0.9% saline + 5% dextrose
80–99	Skip this dose, start with 1 U SQ once glucose > 150, call clinician	6 hr	0.9% saline + 5% dextrose
< 80	Skip this dose, call clinician		0.9% saline + 5% dextrose

* Constructing this chart does not negate the need for the clinician to monitor the patient closely.
† Glucose monitoring every 1–2 hours.

CRI Insulin Adjustments

GLUCOSE	INSULIN INFUSION RATE (2.2 U/kg in 200 ml of 0.9% Saline)	REPLACEMENT/MAINTENANCE FLUID TYPE
> 250	10 ml/hr	0.9% saline
200–250	7 ml/hr	0.9% saline + 2.5% dextrose
150–200	5 ml/hr	0.9% saline + 2.5% dextrose
100–150	5 ml/hr	0.9% saline + 5% dextrose
< 100	Stop infusion	0.9% saline + 5% dextrose

16. Why do ketone levels increase despite insulin therapy?

Most likely, the increase in detectable ketones is due to the metabolism of nondetectable β-hydroxybutyrate to acetoacetate and acetone, which causes an apparent worsening of ketosis.

17. Explain the pathogenesis of hypophosphatemia in patients with DKA.

Hypophosphatemia is not a common complication of DKA but may be life-threatening. Phosphorus is controlled by the body in a similar manner to potassium. Serum phosphorus increases in the absence of insulin and in the presence of acidosis as phosphorous shifts from the intracellular to extracellular spaces. Because vomiting, anorexia, and osmotic diuresis may cause loss of phosphorus, total body stores may be depleted at the time of presentation, although serum levels may be normal. With therapy, phosphorus is moved into the intracellular space, and hypophosphatemia becomes apparent. Phosphorus is necessary for energy-dependent physiologic processes and cell membrane maintenance. Clinical signs and laboratory abnormalities associated with hypophosphatemia include hemolysis, muscle weakness, and neurologic signs such as seizures, mental dullness, and even coma.

If hypophosphatemia is detected, therapy with potassium phosphate at a dose of 0.03–0.12 mmol/kg/hr should be instituted, and phosphorus should be monitored every 12 hours until the serum level exceeds 2.5 mg/dl. The potassium in this solution should be taken into account in calculating total potassium supplementation.

18. What is the pathogenesis of hyperosmolar diabetes mellitus (HDM)?

HDM is characterized by extreme hyperglycemia (> 600 mg/dl), hyperosmolality (serum osmolality > 350 mOsm), and neurologic abnormalities. In humans, it generally is associated with nonketotic diabetes mellitus, although it has been described rarely in both ketotic and nonketotic cats. Hyperglycemia causes osmotic diuresis and water and electrolyte disturbances as in DKA. However, compromised renal function results in decreased renal excretion of glucose, which causes a much higher degree of hyperglycemia than in animals with DKA. Severe hyperglycemia leads to an increase in serum osmolality, and the osmotic gradient between extracellular and intracellular compartments causes a shift of water into the extracellular space, resulting in dehydration of tissues. Severe dehydration of neurologic tissues is evidenced by restlessness, ataxia, nystagmus, disorientation, mental dullness, semicoma, and coma.

To prevent excessive shrinkage in brain cells, idiogenic osmoles, which are osmotically active substances, accumulate. If a rapid decrease in serum osmolality occurs because of rapidly declining blood glucose, idiogenic osmoles are dissipated slowly. The resulting osmotic gradient causes a shift of water into the intracellular space and leads to cerebral edema.

19. What are the goals of therapy for HDM?

- To replace the total body water deficit without creating cerebral edema
- To lower blood glucose concentrations slowly
- To correct electrolyte imbalances.

20. How should fluid replacement be addressed?

A balanced electrolyte solution or 0.9% saline is the initial fluid of choice. If the animal has weak, thready pulses, pale mucous membranes, prolonged capillary refill time, and cold extremities, an initial bolus of fluids should be administered. Do not give more than 20–30 ml/kg in 20–30 minutes. After the initial fluid bolus, it is recommended that 80% of the estimated fluid deficit be replaced in the next 12–24 hours in addition to maintenance fluids. Another approach to fluid replacement is to calculate total body water deficit from glucose and sodium concentrations and to replace the deficit over the next 24–48 hours along with maintenance fluids and ongoing losses. Electrolyte imbalances can be handled as in treatment for DKA.

21. How quickly should blood glucose be lowered?

Rapid decreases in blood glucose concentrations predispose to development of cerebral edema. Therefore, insulin therapy should be delayed until 2–4 hours after initiating fluid therapy,

and a decreased dose should be used (1.1 U/kg/24 hr CRI in dogs, 0.05–0.1 U/kg every 2 hours IM). Blood glucose concentration should be normalized over 24–48 hours with frequent monitoring. Addition of dextrose to fluids and adjustments in insulin dosage should be handled as for DKA.

22. Describe the clinical signs of insulin overdose.

Lethargy, depression, ataxia, weakness, coma, and seizures may be caused by severe hypoglycemia due to overdose of insulin. Because overdose most often occurs at home, it is important to instruct owners how to look for signs and how to treat. Corn syrup should be applied to oral mucous membranes, and the animal should be brought to the veterinary hospital immediately.

23. How is insulin overdose diagnosed?

The history and clinical signs should increase suspicion. It is important to question the owner closely:

- Has there been any change in the type of insulin?
- How old is the bottle that you are currently using?
- Have you changed the type of insulin syringe that you use?
- Did a different person administer the insulin?
- Has the animal been eating well?
- Has the animal's exercise increased recently? (Increasing exercise decreases insulin requirements.)
- Is the animal being treated for hyperadrenocorticism?
- Has the animal recently finished estrus?

Some cats are transiently diabetic and may no longer need insulin at all. Definitive diagnosis of hypoglycemia is made fairly easily with a glucose reagent strip or a glucometer.

24. How do I treat insulin overdose?

An IV bolus of 50% dextrose (0.5 mg/kg diluted 1:4 with normal saline) should be given slowly. The animal is placed on a maintenance drip of 5% dextrose and fed as soon as it can eat. Blood glucose should be monitored hourly. Do not reinstitute insulin therapy until the animal is hyperglycemic. This may take several days, depending on severity and duration of hypoglycemia. The insulin dose should be decreased by 25–50%.

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74. HYPOGLYCEMIA

Chris McReynolds, B.A., D.V.M.

1. How is glucose maintained within the normal range in fasting animals?

Most fasting cats and dogs maintain blood glucose above 60 mg/dl. In a fasting state the counterregulatory hormones—glucagon, cortisol, epinephrine, and growth hormone—increase. These hormones stimulate hepatic production of glucose by glycogenolysis and gluconeogenesis. They also decrease peripheral glucose utilization by causing a conversion from carbohydrate metabolism to fatty acid and ketone body utilization by most tissues. Some cells, however, depend on glucose as their primary fuel, including the central nervous system, erythrocytes, and renal medulla.

2. What are the clinical manifestations of hypoglycemia?

Glucose is the primary fuel utilized by the CNS. In acute hypoglycemia the first area to be affected in mammals is the cerebral cortex, which is much more metabolically active than the spinal cord and brainstem. Common clinical signs in neuroglycopenic animals include lethargy, dullness, ataxia, seizures, and bizarre behavior. Hypoglycemia is a potent stimulus for release of counterregulatory hormones that function to increase blood glucose concentrations. With stimulation of the sympathoadrenal axis, muscle tremors, nervousness, restlessness, and hunger may be seen before neurologic signs because of high circulating catecholamine and cortisol blood levels.

3. What is the most common cause of hypoglycemia?

Artifactual reduction in blood glucose of 10 mg/dl/hr may occur when serum is allowed prolonged contact with red blood cells that utilize the glucose for fuel.

4. What are the primary mechanisms of pathologic hypoglycemia (< 65 mg/dl)?

Iatrogenic: inappropriate insulin dose for treatment of diabetes mellitus

Impaired glucose production
- Hepatic insufficiency
  - Cirrhosis
  - Portosystemic shunts
  - Necrosis
- Fasting in neonates and toy-breed puppies
- Hypopituitarism
- Adrenocortical insufficiency
- Glycogen storage disease
- Sepsis

Increased glucose utilization
- Insulinoma
- Large extrapancreatic tumors
  - Hepatoma or hepatocellular carcinoma
  - Leiomyoma or leiomyosarcoma
- Polycythemia
- Sepsis

Decreased intake
- Chronic starvation
- Malabsorption

5. What diseases cause hypoglycemia due to impaired glucose production?

More than 90% of glucose is produced endogenously by the liver. Thus, hypoglycemia may occur with liver diseases that result in more than 80% loss of hepatic parenchyma. Hypoglycemia also may result from lack of counterregulatory hormones that stimulate hepatic mobilization of glucose, as in hypoadrenocorticism and hypopituitarism. Although most small animals do not become hypoglycemic with 24–48 hour fasting, neonates and toy-breed puppies are at risk for hypoglycemia because of decreased glycogen stores and muscle mass.

6. What diseases cause hypoglycemia due to excessive peripheral glucose utilization?

Insulin-secreting tumors—in particular, pancreatic beta cell tumors—may cause severe hypoglycemia due to inappropriate release of insulin in fasting or exercising animals. Similarly, inappropriate insulin dose for treatment of diabetic animals is a common cause of hypoglycemia.

Many other neoplasms have been reported to cause hypoglycemia because of excessive glucose utilization by the tumor and/or inappropriately low hepatic production of glucose. The most common non–insulin-secreting tumors that cause hypoglycemia include hepatocellular carcinoma, hepatoma, leiomyosarcoma, and leiomyoma. Polycythemia (packed cell volume > 65%) may cause hypoglycemia due to increased utilization of glucose by large numbers of red blood cells dependent on glucose for cellular metabolism.

7. Why are septic animals often hypoglycemic?

Sepsis-induced hypoglycemia results from increased utilization of glucose by macrophage-rich tissues, such as the spleen; sepsis-induced enhancement of insulin production; and decreased hepatic production.

8. Describe the acute management of hypoglycemia.

For animals that show signs of agitation or dullness, a small meal usually alleviates clinical signs of hypoglycemia. For animals with hypoglycemic seizures, administer 1–5 ml of 50% dextrose IV slowly over 10 minutes. Once the animal is sternal and alert, feed a small meal. For seizures unresponsive to the dextrose bolus, one should start a 2.5–5% dextrose drip in a stepwise fashion. If seizures continue, add 0.5–1.0 mg/kg of dexamethasone, administered in the IV fluids over 6 hours. Finally, anesthetize the patient for 4–6 hours while continuing the above therapy if there is no response to glucose drip or glucocorticoids. Animals with intractable seizures also should receive treatment for cerebral edema.

9. Why does rebound hypoglycemia occur in animals with insulinomas?

Most animals showing clinical signs of hypoglycemia respond to an IV bolus of 50% dextrose given slowly over 10 minutes. Unfortunately, after the IV bolus of dextrose the beta cell tumor may be excessively stimulated, resulting in insulin release and rebound hypoglycemia. Cycles of hyperglycemia and hypoglycemia can be avoided by administering small amounts slowly; the endpoint should be dictated by control of clinical signs rather than correction of hypoglycemia.

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75. ACUTE PANCREATITIS

Wayne E. *Wingfield*, M.S., D.V.M.

1. Compare acute and chronic pancreatitis.

ACUTE	CHRONIC
Acute inflammatory condition	Long-standing inflammation
No evidence of fibrosis	Fibrosis and loss of acinar cell mass
Mild or severe	Mild or severe
Reversible histopathologic changes	Irreversible histopathologic changes

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Reversible histopathologic changes	Irreversible histopathologic changes

2. Describe the pathophysiology of severe pancreatitis.

Severe pancreatitis is characterized by extensive pancreatic necrosis and multiple organ involvement (perhaps even organ failure). The exocrine pancreas produces a number of digestive enzymes necessary for the degradation of proteins, fats, and polysaccharides. These enzymes are synthesized in inactive proenzyme forms that are activated only after they are secreted into the small intestine. In pancreatitis digestive enzymes are activated in the pancreas rather than the intestine because of damage to the gland or some stimulatory signal that results in pancreatic autodigestion. Systemic complications develop as activated pancreatic enzymes enter the bloodstream.

3. What is the most common cause of acute pancreatitis?

In most cases, the cause remains unknown. Causes that are often listed include nutrition (high fat meal), drugs (cholinesterase inhibitors and cholinergic agonists, thiazide diuretics, furosemide, estrogens, azathioprine, L-asparaginase, sulfonamides, tetracycline, metronidazole, cimetidine, ranitidine, acetaminophen, procainamide, and nitrofurantoin), organophosphates, trauma, hypoperfusion, hypercalcemia, hyperlipidemia (Schnauzers), and neoplastic infiltration by pancreatic adenocarcinoma. In cats, pancreatitis also is associated with concurrent hepatic lipidosis, infection with *Toxoplasma gondii*, and biliary tract inflammation.

4. Why is ingestion of a meal high in fat implicated as a cause of acute pancreatitis in dogs?

The pancreatic enzyme lipase metabolizes ingested triglycerides to free fatty acids in pancreatic capillaries. These fatty acids are directly injurious to the pancreas. The high incidence of pancreatitis in miniature Schnauzers also may be related to the high prevalence of familial hyperlipoproteinemia.

5. What are the primary presenting complaints and physical findings in dogs with pancreatitis?

Common clinical findings are vomiting, abdominal pain, dehydration, and fever. In dogs the duration of vomiting may be several days or, in acute hemorrhagic pancreatitis, only a few hours. Uncommon systemic complications include icterus, respiratory distress, and bleeding disorders.

6. Do cats present with the same symptoms as dogs?

Of interest, whereas vomiting is a common historical finding in dogs, most cats present with anorexia (97%), lethargy (100%), dehydration (92%), hypothermia (68%), vomiting (35%), abdominal pain (25%), a palpable abdominal mass (23%), respiratory distress (20%), ataxia (15%), and diarrhea (15%).

7. What are the radiographic signs of pancreatitis?

The most common radiographic finding is loss of visceral detail (ground-glass appearance) in the right cranial abdomen. Other radiographic signs include displacement of the descending duodenum to the right and of the stomach to the left, presence of a mass medial to the descending duodenum, and a gas-filled duodenum.

8. Describe the ultrasonic changes associated with pancreatitis.

Ultrasound changes include pancreatic swelling, increased echogenicity of the pancreas, and, less frequently, a mass effect in the area of the pancreas.

9. Are elevations in serum amylase and lipase activities definitive for the diagnosis of pancreatitis?

No. Neither enzyme is pancreas-specific; both are also produced by gastric and intestinal mucosal cells. Furthermore, because both enzymes are eliminated through the urine, a decrease in renal perfusion results in elevations of both enzymes. Finally, the administration of dexamethasone to dogs causes significant elevations in lipase without histologic evidence of pancreatitis.

10. Do normal lipase and amylase values eliminate the possibility of pancreatitis?

No. Many dogs and even more cats have confirmed pancreatitis with normal levels of both enzymes. Normal enzyme values in animals with pancreatitis may be due to impairment in pancreatic perfusion, depletion of stored enzymes, and/or disruption of the synthesis of new enzymes.

11. How is the diagnosis of pancreatitis confirmed?

Other than by histology, pancreatitis cannot be diagnosed on the basis of one test result. Common laboratory findings include leukocytosis, hyperglycemia, hypocalcemia, and elevations in amylase and lipase. Elevations in trypsin-like-immunoreactivity (TLI) correlate well with pancreatitis in both dogs and cats but also are affected by renal perfusion; furthermore, results generally take several days to return. Abdominal fluid analysis—in particular, lipase levels higher than serum lipase values—helps to make a case for pancreatitis. Ultrasound is useful for identifying an enlarged, inflamed pancreas. Diffuse or focal hypoechoic areas in the gland, along with compatible laboratory and physical findings, justify a high index of suspicion of pancreatitis.

12. How can the severity of acute pancreatitis be ascertained?

On admission it may not be easy to predict the severity or probable cause of acute pancreatitis. The clinician should be cognizant of concurrent laboratory abnormalities or clinical signs suggesting systemic complications. Examples include thrombocytopenia or clotting abnormalities, which may suggest disseminated intravascular coagulation (DIC); oliguria, which may indicate acute renal failure; hypotension and tachycardia, which may indicate systemic inflammatory response syndrome; and hypoglycemia, which may suggest sepsis.

13. What are the key components in treatment of pancreatitis?

The most important element of treatment is adequate fluid resuscitation. Decreased pancreatic perfusion due to hypovolemia, which may result from vomiting and third-space losses, may lead to progression of the disease if fluid therapy is inadequate. Recent studies suggest that colloid fluid resuscitation (plasma, hetastarch, and dextran 70) is an important component in the therapy of pancreatitis. In particular, fresh frozen plasma (10–20 ml/kg) is important in treatment of moderate-to-severe cases. Plasma as a colloid provides only small increases in oncotic properties but supplies clotting factors for management of DIC and protease inhibitors that deactivate pancreatic enzymes in the systemic circulation. Prophylactic antibiotics, pain relief, antiemetics, and antacids are also important components of therapy. Studies in cats with experimentally induced acute hemorrhagic pancreatitis have shown that low-dose dopamine (5 mg/kg/min) reduces the severity of pancreatitis by reducing microvascular permeability. Dopamine as an adjunctive treatment awaits clinical evaluation.

14. How is fresh frozen plasma useful in the treatment of pancreatitis?

Studies in dogs suggest when alpha2-macroglobulin, one of the scavenger proteins for activated proteases in serum, is depleted, death rapidly ensues. Fresh frozen plasma (FFP) or fresh whole blood not only contains alpha2-macroglobulin but also albumin. Unfortunately, in a study of human pancreatitis patients, plasma failed to show any benefit. Incubating FFP with heparin may release antithrombin III and thus be useful in DIC secondary to pancreatitis.

15. Is there evidence supporting the use of antibiotics or nonsteroidal antiinflammatory agents in pancreatitis?

No. Studies in humans have shown no benefit to antibiotics nor non-steroidal antiinflammatory agents. No data are available for the dog or cat.

16. What is the role of surgery in acute pancreatitis?

In most instances, pancreatitis is treated medically, and surgical intervention is not recommended. In patients that develop septic peritonitis or pancreatic abscess, however, surgery is the treatment of choice to remove necrotic tissue and to lavage the abdomen. Surgery also should be considered in patients who continue to deteriorate even with aggressive medical management.

17. What is done when the patient vomits every time food is offered?

Most patients with mild pancreatitis recover after avoidance of oral ingestion for 2 days, followed first by gradual introduction of water and then by small meals high in carbohydrates over the next few days. In patients that continue to vomit when offered food, one must first evaluate the case to ensure that no underlying disorder other than pancreatitis explains the persistent vomiting. In cases of smoldering pancreatitis, placement of a jejunostomy tube to provide nutrition with minimal stimulation of the pancreatitis should be strongly considered.

18. What are the long-term complications of pancreatitis?

Recurrent episodes of pancreatitis may result in progressive loss of pancreatic tissue and eventual development of diabetes mellitus and/or exocrine pancreatic insufficiency. Additional complications reported include acute fluid accumulation, infected necrosis, pancreatic pseudocyst formation, and pancreatic abscess.

CONTROVERSIES

19. Do corticosteroids cause severe pancreatitis?

Corticosteroids do not appear to cause pancreatitis, although they do increase serum lipase activity (but decrease serum amylase activity). Corticosteroid therapy is of no proven benefit in pancreatitis and may be harmful in severe pancreatitis.

20. Should food and water be withheld to allow the pancreas to rest and recover from the inflammatory episode?

Pancreatic rest has become the mainstay for treatment of acute pancreatitis, despite the absence of any clinical or experimental evidence to support this approach! Contrary to popular belief, pancreatic rest by avoiding pancreatic exocrine secretion has not made any impact on the clinical outcome of pancreatitis. Furthermore, no conclusive evidence to date indicates that medical treatment intended to decrease pancreatic exocrine secretion has any benefit, other than avoidance of pain, on the course of the disease. These observations are not surprising when one considers the fact that pancreatic exocrine secretion is severely impaired in an inflamed pancreas. If the pancreas is unable to respond to secretory stimuli, it makes perfect sense that therapeutic maneuvers to avoid pancreatic exocrine stimulation will have no bearing on the disease process.

21. Should total parenteral nutrition (TPN) be used in the treatment of pancreatitis?

In human patients, no difference in serum amylase activities between patients receiving TPN and controls is seen in the first 7 days after the diagnosis of acute pancreatitis. Although the TPN group achieved significantly greater nitrogen balance than controls, they also required significantly more days to first oral intake of clear liquids and full caloric intake. Most importantly, TPN patients experienced a significant prolongation of hospital stay (15 vs. 10 days in controls). No information is available in animals with pancreatitis.

22. Should total enteral nutrition (TEN) be used in the treatment of pancreatitis?

In human patients, TEN moderates the acute-phase response and improves disease severity and clinical outcome despite unchanged pancreatic injury on computed tomography scan. Oxidant stress and systemic exposure to endotoxin also are reduced with TEN. In humans, enteral feeding modulates the inflammatory and sepsis response in acute pancreatitis and is clinically beneficial. No information is available in animals with pancreatitis.

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76. HYPOADRENOCORTICISM

Lynda D. *Melendez*, D.V.M, MS, *Diplomate* ACVIM

1. Define hypoadrenocorticism.

Hypoadrenocorticism is the lack of production of glucocorticoids and mineralocorticoids by the adrenal glands. It may be due to a pathologic process that affects either the adrenal glands directly (primary hypoadrenocorticism) or the production or release of corticotropin-releasing hormone (CRH) by the hypothalamus or adrenocorticotropic hormone (ACTH) by the pituitary (secondary hypoadrenocorticism). Typical hypoadrenocorticism (Addison's disease) results from combined mineralocorticoid and glucocorticoid deficiency and is characterized by hyponatremia and hyperkalemia.

If only glucocorticoids are deficient, the disease is termed atypical hypoadrenocorticism. Because there are no electrolyte imbalances, diagnosis is more difficult than for typical hypoadrenocorticism. All cases of secondary hypoadrenocorticism are deficient only in glucocorticoids because ACTH acts primarily on the adrenal zona fasciculata to stimulate glucocorticoid production and release and has little-to-no effect on mineralocorticoid production. Approximately 10% of dogs with primary hypoadrenocorticism are atypical at presentation, but most also develop mineralocorticoid deficiency.

2. What is the common signalment of dogs with hypoadrenocorticism?

Hypoadrenocorticism occurs most frequently in middle-aged females; the median age is 4–5 years. Sexually intact females have a higher risk of developing the disease, and sexually intact males have the lowest risk. Although close to one-third of dogs with hypoadrenocorticism are mixed breed, poodles of any size and flavor, Portuguese water dogs, Leonbergers, and Labrador retrievers have a familial tendency. Other predisposed breeds include Great Danes, Rottweilers, West Highland white terriers, and German shepherd dogs.

3. What are the most common historical complaints made by owners of dogs with hypoadrenocorticism?

Lethargy, anorexia, vomiting, and weight loss are common historical findings. Less frequent complaints are diarrhea, shaking, polyuria and polydipsia, and weakness. An important feature of hypoadrenocorticism is the waxing and waning nature of clinical signs. In general, the owner comments about marked improvement in the pet after administration of fluids and some "injection."

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4. Which abnormalities are most commonly noted on physical examination?

Physical abnormalities include lethargy, weakness, poor body condition, some degree of dehydration, melena, and hypothermia. Approximately 35% of animals present with physical findings consistent with moderate-to-severe shock, including weak pulses, pale mucous membranes, prolonged capillary refill time (CRT), and cold extremities. However, affected animals tend to have bradycardia instead of tachycardia, which is indicative of hyperkalemia.

5. Describe the hematologic abnormalities in patients with hypoadrenocorticism.

Lymphocytosis and eosinophilia (i.e., lack of a stress leukogram in sick animals) occur in approximately 10% and 20% of dogs diagnosed with hypoadrenocorticism disease, respectively. These changes may be the only laboratory clues in the search for the atypical addisonian. A mild normochromic, normocytic nonregenerative anemia is common but often not apparent until dehydration is corrected. In one study, 61% of patients were reported to have anemia after dehydration resolved. In patients with melena, anemia may be severe and ultimately regenerative.

6. List the common serum biochemical and electrolyte abnormalities associated with hypoadrenocorticism.

- Moderate-to-severe azotemia (approximately 80% of patients)
- Hyperkalemia (approximately 90–95%)
- Hyponatremia (approximately 80%)
- Hyperphosphatemia (approximately 70%)
- Low total CO_2 (approximately 40%)
- Hypercalcemia (approximately 30%)
- Increased activities of liver enzymes (approximately 30%)
- Hypoglycemia (approximately 17%)

7. Why is the azotemia associated with hypoadrenocorticism generally considered prerenal?

Most addisonians are azotemic at diagnosis and have a urine specific gravity less than 1.030. This finding argues against the assumption that azotemia is due to prerenal causes and supports primary renal failure. However, in most patients, the creatinine levels are typically less elevated than the blood urea nitrogen (BUN) concentrations. In addition, azotemia resolves in most patients with intravenous (IV) fluid administration. The low specific gravity is generally attributed to medullary wash-out from hyponatremia and increased renal excretion of sodium due to the lack of aldosterone, which results in solute diuresis.

8. How does a low sodium:potassium ratio support the diagnosis of hypoadrenocorticism?

A normal sodium:potassium (Na:K) ratio in dogs is 27:1–40:1 with a mean of 30:1. In one study of 225 addisonian dogs, about 95% had a low Na:K ratio; the mean was 19.3:1. However, 20 dogs had a normal Na:K ratio 1–4 weeks previously. Hypoadrenocorticism is placed on the rule-out list of an ill animal with hyponatremia, hyperkalemia, and a Na:K ratio less than 27:1, but hypoadrenocorticism is not the only disease that lowers the Na:K ratio.

9. List the differential diagnoses for hyperkalemia and hyponatremia.

HYPERKALEMIA	HYPONATREMIA
Anuric or oliguric renal failure	Gastrointestinal disease
Uroabdomen	Nephrotic syndrome
Urinary obstruction	Congestive heart failure
Severe gastrointestinal disease	Hypothyroidism
Metabolic acidosis	Diabetes mellitus
Drugs (potassium-sparing diuretics, nonsteroidal antiinflammatory drugs, angiotensin-converting enzyme inhibitors)	Primary polydipsia
	Inappropriate secretion of antidiuretic hormone
Pleural effusion	Third spacing
Pseudohyperkalemia of Akitas	Postobstructive diuresis
Thrombocytosis	
Leukocytosis	

10. What test is used for definitive diagnosis of hypoadrenocorticism?

Normal dogs may have low resting cortisol levels and so should not be assessed for the diagnosis of hypoadrenocorticism on this basis alone. An ACTH stimulation test is considered the gold standard for diagnosis of hypoadrenocorticism. Dogs with hypoadrenocorticism have low-to-low-normal resting serum cortisol levels and show little-to-no response to ACTH administration. The ACTH stimulation test does not differentiate between primary and secondary hypoadrenocorticism in atypical populations. Dogs with secondary hypoadrenocorticism have only glucocorticoid deficiency and do not develop electrolyte imbalances, whereas dogs with atypical primary hypoadrenocorticism eventually develop mineralocorticoid deficiency. Measurement of endogenous ACTH (eACTH) levels distinguishes between these two groups. Those with secondary hypoadrenocorticism have a low eACTH level, whereas those with primary hypoadrenocorticism have an elevated eACTH. Electrolytes should be monitored periodically in patients with primary atypical hypoadrenocorticism.

11. What is an addisonian crisis?

The term addisonian crisis refers to the development of clinical and biochemical abnormalities associated with acute hypoadrenocorticism and is characterized by vascular collapse and shock. Many patients also have ECG abnormalities associated with hyperkalemia. Approximately 35% of all dogs with hypoadrenocorticism are presented to the veterinarian with classic signs of shock, including obtundation, prolonged capillary refill times, pale mucous membranes, hypothermia, and weak, thready pulses. An important clinical feature is the presence of bradycardia in the face of vascular collapse, which suggests hyperkalemia. The ECG generally reveals atrial standstill or absence of P-waves, prolonged QRS duration, low R amplitude, and peaked T-waves. A small percentage of dogs exhibit some degree of atrioventricular (AV) block.

12. What are the goals of management of an acute adrenal crisis?

Mortality associated with hypoadrenocorticism is usually secondary to shock, hypotension, and hypovolemia rather than hyperkalemia. Therefore, the most important goal of therapy is fluid replacement. Place an IV catheter and collect baseline samples for a complete blood count, chemistry profile, serum cortisol levels, and urinalysis before starting IV fluids. Once the animal is volume-repleted, replacement of glucocorticoid deficits and correction of electrolyte imbalances, hypoglycemia, and acidosis can be addressed.

13. What is the fluid of choice for hypoadrenocorticism? How should it be administered?

Normal saline (0.9% NaCl) provides the greatest concentration of sodium and chloride in a physiologic IV fluid preparation. It has the added advantage of being potassium-free. To achieve volume repletion, to correct hypotension and hypovolemia, and to improve tissue perfusion, saline should be administered IV at approximately 40–80 ml/kg in the first hour, with adjustments according to the clinical picture. Fluid administration not only improves vascular parameters but also dilutes extracellular potassium concentrations, decreasing the risk of cardiac arrhythmias. The correction of dehydration with improvement of tissue perfusion may be adequate to correct acidosis. Once heart rate, pulse quality, CRT, and patient attitude improve, the continuing fluid rate is determined by individual requirements (e.g., degree of dehydration, sensible and insensible losses, maintenance needs). If normal saline is not available, a balanced electrolyte solution such as lactated Ringer's, Normosol, or Plasmalyte may be used. Although these preparations contain potassium, concentrations are minimal, and the volume of fluid administered dilutes potassium concentration in the serum.

14. When should hyperkalemia be treated with something other than IV fluid replacement?

Opinions vary. However, it is agreed that if cardiac arrhythmias are present, hyperkalemia should be treated primarily. Others propose that if the potassium concentration is above 7–8 mEq/L, it should be treated with substances that decrease serum potassium concentrations or counteract the cardiac effects of hyperkalemia. Treatment of hyperkalemia is covered in chapter 78.

15. When should an ACTH stimulation test be performed in a crisis setting?

An ACTH stimulation test is a benign procedure and may be performed immediately. The resting cortisol level should be assessed when baseline blood samples are taken, aqueous synthetic ACTH is administered IV, and poststimulation cortisol level is collected in 1 hour for dogs and in 30 and 60 minutes for cats. Because fluid replacement is the most important aspect of therapy, it is generally not detrimental to wait 1 hour before glucocorticoid therapy is instituted. However, if the clinician believes that glucocorticoids should be given immediately, dexamethasone should be used; it is the only commonly used glucocorticoid that is not detected in cortisol assays.

16. When in the course of therapy should glucocorticoids be given?

Because fluid replacement is the most important aspect of therapy, it generally does no harm to delay glucocorticoids until baseline blood samples are taken, the ACTH stimulation test is completed, and the initial shock dose of fluids is administered. Once volume expansion has been accomplished, glucocorticoid replacement should be addressed. Glucocorticoids should not be given until perfusion is improved. If it is not possible to perform an ACTH stimulation test during the initial management of an addisonian crisis, dexamethasone is the drug of choice for glucocorticoid replacement, as explained in the previous question.

17. Which glucocorticoids are recommended for replacement therapy?

1. Hydrocortisone hemisuccinate and hydrocortisone phosphate possess glucocorticoid as well as mineralocorticoid activity and therefore are recommended in an acute crisis. They are given at a dose of 2–4 mg/kg IV every 6–8 hours until shock is corrected, then at a dose of 0.5–1.0 mg/kg every 6–8 hours.

2. Prednisolone sodium succinate also possesses mild mineralocorticoid activity along with its glucocorticoid activity and is given at a dose of 4–20 mg/kg IV every 2–6 hours, depending on the response of the patient.

3. Dexamethasone sodium phosphate has only glucocorticoid activity and may be given initially at a dose of 0.5–2.0 mg/kg. Once the patient is no longer in shock, this dose is decreased to 0.04–0.1 mg/kg twice daily.

4. Once the patient is stable and eating voluntarily, maintenance glucocorticoid replacement is begun. Prednisone or prednisolone is given orally at an initial dose of 0.5–1.0 mg/kg, divided every 12 hours. This dose is decreased by 50% every week until the lowest dose that maintains the patient is reached. For animals with atypical hypoadrenocorticism, glucocorticoid therapy is lifelong. Patients that require mineralocorticoid therapy and receive fludrocortisone acetate, which also has some glucocorticoid activity, may not require daily prednisone. Patients receiving desoxycorticosterone pivilate (DOCP) require prednisone therapy for life. If signs of lethargy, anorexia, or depression recur, prednisone should be reinstituted at the physiologic dose of 0.22 mg/kg given daily or divided every 12 hours.

In times of stress animals with hypoadrenocorticism require additional glucocorticoids; thus, owners should keep either prednisone or prednisolone on hand.

18. When should mineralocorticoid replacement be instituted?

In the case of a crisis, saline administration corrects hyponatremia and hypochloremia and improves hyperkalemia while expanding the blood volume. Life-threatening hyperkalemia has already been addressed. Usually, nothing more is needed until the patient is rehydrated and eating voluntarily. However, in cases that are slow to respond to saline administration, hydrocortisone hemisuccinate or phosphate provides the mineralocorticoid activity needed to improve electrolyte imbalances until a maintenance mineralocorticoid regimen can be instituted.

19. How is maintenance mineralocorticoid replacement assessed?

Maintenance mineralocorticoid replacement may be given in one of two ways:

1. Fludrocortisone acetate, 0.1 mg/10 lb/day orally in divided doses every 12 hours. (This drug has glucocorticoid activity and may not require the addition of prednisone.)

2. Desoxycorticosterone pivalate (DOCP), 1 mg/lb every 25–30 days IM.

Initially, electrolytes should be monitored every 5–7 days until they are stable. Once therapy is adequate, patients receiving fludrocortisone may be monitored every 4–6 months. After the first 1–2 weeks, animals receiving DOCP are monitored on the 25th day of therapy. If electrolytes are normal at that time, the animal may need injection only every 28 or 30 days. Response to DOCP is variable, and dosage and dosing interval must be tailored to each patient.

20. What other problems need to be addressed in dogs with an adrenal crisis?

1. Approximately 17% of patients are hypoglycemic at presentation; some have seizures. Hypoglycemia may be treated by adding dextrose to the saline infusion.

2. Metabolic acidosis is usually mild and may be corrected by volume expansion and improved tissue perfusion. However, if the acidosis is severe, sodium bicarbonate therapy may be required.

3. Renal function should be monitored closely by measuring urine output. If urine production does not meet or exceed 2–4 ml/kg/hr, diuresis with a constant-rate infusion of dopamine, 2–4 μg/kg/min, and furosemide, 2–4 mg/kg IV, may be necessary.

4. Approximately 15% of hypoadrenal dogs present with melena. In some cases, gastrointestinal bleeding may be severe enough to be life-threatening and require blood transfusion. Such animals should be placed on gastric protectants such as sucralfate, H_2 blockers, proton pump inhibitors, or synthetic prostaglandins. Packed cell volumes, platelet counts, and activated clotting times should be monitored closely. As odd as it seems, glucocorticoid therapy should not be withheld. It is postulated that the lack of physiologic glucocorticoids is the cause for loss of gastromucosal integrity and is necessary for healing.

21. What are the principal differences between hypoadrenocorticism in cats and dogs?

- There is no sex predilection in cats with hypoadrenocorticism.
- Diarrhea has not been reported in cats with hypoadrenocorticism.
- ECG abnormalities are uncommon in cats with hyperkalemia but present in 80% of dogs.
- Cats take 3–5 days to respond to therapy as opposed to 1–2 days for dogs.
- Serum cortisol concentrations in cats must be measured at 30 and 60 minutes after administration of aqueous ACTH and at 60 and 120 minutes after IM administration of ACTH gel.

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77. PERITONITIS

Catriona MacPhail, D.V.M

1. What are the primary functions of the peritoneum?

The peritoneum is the highly permeable lining of the abdominal wall and viscera forming an empty cavity. A small amount of free fluid that acts as a lubricant between the abdominal organs is constantly being formed. Water and other soluble products freely diffuse across the membrane. This property allows for such life-saving procedures as peritoneal dialysis.

2. What is the normal character and amount of peritoneal fluid?

Normal abdominal fluid is clear with a specific gravity of 1.016, less than 2 gm/dl of protein and typically 2000–2500 large mononuclear cells. There is usually less than 1 µl/kg of body weight of peritoneal fluid.

3. List the types of abnormal fluid, along with the cellular and protein characteristic of each, found in the peritoneal space.

Fluids with different characteristics are classified as transudates, modified transudates, or exudates, according to the following criteria:

	PROTEIN		
CELLS	< 2.5 gm/dl	2.5–7.5 gm/dl	> 3.0 gm/dl
< 1500/µl	Transudate		
1000–7000/µl		Modified transudate	
> 7000/µl			Exudate

4. List the most likely differential diagnoses for transudates, modified transudates, and exudates.

Transudates	**Modified Transudates**	**Exudates**
Hepatic insufficiency	Cardiovascular disease	Septic peritonitis
Protein-losing enteropathy	Feline infectious peritonitis	Bile peritonitis
Protein-losing nephropathy	Bile peritonitis	Hemoabdomen
Uroperitoneum	Hemoabdomen	Chylous effusion
	Chylous effusion	Uroperitoneum
	Uroperitoneum	Neoplasia
	Neoplasia	

5. What is peritonitis?

The term *peritonitis* describes any inflammatory process involving the peritoneum and the peritoneal cavity. Feline infectious peritonitis is the only primary peritoneal disease. More often peritonitis is a sequelae of another disease process or an insult associated with disruption of the abdominal viscera or an external wound into the abdominal cavity. Secondary peritonitis usually has an acute or peracute onset with serious systemic symptons and signs.

6. What is the etiology of feline infectious peritonitis (FIP)?

FIP is a highly contagious, systemic, immune-mediated disease caused by a coronavirus. Chronic effusive peritonitis is the classic manifestation of the wet form of the disease, but the peritoneum is only one of many systems affected. Effusion and inflammation result from perivasculitis and subsequent increase in vascular permeability.

7. Outline the major causes associated with secondary peritonitis.

BACTERIAL	CHEMICAL	COMBINED/ MISCELLANEOUS
Pyometritis	Uroabdomen	Neoplasia
Gastrointestinal compromise	Pancreatitis (pancreatic enzymes)	Iatrogenic foreign bodies (e.g., sponges, suture)
Surgical wound dehiscence	Gastrointestinal fluid (rupture, perforation)	Granulomatous (glove powder)
Pancreatic abscess	Bile (biliary tract disruption)	Contrast media (barium, iodides)
Prostatic abscess		Feline infectious peritonitis
Penetrating foreign body		
Puncture or bite wound		

8. What are the main categories of peritonitis?

Peritonitis is characterized as either **localized** or **diffuse (generalized)**. Presentation, diagnosis, treatment, and prognosis differ dramatically between the two forms. Localized peritonitis may or may not require medical intervention; however, if uncontained it may rapidly develop into a diffuse or generalized condition that is potentially life-threatening. Because of the nature of the peritoneum, generalized peritonitis may have profoundly damaging effects on other organ systems.

9. What are typical manifestations of generalized peritonitis?

Animals with generalized peritonitis commonly present with historical and physical abnormalities associated with the primary disease (see question 7). Patients are usually in hypovolemic shock and have marked abdominal pain, although the animal may present with vague, nonspecific signs early in the course of disease. The patient may present with obvious abdominal distention and a fluid wave (succussion) may be elicited on abdominal ballottement. Many animals with peritonitis have a recent history of abdominal surgery. Other historical information that may raise the suspicion of peritonitis may include foreign body ingestion, administration of nonsteroidal antiinflammatory drugs, or administration of immunosuppressive or chemotherapeutic drugs.

10. Is peritonitis always painful?

With acute or peracute onset of diffuse peritonitis, the animal exhibits signs of pain on abdominal palpation. Animals with severe abdominal pain often assume a praying position (the forelimbs are bent, and the rear quarters are elevated in the air with extended legs.) Peritonitis that develops over an extended period, such as FIP, is usually not painful.

11. How does the peritoneum respond to injury?

The initial response is an increase in vascular permeability and subsequent influx of fluid. Increases in cell population and total protein are due to the presence of blood, albumin, fibrin, and debris. Fibrin is produced in an attempt to wall off the insult; it also allows adhesions to form between structures in the peritoneal cavity. Because of the large surface area of the peritoneum, fluid loss can be massive and ultimately results in decreased cardiac output, decreased perfusion, cellular hypoxia, and organ dysfunction. Diaphragmatic lymphatic clearance and macrophage phagocytosis are the first responses to contamination. Rapid neutrophil migration follows. Fibrin production is increased in an attempt to wall off the insult; it also allows adhesion to form between structures in the peritoneal cavity. The amount of protein in the fluid also is increased because of the presence of albumin, blood, fibrin, and necrotic cellular debris.

12. What is the simplest and most rewarding way to diagnose peritonitis?

Abdominocentesis for collection of fluid for cytologic evaluation is the least invasive and quickest way to diagnose peritonitis. If a fluid wave can be ballotted, a single midline pericentesis is usually successful. A four quadrant pericentesis is performed if there are small amounts of fluid, if compartmentalized disease is suspected, or if a midline pericentesis is negative. Usually the animal is standing or in lateral recumbency. The bladder is expressed to avoid unintentional

cystocentesis. The abdomen is clipped, antiseptically prepared, and divided into four quadrants, cranial and caudal to the umbilicus and on either side of the ventral midline. A 20-gauge, 1-inch needle is inserted perpendicular to the midline into each of the four quadrants. Fluid should be allowed to drip out the open end of the needle and initially collected into a tube of ethylenediamine tetraacetic acid (EDTA) for cytologic analysis, which should include protein measurement and differential cell count. Other potential tests, as dictated by the suspected primary cause, include culture and sensitivity testing and measurement of packed cell volume, blood urea nitrogen (BUN), creatinine, total bilirubin, amylase, lipase, or triglycerides.

13. What if no fluid is retrieved from the abdominocentesis?

A negative abdominocentesis does *not* rule-out peritonitis. The technique descibed in question 12 commonly yields false-negative results, especially if only a small amount of fluid is present. Alternatives include use of a larger-gauge needle, an over-the-needle catheter, or placement of a peritoneal dialysis catheter. Diagnostic peritoneal lavage may be performed using an 18 or 20-gauge, 1¼-inch over-the-needle catheter. After the area is prepared, the catheter is inserted into the abdomen and the stylet is removed. Warm isotonic fluid (22 ml/kg) is then infused into the abdomen through the catheter. After the fluid is allowed to disperse and mix in the abdomen momentarily, it is aspirated back and examined cytologically and biochemically.

14. After a routine, uncomplicated exploratory laparotomy, what type of fluid does postoperative abdominocentesis retrieve?

The fluid should be highly cellular representing a mild inflammatory reaction from the tissue manipulation. The primary cell population should be nondegenerate neutrophils. In a clean-contaminated surgery, such as an enterotomy, diaphagmatic lymphatics should clear mild bacterial contamination within 6 hours.

15. When is a peritonitis characterized as septic? What are the most common causes of a septic abdomen?

The presence of one bacterium in the abdominal fluid with high numbers of degenerate neutrophils characterizes the fluid as septic. The route of infection is usually from rupture of the gastrointestinal tract secondary to gastric dilatation-volvulus, mechanical obstruction, or breakdown of a previous surgical intestinal resection and anastomosis or enterotomy sites. Other possibilities include rupture of localized hepatic, pancreatic, or prostatic abscesses or contamination from pyometra.

16. What are the most common causes of a nonseptic exudate?

Nonseptic exudate usually is associated with inflammation from a chemical irritant such as urine, bile, pancreatic enzymes, or blood. The term *nonseptic* implies the absence of bacteria; however, nonseptic generalized peritonitis can quickly progress to septic peritonitis if not treated. Chemical, nonseptic peritonitis may cause adynamic ileus of the small intestine, resulting in compromise of the lumen and possible induction of septic peritonitis due to bacterial translocation.

17. What are the typical characteristics of an FIP effusion?

The effusion associated with FIP is usually a nonseptic, protein-rich, straw-colored fluid with a relatively low cell count. The fluid is viscous and foamy because of high protein content and often has visible strands or flecks of fibrin. The cell population is typically characterized as pyogranulomatous because of the predominance of macrophages and non-degenerative neutrophils. If the ratio of albumin to globulin in the effusion is > 0.81, FIP is unlikely.

18. How can a suspected uroabdomen be confirmed?

Uroabdomen generally results in a transparent serosanguinous fluid and is initially aseptic unless an underlying urinary tract infection was already established. BUN and creatinine should be measured on the abdominal fluid and serum. The BUN should be roughly the same in both fluids as it rapidly equilibrates over the compromised membrane, whereas the concentration of

creatinine is greater in abdominal fluid than in serum. Of interest, BUN is now found to be as accurate as creatinine in identifying acute uroabdomen.

19. Can pancreatitis-associated peritonitis be diagnosed using peritoneal effusions?

Peritoneal effusions associated with pancreatitis are generally classified as nonseptic, suppurative modified transudates or exudates. Comparison of serum and effusion amylase and lipase activities generally reveals higher activities in the effusion.

20. How do you differentiate between hemorrhagic effusion and blood pericentesis from a vessel or organ?

The packed cell volume of the fluid should be compared with that from the peripheral blood; if the values are different, a hemorrhagic effusion should be suspected. The absence of platelets and the presence of erythrophagocytosis on cytological examination of the fluid is also consistent with hemorrhagic effusion. If a moderate to large amount of fluid is collected, a sample should be evaluated for clotting; if clotting occurs, the fluid is either peripheral blood or peracute abdominal hemorrhage. Traumatic rupture of abdominal organs or vessels, coagulopathies, and neoplasia are common causes of hemoperitoneum.

21. Describe the lethal factors in peritonitis.

The prognosis for a patient with generalized peritonitis depends on the underlying primary cause or preexisting or concurrent disease, duration of the condition, and the patient's physical status. However, certain concurrent conditions increase the likelihood of mortality. If hypovolemic shock develops or a mixed bacterial population or free hemoglobin is found in the effusion, alone or in combination, the prognosis is dramatically worsened. Hemoglobin is believed to enhance the virulence of bacteria by a mechanism not well understood.

22. Do abdominal radiographs have any diagnostic value in patients with confirmed peritonitis?

Fluid in the abdomen causes a ground-glass appearance on radiographs, which obscures serosal detail of abdominal organs. However, abdominal radiographs may delineate free gas in the abdomen, suggestive of gastric or intestinal perforation. This scenario is best appreciated on a standing lateral radiograph, which demarcates a line between fluid and free gas. Plain abdominal radiographs also demonstrate the presence of functional intestinal ileus which is a common complication of generalized peritonitis. The presence of the urinary bladder or abdominal masses may also be determined from survey films, if fluid volumes are minimal. Thoracic radiographs should be performed if the animal is showing any respiratory symptoms. Conditions identified on radiographs that may affect treatment options and prognosis include pleural effusion, pulmonary edema, aspiration pneumonia, and metastatic neoplasia.

23. What other diagnostic tests may help to determine the cause of peritonitis?

Abdominal ultrasound is useful in finding an underlying cause of peritonitis such as pancreatitis. It also may detect pockets of small amounts of fluid, as in a localized peritonitis that can be associated with pancreas or liver abscess. A positive **contrast cystourethrogram** may help differentiate between a ruptured bladder or an avulsed ureter. An **upper gastrointestinal series** is indicated in some cases to confirm a mechanical obstruction or perforation of the bowel. However, often advanced imaging studies are not required and may delay therapy.

24. What are the significant metabolic alterations and sequelae associated with a generalized peritonitis? How could they be corrected or avoided?

Shock, metabolic acidosis, acute renal failure, acute hepatic failure, hypoglycemia, pancreatitis, sepsis, cardiac dysrrhythmias, pleural effusion, and disseminated intravascular coagulation are the most common secondary problems in animals with generalized peritonitis.

25. What is a suitable antibiotic choice for a septic abdomen?

Because the bowel is the usual source of bacteria in animals with septic peritonitis, single or combination antibiotics for empirical treatment of gram-negative, gram-positive, and anaerobic bacteria are indicated. In combination therapy, enrofloxacin or aminoglycosides are usually chosen for gram-negative organisms and combined with penicillins, first-generation cephalosporins, or clindamycin, each of which has a broad spectrum of action against gram-positive anaerobic organisms. If a single antibiotic is preferred, second-generation cephalosporins, third-generation cephalosporins, and imipenem are good choices. Initial empirical antimicrobial therapy should be started as soon as peritonitis is suspected and a sample of abdominal fluid is retrieved for culture and sensitivity testing.

26. At what point is surgery indicated? What are the primary goals of surgical intervention?

Every patient with septic peritonitis should be surgically explored to locate and correct the underlying cause and source of contamination. Surgery also allows for removal of foreign material, lavage of the peritoneal cavity, and, potentially, placement of peritoneal drains, gastrotomy feeding tubes, or jejunostomy feeding tubes. Irrigation of the abdominal cavity with large volumes of warm isotonic fluid aids removal of necrotic debris, potentially reduces adhesion formation, and dilutes the bacterial population, thus lessening the potential for abscess formation.

27. What subjective parameters may be used to determine organ viability?

Abdominal structures should be evaluated for blood supply based on color, thickness, temperature, and perfusion (arterial pulse; bleeding of incised surface). Peristalsis is also a good indicator of viability of the stomach and intestines.

28. What is the role of peritoneal drain systems in the treatment of peritonitis?

Peritoneal drains are useful for providing local drainage of intraabdominal abscesses or other pockets of localized peritonitis. Placement of a closed peritoneal drain for management of generalized peritonitis has been associated with many complications. Because of the peritoneum's ability to respond rapidly to injury, most drainage systems are sealed over within 6 hours by fibrin and adhesion formation. Efficacy of peritoneal drains for continual effusion of abdominal fluid may be enhanced by placement of multiple drains and by intermittent or continuous peritoneal lavage. Cytologic evaluation of the effluent measures the patient's progress and determines when the drains may be removed. The most effective type of abdominal drain is the sump-Penrose system, whereby a sump drain is placed inside a fenestrated Penrose drain. This configuration is thought to protect the abdominal viscera and to provide more efficient drainage than the use of Penrose, tube, or sump drains alone.

29. Describe complications associated with closed abdomen peritoneal drainage and peritoneal lavage.

Any type of drainage system provides a route for ascending infection. The introduction of foreign material into the peritoneal cavity causes an increase in inflammatory response and formation of adhesions. Drains may be directly damaging to abdominal viscera by erosion of the serosal surface. Problems with peritoneal lavage are associated with the introduction and removal of large amounts of fluid and loss of cells, protein, and electrolytes. The most likely complications are anemia, hypoproteinemia, hypokalemia, hyponatremia, and hypocalcemia. Hypothermia is easily avoided by the use of warm lavage fluids. Sterile occlusive dressings around the drain sites may minimize the risk of ascending infection.

30. How much of a benefit is there to leaving the abdomen open to drain? What are the advantages, disadvantages, and complications of open abdominal drainage?

Open abdominal drainage is believed to provide a more rapid and more effective means of drainage of the peritoneal cavity. The obvious risks are infection and sepsis as well as dehiscence and evisceration, but this can be avoided by frequent sterile bandage changes and close observation of the patient. At surgery, the abdomen is incompletely closed by loose apposition of the external rectus sheath in a simple continuous pattern. Subcutaneous tissue and skin may be left open or

closed depending on the amount of local contamination. Sterile dressings are placed over the incision and secured to the patient with a circumferential abdominal wrap. This bandage should be changed as often as necessary, typically once or twice a day, and the quantity and appearance of the fluid should be evaluated. A major disadvantage is that this technique requires at least a second surgical procedure for completing abdominal closure. However, it also allows a second look to assess organ viability and surgical repairs and provides an opportunity for additional intraoperative lavage. Other complications include significant fluid and protein loss, resulting in hypovolemia, anemia, and hypoproteinemia. These conditions need to be recognized and treated appropriately.

CONTROVERSY

31. Should antibiotics or antispetics be administered intraabdominally with generalized septic peritonitis?

Intraabdominal administration of antibiotics frequently is used in equine abdominal surgery and is advocated by some for use in small animals as well. However, antibiotics can increase the inflammatory reaction in the abdomen, increase the risk of adhesions, and may increase the risk of drug toxicity if the animal is receiving systemic antibiotics concurrently. Addition of antiseptics to the lavage fluid is also controversial due to risk of irritation and toxicity.

32. What role do corticosteroids and nonsteroidal antiinflammatory drugs (NSAIDs) have in treatment of generalized peritonitis?

The use of corticosteroids in septic animals remains controversial. Benefits of steroids include stabilization of vascular and lysosomal membranes, reduced adhesion formation, positive cardiac inotropic effect, and increased regional blood flow. Disadvantages to steroid use include gastrointestinal ulceration and potential immunosuppression in the face of potential infection. NSAIDs block prostacyclin and thromboxane A_2 production, which may contribute to multiple organ failure. These drugs may also be helpful in treating acute endotoxic or septic shock. Flunixin meglamine (Banamine) has been shown to be beneficial in experimental models of septic peritonitis. However, the risk of adverse effects of NSAIDs, such as gastrointestinal ulceration and renal toxicity, makes their use in animals with septic peritonitis controversial.

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78. POTASSIUM ABNORMALITIES

Wayne E. *Wingfield*, M.S., D.V.M.

1. Where is most of the potassium in the body located?

Potassium concentrations equal approximately 150 mEq/L in the intracellular fluid (ICF) compartment, whereas extracellular fluid (ECF) or plasma concentrations are about 4–5 mEq/L.

2. How is the large chemical gradient between ICF and ECF potassium concentration maintained?

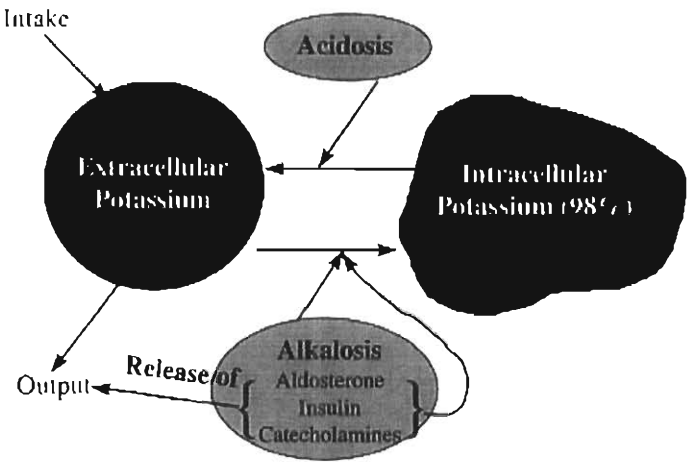
The sodium/potassium (Na^+/K^+) adenosine triphosphatase pump actively extrudes sodium from the cell and pumps potassium into the cell. This pump is present in all cells of the body. In addition, the cell is electrically negative compared with the exterior, which serves to keep potassium inside the cell.

3. Given the small ECF compared with ICF concentration of potassium, why are some electrical processes so sensitive to changes in ECF potassium concentration?

It is the ratio of ECF to ICF potassium concentration that determines the sensitivity of electrical processes such as cardiac conduction and smooth and skeletal muscle contraction. Because the ECF potassium concentration is small, a slight absolute change in ECF potassium concentration results in a large change in the ratio of ECF to ICF potassium concentration.

4. What common factors influence the movement of potassium between ECF and ICF compartments?

- **Acid–base changes.** Acidemia leads to intracellular buffering of the hydrogen ion, with subsequent movement of potassium to the extracellular compartment, thus increasing the potassium in ECF. In alkalosis, potassium moves from the extracellular to the intracellular space.
- **Hormones.** Insulin, epinephrine, growth hormone, and androgens promote movement of potassium into cells.
- **Cellular metabolism.** Synthesis of protein and glycogen is associated with intracellular binding of potassium.
- **Extracellular potassium concentration.** When ECF potassium levels are high, potassium tends to move into the ICF and vice versa.



Control of potassium in the body.

5. How is potassium handled by the kidney?

Most potassium is reabsorbed by the proximal tubule, with net secretion or reabsorption by the distal nephron. Most normal animals have a net excess of potassium, requiring its excretion.

6. What is the main regulatory hormone for potassium?

Aldosterone, produced in the adrenal cortex, promotes sodium reabsorption and potassium secretion in the distal nephron, gut, and sweat glands. The main effect is in the kidneys. Release of aldosterone is increased when ECF potassium increases and decreased when ECF potassium decreases.

7. What factors lead to increased renal excretion of potassium?

- Potassium supplementation in intravenous fluids.
- Volume depletion leads to increased aldosterone secretion.
- Alkalosis promotes renal excretion of potassium.
- Increased sodium delivery to the distal nephron promotes sodium reabsorption in exchange for potassium secretion in the distal nephron.
- Decreased chloride concentration in the distal nephron allows sodium to be reabsorbed with a less permeable ion, such as bicarbonate or sulfate, and thus increases the negativity of the tubular lumen in the distal nephron. The increased negativity promotes potassium secretion.
- Drugs, particularly diuretics.

8. What are the other sources of potassium loss?

The gastrointestinal (GI) tract is the other route of potassium loss. Generally, diarrhea increases gut loss of potassium. Vomiting from the upper GI tract causes renal potassium losses from alkalosis, volume depletion (increased aldosterone secretion), or chloride depletion (see question 7).

9. When does serum concentration of potassium falsely estimate total body concentration?

The reciprocal movement of potassium and hydrogen ions across the cell membrane results in a rise in serum potassium of approximately 0.6 mEq/L for every drop in pH of 0.1 units in patients with acidemia. Alkalemia results in a fall in serum potassium of 0.1–0.4 mEq/L for every rise in pH of 0.1 units. Thus, it is important to consider acid–base status in interpreting serum potassium.

HYPERKALEMIA

10. What concentration of potassium results in a diagnosis of hyperkalemia?

The serum potassium concentration should be > 5.5 mEq/L to diagnose hyperkalemia.

11. What are the most common causes of hyperkalemia in dogs and cats?

1. **Increased intake**
   - Most commonly due to excessive potassium chloride or inadequate mixing in intravenous fluids
   - Transcellular shifts
     - Lack of insulin
     - Acute mineral acidosis (HCl, NH_4Cl)
     - Acute tumor lysis syndrome
     - Massive tissue injury
     - Digitalis toxicity
     - Reperfusion after thromboembolism
2. **Decreased renal excretion**
   - Urethral obstruction
   - Anuric or oliguric renal failure (requires significant reduction in glomerular filtration rate and urinary output)
   - Adrenal insufficiency

- Drugs
  - Angiotensin-converting enzyme (ACE) inhibitors
  - Potassium-sparing diuretics
  - Nonsteroidal antiinflammatory drugs (NSAIDs)
  - Heparin

12. What are the clinical manifestations of hyperkalemia?

Weakness and neuromuscular paralysis (without CNS disturbances), suppression of renal ammoniogenesis (which may result in metabolic acidosis), and bradycardia commonly result from hyperkalemia.

13. What are the most common electrocardiographic (ECG) signs of hyperkalemia?

Decreased heart rate, decreased P-wave amplitude, and increased QRS duration are the most sensitive ECG indicators of hyperkalemia. The spiked T-wave, which is classically considered an ECG sign of hyperkalemia, is rarely recognized clinically.

14. What is pseudohyperkalemia?

Circulating blood cells, particularly platelets and white blood cells, release potassium when activated or destroyed. Potassium is normally released from platelets during the clotting process. In dogs with thrombocytosis, mild to moderate increases in serum potassium are observed. This in vitro event has no physiologic effect in the animal. Erythrocytes in dogs and cats contain little intracellular potassium. Thus, hemolysis does not increase serum potassium concentrations.

15. What are the goals in treating hyperkalemia?

- To reverse the toxic effects on the heart.
- To shift potassium from the ECF compartment into the ICF compartment.
- To lower total body potassium levels.

16. How is hyperkalemia managed?

- Discontinue potassium administration (e.g., IV fluids, salt substitutes, potassium chloride, potassium penicillin).
- Administer calcium gluconate (2–10 ml of 10% solution) (reverses toxic effects on the heart).
- Consider administering sodium bicarbonate (0.25–1 mEq/kg IV) or 25% dextrose (1 gm/kg IV) with regular insulin (0.5–1.0 U/kg IV) to shift potassium from the ECF into the ICF.
- Administer bolus potassium-free intravenous crystalloids to dilute ECF potassium.

HYPOKALEMIA

17. What level of serum potassium is necessary to diagnose hypokalemia?

Moderate-to-severe hypokalemia is present when the serum potassium concentration is < 3.0 mEq/L. In hypokalemia, many veterinarians forget that acidosis elevates serum potassium concentrations by shifting potassium from the ICF to the ECF compartment. Thus, in patients with acidosis, the actual total body serum potassium concentration is lower than the measured serum potassium concentration (see question 9).

18. What is the most common electrolyte disorder in critically ill animals?

Since you are reading about hypokalemia, surely you can guess the answer! In fact, about 43.5% of 460 animals in a study by Van Pelt were found to be hypokalemic. When you read the chapter about magnesium, you may find the claim that magnesium imbalance is the most common electrolyte disorder. It makes little difference which ion is abnormal most often; the important point is to expect many dogs and cats with low serum concentrations of both. An association between the two ions is very likely. Often, refractory hypokalemic animals respond rapidly after magnesium supplementation is instituted.

19. What are the common causes of hypokalemia?

1. Decreased dietary intake
2. Transcellular shift
   - Catecholamines (epinephrine, dobutamine)
   - Alkalosis
   - Metabolic acidosis
   - Insulin- or glucose-containing fluids
   - Hypothermia (?)
   - Hypokalemic periodic paralysis (Burmese cats)
3. Potassium loss
   - Renal
     - Diuretic therapy
     - Vomiting
     - Hyperventilation
     - Cirrhosis
     - Steroid therapy
     - Excessive gastric suction losses
     - Administration of potassium-free crystalloids or glucose
     - Chronic renal failure in cats
     - Postobstructive polyuria
     - Mineralocorticoid excess (hyperadrenocorticism and primary hyperaldosteronism)
     - ACE inhibitor therapy
   - Extrarenal
     - Diarrhea
     - Vomiting (mostly via renal losses with alkalosis)

20. What are the clinical signs of hypokalemia?

Signs of hypokalemia are associated with cervical ventroflexion (cats) and polyuria/polydipsia from impaired renal concentrating ability. In general, these findings occur with moderate-to-severe potassium depletion. Thus, any reduction in serum potassium concentration is significant, regardless of magnitude.

The most important effect of hypokalemia is on cardiac muscle (arrhythmias). This effect is magnified when the animal is given cardiac glycosides. Hypokalemia also affects striated and smooth muscles. Most animals have signs of muscle weakness or even paralysis and abnormal gastrointestinal function (ileus).

21. How do you estimate the magnitude of total body potassium losses in dogs and cats?

Currently no method is available to estimate total potassium losses; thus, serum potassium concentration is used to govern replacement therapy.

22. What are the guidelines for intravenous supplementation of potassium chloride?

SERUM POTASSIUM CONCENTRATION (mEq/L)	AMOUNT OF POTASSIUM (mEq/L) ADDED TO 1 LITER OF CRYSTALLOID FLUIDS
< 2.0	80
2.1–2.5	60
2.6–3.0	40
3.1–3.5	30
3.6–5.0	20

23. What are the two main complications of potassium supplementation in animals?

1. When potassium is administered too rapidly, cardiac arrhythmias (often fatal) result.
2. Potassium chloride is an irritant that may induce phlebitis when given parenterally or vomiting during oral supplementation.

CONTROVERSY

24. Could hypokalemia be the cause of chronic renal failure and not just be a consequence of it?

This is an intriguing concept. In rats, hypokalemia promotes renal injury by enhancing renal ammoniogenesis. Variable results are seen in cats fed potassium-restricted, acidifying diets. To date it is not clear whether potassium depletion or hypokalemia precedes the onset of renal failure in cats with spontaneous chronic renal failure, or if hypokalemia and potassium depletion are simply consequences of chronic renal failure in cats.

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79. MAGNESIUM ABNORMALITIES

Linda G. *Martin*, D.V.M., M.S.

1. What are the important functions of magnesium?

Magnesium participates in the regulation of vascular smooth muscle tone, signal transduction, adenosine triphosphate (ATP) production, synthesis of nucleic acids, lymphocyte activation, and cytokine production.

2. Which cellular membrane-bound pumps utilize magnesium as a coenzyme?

Sodium-potassium ATPase, calcium ATPase, and proton pumps.

3. How is magnesium distributed within the body?

Magnesium is primarily an intracellular cation. The majority of magnesium is found in bone (60%) and muscle (20%). The remainder is found in other tissues, primarily the heart and liver. Approximately 1% of total body magnesium is present in the serum and interstitial body fluids.

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4. How does magnesium exist in the serum?

Magnesium exists in three distinct forms: an ionized fraction, an anion-complexed fraction, and a protein-bound fraction. The ionized fraction is believed to be the physiologically active component and accounts for 55% of the total serum magnesium concentration. Approximately 15% is complexed to anions such as phosphate, bicarbonate and citrate. The remaining 30% of total serum magnesium is bound to protein, primarily albumin.

5. How is magnesium homeostasis achieved in the body?

Primarily by intestinal absorption and renal excretion. The absorption of magnesium occurs primarily in the small intestine with little or no absorption occurring in the large intestine. The kidney appears to be the main regulator of serum magnesium concentration and total body magnesium content. This is achieved by both glomerular filtration and tubular reabsorption.

6. What are the three general causes of hypomagnesemia?

- Decreased intake
- Increased losses
- Alterations in distribution

7. Is short-term anorexia likely to cause significant hypomagnesemia?

No. Decreased dietary intake of magnesium must be sustained for several weeks to cause magnesium depletion.

8. In the clinical setting, how can hypomagnesemia be induced by decreased intake?

Prolonged intravenous fluid therapy, peritoneal dialysis, or total parenteral nutrition without magnesium replacement or supplementation of maintenance levels.

9. What are the primary routes for loss of magnesium from the body?

Gastrointestinal and renal.

10. Which drugs have been known to increase urinary excretion of magnesium?

Digitalis, furosemide, thiazide diuretics, and mannitol.

11. Which drugs may predispose to renal tubular injury and subsequent renal loss of magnesium?

Aminoglycosides, amphotericin, cisplatin, carbenicillin, and cyclosporine.

12. How can redistribution of circulating magnesium result in hypomagnesemia?

Hypomagnesemia can be produced by extracellular to intracellular shifts and chelation or by sequestration of magnesium. Administration of glucose, insulin, or amino acids may cause magnesium to shift intracellularly. Elevation of catecholamines in animals with sepsis or trauma may cause hypomagnesemia by beta-adrenergic stimulation of lipolysis. Free fatty acids are generated and chelate magnesium, thereby producing insoluble salts. Also, when administered in large quantities, citrated blood products avidly chelate magnesium ions. In acute pancreatitis, magnesium may form insoluble soaps, and sequestration of magnesium may occur in areas of fat necrosis.

13. What are the two most commonly affected organ systems in patients with significant hypomagnesemia?

Cardiovascular and neuromuscular systems.

14. What electrocardiographic (ECG) changes can be seen with hypomagnesemia?

Prolongation of the PR interval, widening of the QRS complex, depression of the ST segment and peaking of the T wave.

15. Which other electrolyte abnormality shows ECG changes similar to hypomagnesemia?
Hyperkalemia.

16. Which arrhythmias have been associated with hypomagnesemia?
- Atrial fibrillation
- Supraventricular tachycardia
- Premature ventricular contractions
- Ventricular tachycardia
- Ventricular fibrillation
- Digitalis-induced arrhythmias

17. How does hypomagnesemia predispose patients to digitalis-induced arrhythmias?
Magnesium deficiency not only enhances digitalis uptake by the myocardium but also inhibits the myocardial sodium-potassium ATPase pump, as does digitalis. This inhibition results in disturbances in the resting membrane potential and the repolarization phase of the action potential. In addition, the calcium channel-blocking effect of magnesium appears to be decreased in states of magnesium deficiency and subsequently increases intracellular calcium content. This increase results in enhanced sensitivity to toxic effects of cardiac glycosides and development of digitalis-mediated arrhythmias.

18. What are the neuromuscular manifestations of hypomagnesemia?
- Weakness
- Ataxia
- Muscle twitching
- Hyperreflexia
- Seizures
- Coma

19. Which other electrolyte abnormalities are commonly associated with hypomagnesemia?
- Hypokalemia
- Hyponatremia
- Hypocalcemia
- Hypophosphatemia

20. Hypomagnesemia can be a common electrolyte abnormality in patients with diabetes mellitus and diabetic ketoacidosis. Explain how this occurs.
Hypomagnesemia may be caused by hyperglycemia-induced osmotic diuresis and increased renal excretion of magnesium. In addition, insulin induces a shift of magnesium from the plasma to the intracellular compartment.

21. Why is the evaluation of magnesium deficiency so difficult?
Because 99% of the total body magnesium is located in the intracellular compartment, serum magnesium levels do not consistently reflect total body stores. Therefore, serum magnesium levels may be normal in the presence of total body magnesium deficiency.

22. Besides measuring serum magnesium concentrations, what are other methods of evaluating magnesium status?
Alternate methods of evaluating magnesium status include determination of ultrafilterable, ionized, and mononuclear blood cell magnesium levels. In addition, a clinical approach to assessing magnesium status involves administering an intravenous magnesium loading dose to a patient and then determining the percentage of magnesium retained by the body. Because magnesium is excreted primarily in the urine, retention of an intravenously administered dose of magnesium can be evidence of magnesium depletion.

23. How may hypomagnesemia cause hypokalemia that is refractory to potassium supplementation?
Because magnesium is a cofactor for the membrane-bound sodium-potassium ATPase pump, magnesium deficiency results in impaired pump function and allows potassium to escape from the cell. Ultimately the potassium is lost in urine. In some instances, total body potassium depletion is profound, and massive supplementation of potassium may fail to correct the hypokalemia until the magnesium deficit is replaced.

24. When is supplementation of magnesium recommended?

Supplementation is recommended if serum magnesium levels are less than 1.5 mg/dl or at higher serum concentrations in the presence of clinical signs (refractory hypokalemia, seizures, cardiac arrhythmias) that can be attributed to hypomagnesemia.

25. What two factors should be assessed before supplementing magnesium?

Renal function and cardiac conduction disturbances. Because magnesium is excreted primarily by the kidneys, the dose of magnesium should be reduced by 50% in azotemic patients and serum levels should be monitored frequently to prevent development of hypermagnesemia. Magnesium also prolongs conduction through the atrioventricular (AV) node. Therefore, any patient with cardiac conduction disturbances should have judicious supplementation of magnesium and frequent ECG monitoring.

26. How can magnesium be supplemented?

Both sulfate and chloride salts are available for parenteral supplementation. The intravenous route is preferred for rapid repletion of magnesium concentrations. An initial dose of 0.75–1.0 mEq/kg/day can be administered by continuous rate infusion in normal saline or 5% dextrose in water. A lower dose of 0.3–0.5 mEq/kg/day can be used for an additional 3–5 days. For treatment of life-threatening ventricular arrhythmias, a dose of 0.15–0.3 mEq/kg of magnesium diluted in normal saline of 5% dextrose in water can be administered slowly over 5–15 minutes. Chloride, gluconate, oxide and hydroxide salts are available for oral administration. The suggested dose is 1-2 mEq/kg/day.

27. Which type of magnesium should be administered parenterally when hypocalcemia is present?

Magnesium chloride. Parenteral administration of magnesium sulfate may further aggravate hypocalcemia because of chelation of calcium with sulfate.

28. What are the causes of hypermagnesemia?

1. Acute or chronic renal failure
2. Endocrine disorders
   - Hypoadrenocorticism
   - Hyperparathyroidism
   - Hypothyroidism
3. Iatrogenic overdose of magnesium, especially in patients with impaired renal function

Because magnesium excretion decreases as the glomerular filtration rate declines, it is not surprising that most cases of hypermagnesemia involve patients with some degree of renal insufficiency. Hypoadrenocorticism, hyperparathyroidism, and hypothyroidism tend to cause only mild elevations in serum magnesium concentrations.

29. What are the cardiovascular manifestations of hypermagnesemia?

Hypermagnesemia produces ECG changes, including prolongation of the PR interval and widening of the QRS complex, due to delayed atrioventricular and interventricular conduction. At severely elevated serum magnesium levels, third-degree AV block and asystole may occur. Hypermagnesemia also has been reported to produce hypotension secondary to relaxation of vascular resistance vessels. Myocardial contractility is probably not affected by hypermagnesemia.

30. What are the neuromuscular manifestations of hypermagnesemia?

The most common clinical signs of hypermagnesemia are weakness and hyporeflexia. Profound magnesium toxicity has been associated with coma and respiratory depression secondary to respiratory muscle paralysis.

31. Describe the treatment for hypermagnesemia.

The first step is to stop all exogenous magnesium administration. Further treatment is based on the degree of hypermagnesemia, clinical signs, and renal function. Saline diuresis combined

with loop diuretics should be the first line of therapy in patients with functioning kidneys and hypermagnesemia that is not immediately life threatening. In patients with severely impaired renal function, peritoneal dialysis may be required if treatment is necessary. In severe cases complicated by cardiopulmonary arrest, intubation, mechanical ventilation, and intravenous calcium gluconate are recommended. Calcium acts as a direct antagonist of magnesium at the neuromuscular junction and may be beneficial in reversing the effects of hypermagnesemia. Calcium gluconate can be given at 5–15 mg/kg as a slow intravenous bolus over 10 minutes. In such a setting, anticholinesterases may also be given to offset the neurotoxic side effects of hypermagnesemia. Physostigmine can be given intravenously at 0.02 mg/kg every 12 hours. Unfortunately, hypermagnesemic shock may be refractory to epinephrine, norepinephrine, and other pressors, making resuscitation efforts difficult.

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80. HYPOPROTEINEMIA

Michael R. Lappin, D.V.M., Ph.D.

1. What constitutes hypoproteinemia?

Hypoproteinemia exists if the total serum protein is < 5.4 gm/dl for dogs and < 5.9 gm/dl for cats. Hypoproteinemia usually results from decreased globulins (dogs, < 1.9 gm/dl; cats, < 2.9 gm/dl), decreased albumin (dogs, < 2.7 gm/dl; cats, < 2.3 gm/dl), or decreased globulins and albumin (panhypoproteinemia). Other proteins found in the body include lipoproteins, glycoproteins, mucoproteins, fibrinogen, and clotting factors.

2. What are the primary sources of serum globulins?

Alpha, beta, and gamma globulins make up total serum globulin concentrations. Alpha and beta globulins are produced primarily by the liver. Gamma globulins are produced by B-lymphocytes and plasma cells.

with loop diuretics should be the first line of therapy in patients with functioning kidneys and hypermagnesemia that is not immediately life threatening. In patients with severely impaired renal function, peritoneal dialysis may be required if treatment is necessary. In severe cases complicated by cardiopulmonary arrest, intubation, mechanical ventilation, and intravenous calcium gluconate are recommended. Calcium acts as a direct antagonist of magnesium at the neuromuscular junction and may be beneficial in reversing the effects of hypermagnesemia. Calcium gluconate can be given at 5–15 mg/kg as a slow intravenous bolus over 10 minutes. In such a setting, anticholinesterases may also be given to offset the neurotoxic side effects of hypermagnesemia. Physostigmine can be given intravenously at 0.02 mg/kg every 12 hours. Unfortunately, hypermagnesemic shock may be refractory to epinephrine, norepinephrine, and other pressors, making resuscitation efforts difficult.

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2. What are the primary sources of serum globulins?

Alpha, beta, and gamma globulins make up total serum globulin concentrations. Alpha and beta globulins are produced primarily by the liver. Gamma globulins are produced by B-lymphocytes and plasma cells.

3. What is the primary source of serum albumin?

Albumin is produced by the liver.

4. What are the primary causes of hypoalbuminemia?

The most clinically relevant causes of hypoalbuminemia are losses from the vascular space, decreased hepatic production, or hemodilution with excessive intravenous fluids. The most common sites for albumin loss from the vascular space include the kidneys, gastrointestinal (GI) tract, and third spacing of albumin in tissues or serosal spaces, including the pleural space and peritoneal cavity. Decreased production of albumin from severe hepatic insufficiency also causes hypoalbuminemia. It is possible that chronic starvation or malnutrition could result in hypoalbuminemia.

5. What are the primary causes of hypoglobulinemia?

Hypoglobulinemia results almost exclusively from gastrointestinal loss; albumin is usually lost concurrently, resulting in panhypoproteinemia. Renal diseases and third spacing rarely result in loss of globulins from the vascular space. Occasionally, amyloidosis may result in renal lesions severe enough to result in the loss of globulins. Hypoglobulinemia rarely results from hepatic insufficiency; although alpha and beta globulins are decreased, gamma globulins are generally increased. This polyclonal gammopathy results from decreased antigen removal by the hepatic reticuloendothelial system; the increased peripheral antigen load stimulates peripheral B-lymphocytes and plasma cells to produce antibodies. Congenital hypoglobulinemias are extremely rare but occur in both dogs and cats. If gamma globulins are decreased, evidence of infection may be present.

6. Why are animals with hypoproteinemia presented for emergency care?

Most animals with hypoalbuminemia are evaluated for respiratory distress, abdominal distention, or peripheral edema. Albumin is the most important protein for maintenance of oncotic pressure; hypoalbuminemia is the most common cause of transudative pleural and peritoneal effusions. Rarely, pericardial effusion and cardiac tamponade result from hypoalbuminemia. Clinical signs referable to the primary cause of hypoproteinemia are often recognized. Antithrombin III (AT III) is approximately the same molecular weight as albumin and so is lost with protein-losing enteropathies and protein-losing nephropathies. Deficiency in AT III can result in respiratory distress from pulmonary thromboembolic disease.

7. What are the causes and clinical signs of protein-losing nephropathy?

Polyuria and polydipsia are the most common signs; anorexia and other signs of renal failure occur in some cases. Protein-losing nephropathy is associated with glomerulonephritis and amyloidosis. In dogs and cats, glomerulonephritis is generally an immune complex disease. Systemic lupus erythematosus is the most common primary immune disease. Any chronic antigenic stimulation from bacteria, fungi, parasites, neoplasia, drugs, or vaccines may result in protein-losing nephropathy. *Ehrlichia canis, Brucella canis, Borrelia burgdorferi,* and *Dirofilaria immitis* are infectious agents that can result in glomerulonephritis.

8. What are the causes and clinical signs of protein-losing enteropathy?

Most animals with protein-losing enteropathy have vomiting and small bowel, large bowel, or mixed bowel diarrhea. Approximately 5–10% have no known GI tract signs. Protein-losing enteropathy can result from any diffuse or focal disease of the GI tract; parasites, inflammatory bowel disease, neoplasia, and lymphangiectasia are common causes.

9. What are the causes and clinical signs of hepatic insufficiency?

Hepatic insufficiency generally is due to either congenital portosystemic shunts, which result in hepatic atrophy, or chronic inflammatory hepatic disease, which results in hepatic cirrhosis. Animals with hepatic insufficiency generally present for evaluation of inappetence, ptyalism, vomiting, diarrhea, failure to thrive, hepatic encephalopathy, or lower urinary tract signs from urate calculi formation.

10. What are the causes and clinical signs of third spacing of albumin?

Albumin can be lost from the vascular space into the pleural space, peritoneal cavity, or tissues. Tissue third spacing generally results from vasculitis due to immune-mediated or infectious diseases, such as ehrlichiosis or Rocky Mountain spotted fever. High-protein ascites (modified transudate) results most frequently from right heart disease, vena caval disease, or cardiac tamponade. Neoplasia may result in the loss of albumin and other proteins into the pleural space or peritoneal cavity. Animals with vasculitis generally have depression, fever, and inappetence. Nonspecific clinical signs depend on the tissues with third spacing of fluids. Dyspnea and abdominal distention are common.

11. What is the initial diagnostic plan for animals suspected of hypoproteinemia?

Diagnostic and therapeutic thoracocentesis is indicated in all animals with dyspnea and muffled chest sounds. Abdominal paracentesis is indicated if a fluid wave is balloted on physical examination. Cell counts, protein quantitation, and cytologic analysis should be performed on fluid obtained. Hypoalbuminemia, hypoglobulinemia, or both are confirmed by measurement in serum; a complete blood cell count, serum biochemical panel, and urinalysis are performed in most animals with clinical signs referable to hypoproteinemia. Differential diagnoses can be ranked based on albumin and globulin results.

Differential Diagnoses in Animals with Hypoalbuminemia Based on Globulin Concentrations

SYNDROME	GLOBULIN CONCENTRATION
Protein-losing nephropathy	Normal
Protein-losing enteropathy	Decreased
Hepatic insufficiency	Normal or increased
Third spacing	Normal or increased

12. What specialized diagnostic procedures are used to assess animals with hypoalbuminemia?

- If proteinuria without pyuria or hematuria is detected, a protein:creatinine ratio is performed to assess magnitude of protein loss. Infectious disease serologic tests, antinuclear antibody testing, and thoracic and abdominal radiographs are often performed in the search for an antigen source.
- If panhypoproteinemia is detected, fecal fats, fecal flotation, abdominal radiographs, GI contrast studies, and endoscopy are commonly used to assess potential primary causes.
- If hematologic, serum biochemical, and urinalysis abnormalities consistent with hepatic insufficiency are detected, preprandial and postprandial serum bile acids may be measured to confirm hepatic dysfunction. Ultrasound evaluation and hepatic biopsy are commonly included in the further diagnostic plan for animals with proven hepatic insufficiency.
- If protein-losing enteropathy or nephropathy is present, AT III may be measured to assess risk for developing thromboembolic disease.

13. How do you manage hypoproteinemic animals in the emergency setting?

- Perform diagnostic and therapeutic thoracocentesis if dyspnea is present.
- Remove only enough fluid from the pleural space or peritoneal cavity to relieve dyspnea and to obtain fluid for cytologic evaluation. Until the primary cause is identified and corrected, fluid will reform, potentially further lessening serum protein concentrations.
- Collect blood and urine samples for diagnostic evaluations.
- Administer plasma or synthetic colloids if hypoalbuminemia is life-threatening. The goal of therapy is to increase oncotic pressure enough to lessen transudate formation. It requires large volumes of plasma to normalize albumin concentrations. Hetastarch or low-molecular-weight dextrans are the synthetic colloids used most frequently (see chapter 81).

14. How do I manage hypoproteinemic animals chronically?

The only effective management is to diagnose and treat successfully the underlying cause. Some recommend aspirin administered at 1–5 mg/kg/day orally to lessen risk of thromboembolic disease in animals with hypoalbuminemia (and presumed AT III deficiency) due to protein-losing nephropathy or protein-losing enteropathy.

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81. FLUID AND ELECTROLYTE THERAPY

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is plasma osmolality?

Plasma osmolality is a function of the ratio of body solute to body water; it is regulated by changes in water balance. Water intake is derived primarily from three sources: ingested water, water contained in food, and water produced from oxidation of carbohydrates, proteins, and fats. Water losses occur in the urine and stool as well as through evaporation from the skin and respiratory tract. Alterations in plasma osmolality of as little as 1–2% are sensed by osmoreceptors in the hypothalamus. These receptors initiate mechanisms that affect water intake (via thirst) and water excretion (via antidiuretic hormone [ADH]) to return plasma osmolality to normal.

2. Define effective circulating volume.

Effective circulating volume is defined as the part of the extracellular fluid (ECF) in the vascular space that effectively perfuses tissues. It varies directly with ECF volume and also with total body sodium, because sodium salts are the primary solutes that hold water in the extracellular space. Therefore, regulation of sodium balance by changes in renal sodium ion and maintenance of effective circulating volume are closely related.

3. What are the major effectors of effective circulating volume?

Three major effectors alter effective circulating volume: (1) sympathetic nervous system, (2) angiotensin II, and (3) renal sodium excretion. Volume depletion, sensed by arterial baroreceptors as hypotension, causes an increase in peripheral sympathetic tone. Increased sympathetic tone returns volume to normal by initiating specific compensatory changes, including the following:

- Venous constriction, which increases venous return
- Increased myocardial contractility and heart rate, which increases cardiac output
- Arterial vasoconstriction, which increases systemic vascular resistance and blood pressure
- Increased renin secretion, which increases levels of angiotensin II, a potent vasoconstrictor
- Increased renal tubular sodium resorption (due to increased levels of angiotensin II and aldosterone)

Sympathetic tone-induced changes in effective circulating volume are transient and compensatory; appropriate changes in renal sodium excretion are required to restore normal volume.

14. How do I manage hypoproteinemic animals chronically?

The only effective management is to diagnose and treat successfully the underlying cause. Some recommend aspirin administered at 1–5 mg/kg/day orally to lessen risk of thromboembolic disease in animals with hypoalbuminemia (and presumed AT III deficiency) due to protein-losing nephropathy or protein-losing enteropathy.

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Sympathetic tone-induced changes in effective circulating volume are transient and compensatory; appropriate changes in renal sodium excretion are required to restore normal volume.

4. What is the body's main defense against hyperosmolality?

The major defense against hyperosmolality (accumulation of solute in excess of body water) is increased thirst. Although the kidney can minimize water losses via the action of ADH, water deficits can be corrected only by increased dietary intake.

5. When does hypoosmolality result?

Hypoosmolality may result from excessive body water retention with subsequent dilution of body solutes or from solute loss in excess of water loss (e.g., diarrhea). Because the kidney excretes large volumes of water daily, persistent water retention resulting in hypoosmolality occurs only in the presence of decreased renal water excretion. In patients with normal renal function, hypoosmolality must therefore be due to solute loss in excess of body water loss.

6. How does hypovolemia (i.e., dehydration) increase the circulating volume?

Hypovolemia causes an increase in renin secretion. The subsequent increase in angiotensin II causes an increase in blood pressure (as a result of arterial vasoconstriction) as well as renal sodium retention (which is both a direct effect and also the result of increased aldosterone secretion). With sodium retention, water is also retained.

7. How do you determine the degree of dehydration in an animal?

Clinical assessment of dehydration is best accomplished by serial body weight monitoring. Experience has shown that the physical findings often underestimate the degree of dehydration. During the acute phase of volume depletion, only classical physical findings are available. The general guidelines below assume that more serious hypovolemia is present.

ESTIMATED % DEHYDRATION	PHYSICAL FINDINGS
≤ 5	History of fluid loss but no findings on physical examination
5	Dry oral mucous membranes but no panting or pathologic tachycardia
7	Mild-to-moderate degree of decreased skin turgor, dry oral mucous membranes, slight tachycardia, and normal pulse pressure
10	Moderate-to-marked degree of decreased skin turgor, dry oral mucous membranes, tachycardia, and decreased pulse pressure
12	Marked loss of skin turgor, dry oral mucous membranes, and significant signs of shock

8. When and how much fluid can be given via the subcutaneous route?

In mild dehydration, subcutaneous fluids are useful. Isotonic fluids should be used, and no more than 5–10 ml/lb should be given at each injection site. The rate of subcutaneous fluid flow usually is governed by patient comfort. These fluids are aseptically administered, and multiple sites are required to provide adequate fluid volume. In general, all subcutaneous fluids are resorbed within 6–8 hours. If fluids are still noted subcutaneously after this time, the use of intravenous fluids to reestablish peripheral perfusion should be considered.

9. How about using the intraperitoneal route for fluid administration?

The intraperitoneal route is quick and easy, and the fluids generally are resorbed, thus increasing the circulating volume. However, intraperitoneal administration involves the risk of bacterial peritonitis, visceral perforation, and decreased ventilation due to impeding diaphragmatic excursion. Experience with peritoneal dialysis in dogs has shown that peritoneal fluids often traverse the diaphragm, enter the thoracic space, and further affect ventilation. Currently, intraperitoneal fluids cannot be recommended.

10. When and how do you administer intravenous fluids?

In general, intravenous fluid administration is indicated in dogs and cats with 7% or greater dehydration. Potential routes for intravenous fluid administration include peripheral veins, jugular veins, and the intraosseous route.

11. When and how do you estimate the volume of fluids to be given?

The amount of fluid needed for replacement depends on the patient's status. Of primary concern is the status of blood volume; later concern is directed to restoration of total body water and electrolytes.

12. What are the three phases of fluid therapy?

- Emergency phase (see chapter 14)
- Replacement phase
- Maintenance phase

13. How much fluid should be given during replacement therapy?

The volume of fluid administered during the dehydration phase is based on assessment of fluid needs for the following:

1. Returning the patient's status to normal (deficit volume)
2. Replacing normal ongoing losses (maintenance volume)
3. Replacing continuing abnormal losses (continuing losses volume)

14. How do you calculate the deficit volume?

The deficit volume is an estimate based on findings from the physical examination or on known changes in body weight. To calculate the deficit volume, the estimated dehydration is multiplied by the body weight. It is difficult to replace all deficits in a 24-hour period. An attempt to do so may result in urinary losses that further dehydration. Thus, it is recommended that only 75–80% of the deficit volume be replaced during the first 24 hours. You must also add daily maintenance volumes to the calculated deficit volume if the animal is not eating or drinking.

Example: A 22-lb (10-kg) dog is assessed to be 7% dehydrated. What volume of fluid deficit should be given during the first 24 hours? Remember that 454 ml = 1 lb of water and that 1000 ml = 1 kg of water.

Total deficit replacement volume = deficit volume + maintenance volume

Deficit replacement volume (ml) = % dehydration × body weight (lb) × 454 × 0.80

Deficit replacement volume (ml) = 0.07 × 22 lb × 454 × 0.80 = 560 ml

or

Deficit replacement volume (ml) = % dehydration × body weight (kg) × 1000 × 0.80

Deficit replacement volume (ml) = 0.07 × 10 × 1000 × 0.80 = 560 ml

15. What are maintenance volumes for fluid therapy?

Maintenance volumes are normal ongoing losses. Ongoing losses are divided into sensible and insensible losses. Sensible losses, or water losses in urine and feces, can be measured. Insensible losses are normal but are not easily quantitated. Insensible water losses occur during panting or sweating. One-third of the maintenance volume is made up of insensible volumes and two-thirds of sensible volumes. For calculation of maintenance volume, see Question 21.

16. How do you account for continuing losses during the replacement phase of fluid therapy?

A crude but effective guideline for replacing continuing abnormal losses is to estimate the volume of fluid loss and then double the estimate. The result is surprisingly close to the actual volume of vomitus, diarrhea, and urine.

17. How do you tell when an animal is receiving inadequate fluid volume?

Any acute change in body weight results from losses or gains in water. The animal that loses body weight while receiving crystalloid fluids is probably receiving inadequate volumes of fluid. Body weight may be deceptive in animals with third spacing of fluids (peritonitis, pyometritis, pleural effusions). Such animals may still be dehydrated, but body weight may not have changed. Monitoring of central venous pressure results in a value that is well below 5 cmH_2O. In addition, if renal function is adequate, a dehydrated animal has a urine specific gravity above 1.025.

18. What are the clinical signs of overhydration?

Classically, pulmonary edema is associated with overhydration. Clinically, however, pulmonary edema is the terminal event of overhydration. Before pulmonary edema results, you first note an increased serous nasal discharge, followed by chemosis; finally, pulmonary congestion is auscultated before edema develops.

19. List the common crystalloid fluids and their electrolyte composition, pH, and osmolality.

SOLUTION	Na^+	K^+	Cl^-	Ca^{2+}	Mg^{2+}	BUFFER (mEq/L)	CALORIES (kcal/L)	OSMOLALITY (mOsm/L)
Dextrose 5% in water	—	—	—	—	—	—	170	278
Dextrose 2.5% in 0.45% saline	77	—	77	—	—	—	85	280
Ringer's lactate	130	4	109	3	—	Lactate, 28	9	272
Ringer's	147	4	156	4.5	—	—	—	309
Normosol-R	140	5	109	—	3	Acetate, 27 Gluconate, 23	15	294
Dextrose 5% in Ringer's lactate	130	4	109	3	—	Lactate, 28	179	524
Normal saline (0.9%)	154	—	154	—	—	—	—	308
Dextrose 50%	—	—	—	—	—	—	1700	2525
Dextrose 5% in saline (0.9%)	154	—	154	—	—	—	170	—
Potassium chloride	—	2	2	—	—	—	—	—

20. How do you select the parenteral fluid?

In selecting a fluid, it is important to know which electrolytes are lost and to institute replacement therapy based on knowledge of the pathophysiology of the disease.

Selection of Fluids for Specific Diseases

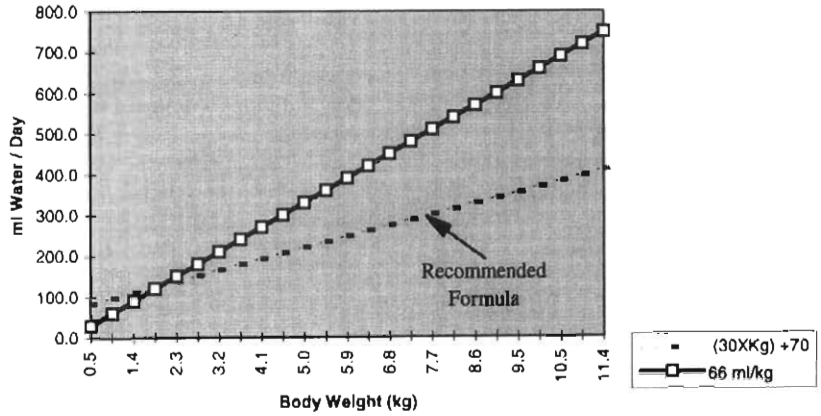
CONDITION	Na^+	Cl^-	K^+	HCO_3^-	VOLUME	FLUID OF CHOICE
Diarrhea	D	D	D	D	D	Normosol-R + KCl or lactated Ringer's + KCl
Pyloric obstruction	D	D	D	I	D	0.9% saline + KCl
Dehydration	I	I	N	N/D	D	Normosol-R + KCl, lactated Ringer's + KCl, 0.9% saline + KCl, 5% dextrose
Congestive heart failure	N/D	N/D	N	N	I	0.45% saline 2.5% dextrose + KCl, 5% dextrose
End-stage liver disease	N/I	N/I	D	D	I	0.45% saline + 2.5% dextrose + KCl
Acute renal failure						
Oliguria	I	I	I	D	I	0.9% saline
Polyuria	D	D	N/D	D	D	Normosol-R + KCl, lactated Ringer's + KCl
Chronic renal failure	N/D	N/D	N	D	N/D	Normosol-R, lactated Ringer's, 0.9% saline
Adrenocortical insufficiency	D	D	I	N/D	D	0.9% saline
Diabetic ketoacidosis	D	D	N/D	D	D	0.9% saline (± KCl)

D = decreased, I = increased, N= normal, KCl = potassium chloride.

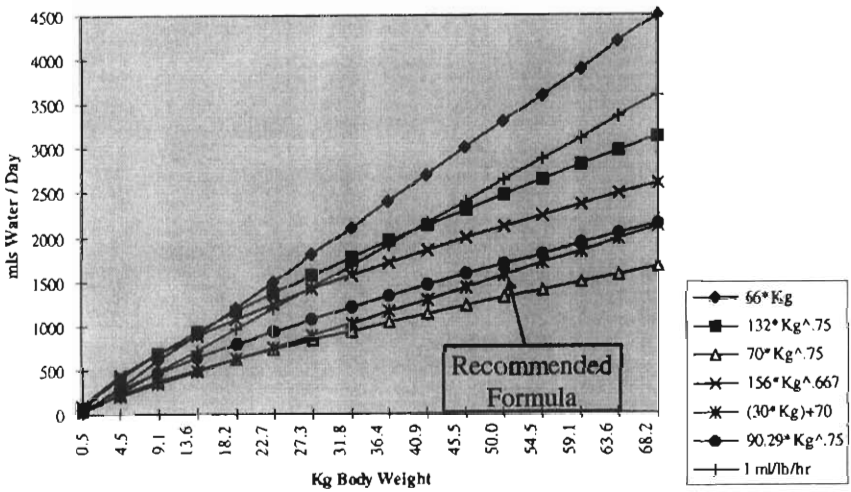
CONTROVERSIES

21. How much fluid should you give for maintenance volume if the animal is not eating or drinking?

Data about water needs for dogs and cats are few. Water and energy requirements are numerically the same (1 kcal of energy = 1 ml of water). Unfortunately, many authors recommend dramatically different fluid and energy requirements. Estimates of water needs include 66 ml/kg/day (30 ml/lb/day), 132 kcal × $kg^{0.75}$, 156 × $kg^{0.667}$, (30 × kg) + 70, and 70 × $kg^{0.75}$. Studies using indirect calorimetry document that previously recommended formulas overestimate energy (and thus water) needs for dogs and cats.



Maintenance fluid volumes for cats. Recommended volumes are calculated from the formula (30 × body weight [kg]) + 70.



Maintenance fluid volumes for dogs. Recommended volumes are calculated from the formula (30 × body weight [kg]) + 70.

Example: A 22-lb (10-kg) dog is assessed to be 7% dehydrated and has been vomiting. How much fluid should be given during the next 24 hours?

Volume (ml of fluid required) = deficit volume + maintenance volume
$= [0.07 \times 22\ \text{lb} \times 454 \times 0.80] + [(10 \times 30) + 70]$
$= [560] + [370] = 930\ \text{ml}$

or

$= [0.07 \times 10\ \text{kg} \times 1000 \times 0.80] + [(10 \times 30) + 70]$
$= [560] + [370] = 930\ \text{ml}$

22. Does the above formula satisfy water needs in sick animals?

The question of energy (water) requirements in sick animals continues to elicit controversy. Traditionally, it has been taught that illnesses, injuries, and surgery result in increased need for energy (water). These teachings were extrapolated from human and rodent data. Mounting evidence indicates that increased energy requirements are not common in sick, injured, or surgical dogs. In fact, increasing numbers of publications document lower energy (water) requirements for both normal and sick or traumatized dogs. In addition, from an evolutionary perspective, it seems logical to expect dogs to preserve available energy with illness or injury. The reserves are already minimal, and it makes little sense to increase metabolic requirements in order to survive. It makes more sense to conserve available energy and to reduce metabolic (thus energy and water) requirements. Studies of dogs in a critical care unit have documented significant hypothyroid function. Thus, metabolic requirements are reduced. The decision to change the formulas for calculating water requirements will come only with more objective evidence from normal and sick dogs and cats.

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82. ACID–BASE DISORDERS

Wayne E. *Wingfield*, M.S., D.V.M. *and Suzanne* G. *Wingfield*, R.V.T., V.T.S.

1. What are the "weak links" associated with blood gas analyis?

Preparation. Preparing a sampling device involves the choice of syringe, needle, and anticoagulant. Unnecessary patient stress, which may cause hyperventilation, also must be avoided.

Sampling. The sampling phase includes making the patient as comfortable as possible, puncturing the artery, expelling possible air bubbles, closing the tip of the syringe, and, finally, mixing the sample with anticoagulant.

Storage. This phase covers the time from completion of the sampling process until the blood sample is transferred to the analyzer. Storage time should be kept to a minimum.

Transfer: The sample must be remixed, a few drops should be expelled, and the sample is transferred to the analyzer.

2. What are the two most serious preanalytical errors in blood gas sampling?

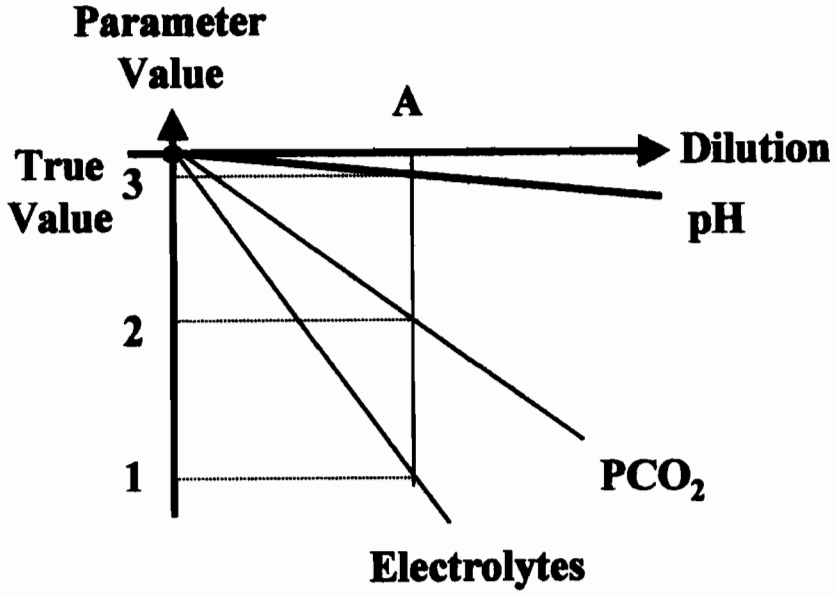
The two most serious preanalytical errors are use of the wrong type or wrong amount of anticoagulant and the presence of air bubbles in the sample.

3. What is the preferred anticoagulant for blood gas analysis?

Lithium heparin. Ethylenediamine tetraacetic acid (EDTA) or citrate may cause significant changes in the pH of the sample.

4. What effect does adding liquid to a sample have on the results?

The figure below illustrates the changes that are expected if there is a dilution error. Of particular importance, the type of anticoagulant may affect electrolyte analysis.



Diluting the blood sample (to point A) may significantly decrease electrolyte values (1) and PCO_2 values (2). There is almost no change in pH values (3).

5. List the five common acid–base disorders and give an example of each.

Acid–base disorder	Common example
Metabolic acidosis	Cardiopulmonary arrest
Metabolic alkalosis	Vomiting from pyloric obstruction
Respiratory acidosis	Chronic obstructive pulmonary disease
Respiratory alkalosis	Hyperventilation
Mixed acid–base disorder	Gastric dilatation-volvulus

6. How do you diagnose the four primary acid–base disorders? How does the body compensate for each disturbance?

Acid-base disorder	Primary disturbance	Compensation
Metabolic acidosis	$\downarrow HCO_3^-$	$\downarrow PaCO_2$
Metabolic alkalosis	$\uparrow HCO_3^-$	$\uparrow PaCO_2$
Respiratory acidosis	$\uparrow PaCO_2$	$\uparrow HCO_3^-$
Respiratory alkalosis	$\downarrow PaCO_2$	$\downarrow HCO_3^-$

7. The integrated actions of which three organs are involved in acid–base homeostasis?

- Liver: hepatic metabolism of organic acids (lactate)
- Lungs: excretion of carbon dioxide
- Kidneys: reclaim filtered bicarbonate and excrete accumulated acid

8. List the common causes of metabolic acidosis.

- Renal failure
- Diarrhea
- Chronic vomiting
- Severe shock
- Diabetes mellitus
- Hypoadrenocorticism

9. List the common causes of metabolic alkalosis.

- Acute profuse vomiting
- Pyloric outflow obstruction
- Excessive use of diuretics
- Bicarbonate therapy

10. List the common causes of respiratory acidosis.

- Anesthesia
- Respiratory depressant drugs
- Obesity
- Chronic obstructive lung disease
- Brain injuries

11. List the common causes of respiratory alkalosis.

- Fever
- Left-to-right shunts
- Shock
- Hypoxemia

12. What is meant by the anion gap?

The anion gap represents the difference between the routinely measured cations and anions in a plasma or serum sample. It is usually calculated as follows:

$$([Na+] + [K+]) - ([Cl-] + [HCO_3^-])$$

where Na = sodium, K = potassium, Cl = chloride, and HCO_3^- = bicarbonate. Because potassium makes such a small contribution to the anion gap, it is often not used in the above formula. The normal values at our hospital for anion gap are 10–27 in cats and 8–25 in dogs. The negative charges on plasma proteins account for most of the missing anions, because the charges of the other cations (calcium $[Ca^{2+}]$ and magnesium $[Mg^{2+}]$) and anions (phosphate, sulfate, and organic anions) tend to balance out. Determining the anion gap is useful in the differential diagnosis of metabolic acidosis because the causes of the disorder may be divided into those that elevate the anion gap and those that do not.

As acid accumulates in the body, there is rapid extracellular buffering by bicarbonate. If the acid is hydrochloric acid (HCl), the following formula applies:

$$HCl + NaHCO_3 \rightarrow NaCl + H_2CO_3 \rightarrow H_20 + CO_2$$

The net effect is an mEq-for-mEq replacement of extracellular bicarbonate by chloride ion. Because the sum of Cl^- and HCO_3^- concentrations remains constant, the anion gap is unchanged. Because of the increase in the plasma chloride ion concentration, this state is often referred to as hyperchloremic acidosis. Conversely, if H^+ accumulates with any anion other than Cl^-, extracellular HCO_3^- is replaced by an unmeasured anion. The results are a decrease in the sum of the chloride and bicarbonate concentrations and an increase in the anion gap.

13. List the common causes of an increased anion gap metabolic acidosis.

- Ethylene glycol ingestion
- Ketoacidosis
- Uremia
- Lactic acidosis
- Salicylate toxicity
- Severe starvation

14. List the common causes of a decreased anion gap.

- Increased unmeasured cations (K^+, Mg^{2+}, Ca^{2+})
- Addition of abnormal cations (lithium)
- Increase in cationic immunoglobulins (plasma cell dyscrasias)
- Loss of unmeasured anions such as albumin (hypoalbuminemia)
- Severe acidosis resulting in loss of effective negative charge on albumin

15. What is a strong ion?

Strong ions are salts that are completely dissociated in water (e.g., Na^+, K^+, and Cl^-).

16. What is the strong ion difference (SID)?

The SID is the difference in all positive and negative strong ions (normally Na^+, K^+, and Cl^-). When SID increases, it is usually due to metabolic alkalosis; decreases in SID usually result from metabolic acidosis.

17. What is Stewart's acid–base analysis? How is it used?

Traditional acid–base analysis is based on the fact that hydrogen and bicarbonate ion concentrations are considered independent variables affected by disease processes and mechanisms of homeostasis. Stewart's analysis is based on the assumption that the hydrogen and bicarbonate ion concentrations are dependent on the effects of four independent variables: (1) strong ions, (2) weak nonvolatile acids, (3) free water, and (4) PCO_2. Furthermore, the interaction of these independent mechanisms rather than a single mechanism determines the acid–base state. For additional information and extremely useful strong ion difference calculators, the reader is referred to the following website: www.anaesthetist.com/icu/elec/ionz/Stewart.htm

18. What is the base excess (BE)?

Base excess is the amount of base (substances that can accept a hydrogen ion) above or below the normal buffer base. BE is expressed in mEq/L. Positive BE values reflect an excess of base (or a deficit of acid), whereas negative BE values reflect a deficit in base (or an excess of acid).

19. What four factors influence BE?

- Free water (Na^+)
- Chloride concentration
- Protein concentration
- Unidentified anions (lactic acid)

20. What is lactic acidosis? List the common causes.

Lactic acidosis is due to the accumulation of lactic acid, the end-product of glycolysis. This accumulation leads to depletion of the body's buffers and drop in pH. Common causes of lactic acidosis include the following:

- Cellular hypoxia
- Decreased hepatic utilization of lactic acid
- Cyanide poisoning
- Neoplasms with large tumor burden
- Diabetic ketoacidosis
- Carbon monoxide poisoning
- Sodium nitroprusside infusions

21. How do you determine the efficiency of oxygenation in patients?

Oxygenation is determined by calculating the alveolar–arterial oxygen gradient (A–a gradient). The formula used for this calculation when the animal is breathing room air (e.g., 21% oxygen) is as follows:

A = calculated alveolar oxygen = (barometric pressure – 47)(0.21) – $PaCO_2$/0.8

a = measured PaO_2

A–a gradient = A – a

In this equation you need the barometric pressure, water vapor pressure (47), concentration of oxygen in room air (21% or 0.21), measured $PaCO_2$, respiratory quotient (0.8), and measured PaO_2.

22. What are the normal values for the A–a gradient when an animal is breathing room air?

- Normal = 0–10
- Normal (?) = 11–20
- Acute respiratory distress syndrome (?) = 21–30
- Acute respiratory distress syndrome ≥ 30

23. Does aging of the patient affect normal A-a gradients?

Apparently there is an effect of aging. With pulmonary fibrosis seen in aging, the older animals often have higher A-a gradients. To date, no data have been published to confirm these clinical observations.

24. How do you assess oxygenation if the animal is breathing supplemental oxygen?

If the animal is breathing supplemental oxygen, you cannot use the equation in question 16; you must use the following equation:

$$\text{A–a gradient (supplemental oxygen)} = PaO_2/FIO_2$$

In this case an arterial PO_2 is required along with the concentration of inspired oxygen (FIO_2). When breathing via a face mask or nasal insufflation cannula, the FIO_2 is approximately 40% (FIO_2 = 0.40). If an endotracheal tube is in place and the cuff is inflated, the concentration is 100% (FIO_2 = 1.0). If the result of the above equation is ≥ 200 mmHg, the animal is oxygenating adequately.

25. What are the common causes of alveolar hypoxia? What are their effects on the A–a gradient?

Cause	Effect on PaO_2	Effect on A–a gradient
Diffusion abnormality	Decreased	Increased
Ventilation–perfusion mismatch	Decreased	Increased
Right-to-left shunt	Decreased	Increased

26. How do you assess the animal's ability to ventilate?

Examine the $PaCO_2$ in an arterial blood sample. If the animal is hypoventilating, the $PaCO_2$ is increased. With hyperventilation the animal's $PaCO_2$ is decreased.

27. What are the normal values for an arterial blood gas (ABG) sample?

Parameter	Normal value	Range
pH	7.40	7.35–7.45
$PaCO_2$	38	35–45
HCO_3^-	24	22–27
PaO_2	92	80–110

28. Does the environmental altitude affect blood gas values?

Yes. Living in a state such as Colorado results in an increase in red blood cells in response to the hypoxia (normal PaO_2 = 78–92) of altitude. In addition, animals at high altitude breathe more rapidly, resulting in decreased $PaCO_2$ (normal = 28–32) and bicarbonate (normal = 18–22).

29. Describe the sequence of steps in assessing an ABG sample.

1. The first question that you must answer is whether the sample is arterial or venous blood. The distinction is commonly based on hemoglobin saturation (> 90%) and PaO_2 (> 75 mmHg).
2. Next, determine the pH. Is the animal acidotic (pH < 7.35) or alkalotic (pH > 7.45)?
3. Assess $PaCO_2$:
   - Respiratory acidosis: $PaCO_2$ > 45 mmHg
   - Respiratory alkalosis: $PaCO_2$ < 32 mmHg
4. Assess HCO_3^-:
   - Metabolic acidosis: HCO_3^- < 20 mEq/L and BE < – 5 mEq/L
   - Metabolic alkalosis: HCO_3^- > 27 mEq/L and BE > + 5 mEq/L
5. Determine whether there is compensation in response to the primary metabolic or respiratory disorder.
6. Examine BE for evidence of a mixed acid–base disorder.
7. Assess oxygenation by calculating the A–a gradient.
8. Calculate the anion gap.

30. What do ABGs and tic-tac-toe have in common?

Simplifying the interpretation of ABGs to diagnose an acid–base imbalance involves asking three questions:

1. Does the pH indicate acidosis or alkalosis?
2. Is the cause of the pH imbalance respiratory or metabolic?
3. Is there compensation for the acid–base imbalance?

To answer these questions, set up a tic-tac-toe grid and write the words *acid, normal,* and *alkaline* in the boxes across the top row:

Acid	Normal	Alkaline

Comparing the patient's ABG results with normal values, write *pH, $PaCO_2$,* and *HCO_3^-* under the appropriate column head. Once three items—including the head—are in a vertical column, you are ready to diagnose the patient's condition.

For example, let us consider the case of "Sage," a 10-year-old, yellow Labrador retriever with diabetes mellitus. The following ABG results are reported: pH = 7.26, $PaCO_2$ = 42, and HCO_3^- = 17. Plug these values into the grid as follows:

Acid	Normal	Alkaline
pH	$PaCO_2$	
HCO_3^-		

The column in which the pH is located tells you whether the patient has acidosis or alkalosis. The relative positions of pH, $PaCO_2$, and HCO_3^- reveal the origin of any acid–base imbalance. If the pH and $PaCO_2$ fall in the same column (other than normal), the problem is respiratory. If the pH and HCO_3^- fall in the same column, the problem is metabolic. Thus, Sage's diagnosis is metabolic acidosis.

31. Which electrolyte is most commonly affected by a change in acid–base balance?

Serum potassium. Animals with severe metabolic acidosis tend to have elevated serum potassium concentrations, whereas animals with severe alkalosis tend to have low serum potassium

concentrations. A change in pH of 0.1 is consistent with a corresponding change in serum potassium of about 0.6 (0.3–0.8) mEq/L. If the pH is elevated by 0.1, the serum potassium falls by about 0.6 mEq/L; if the pH is diminished by 0.1, the serum potassium rises by about 0.6 mEq/L. This concept is extremely important in treating diabetic ketoacidotic patients. Although total body potassium may be severely depleted, initial serum potassium concentrations may actually be elevated in severely acidotic animals. As the patient is treated with intravenous crystalloids and insulin, the acidosis resolves and the serum concentrations of potassium fall precipitously, requiring potassium supplementation.

32. How does the core body temperature of an animal affect ABGs?

With hypothermia, uncorrected ABGs yield falsely elevated pH as well as falsely decreased PaO_2 and $PaCO_2$. For every 1° C (1.8° F) decrease in body temperature, the pH increases by 0.015, $PaCO_2$ (mmHg) decreases by 4.4%, and PaO_2 decreases by 7.2% (37° C reference). Hyperthermia decreases the pH and increases the $PaCO_2$ and PaO_2 by an equivalent amount. All samples should be corrected for temperature before interpretation of ABG results.

33. What does pulse oximetry contribute to the understanding of acid–base status?

Nothing. Pulse oximetry measures oxyhemoglobin saturation and does not provide a measurement of acid–base or ventilatory status. ABG analysis is necessary to determine acid–base status.

34. Can venous blood gases be used to assess acid–base balance?

Yes. There is good statistical correlation between arterial vs. venous pH, PCO_2, and HCO_3^-. Unfortunately, you must insert venous blood gas values into regression equations, as follows:

(1) Arterial pH = 0.329 + (0.961 × venous pH)

(2) Arterial PCO_2 = 7.735 + (0.572 × venous PCO_2)

(3) Arterial HCO_3^- = 0.538 + (0.845 × venous HCO_3^-)

35. In circulatory failure, which is less severe than cardiopulmonary arrest, why should you assess both arterial and central venous samples?

In patients with severe hemodynamic compromise, ABGs provide useful information about pulmonary gas exchange. However, in the presence of severe hypoperfusion, hypercapnia and acidemia at the tissue level are better detected in central venous blood.

36. What is a mixed acid–base disorder?

Thus far, we have assumed that only one primary disorder is present. Real patients, however, often have more than one disorder (mixed acid–base disorder). These disturbances can be identified by determining the expected compensatory response to a given change in the primary abnormality and assuming that any value that falls outside this range represents an additional primary disorder. Numerous nomograms and mathematical formulas are available. Unfortunately, mathematical equations, especially ones that are different for acute and chronic disorders, are difficult to memorize. Nomograms are relatively simple but further mystify acid–base analysis by providing answers without necessarily requiring an understanding of the relevant pathophysiology. A simpler alternative is first to identify the most clinically important disorders as outlined by the rules below:

Rule 1. *Look at the pH.* On whichever side of 7.40 the pH falls, the process that caused it to shift is the primary abnormality. Principle: The body does not fully compensate for primary acid–base disorders.

Rule 2. *Calculate the anion gap.* If the anion gap is ≥ 20 mEq/L, the patient has a primary metabolic acidosis, regardless of the pH or bicarbonate concentration. Principle: The body does not generate a large anion gap to compensate for a primary disorder.

Rule 3. *Calculate the excess anion gap* (the total anion gap minus the normal anion gap) and add this value to the measured bicarbonate concentration. If the sum is greater than normal serum bicarbonate, there is an underlying metabolic alkalosis; if the sum is less than normal serum bicarbonate, there is an underlying nonanion gap metabolic acidosis. *Principle:* 1 mEq of unmeasured acid titrates 1 mEq of bicarbonate ($+ \Delta$ anion gap $= - \Delta [HCO_3^-]$).

CONTROVERSY

37. When do you use sodium bicarbonate to treat metabolic acidosis?

Most acid–base disorders correct themselves if adequate fluid volume is provided to normalize tissue perfusion. The difficult question is whether to administer sodium bicarbonate to severely acidotic animals (pH < 7.10; bicarbonate < 8). In this case sodium bicarbonate should be administered, but do not try to replace the entire base deficit with bicarbonate because you will usually induce metabolic alkalosis. The bicarbonate replacement formula that we use is as follows:

$$\text{Amount of bicarbonate} = 0.4 \times \text{body weight (kg)} \times (12 - \text{patient's bicarbonate})$$

In most cases, one-third of this volume is administered in a slow intravenous bolus, and the remainder is given over the next 8 hours. Ideally, sodium bicarbonate is given only if blood gases can be monitored. If empirical doses are used, no more than 0.25 mEq/kg should be given.

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83. PORTOSYSTEMIC SHUNTS

Derek P. B*urney*, D.V.M., P*h*.D.

1. What is a portosystemic shunt?

A portosystemic shunt is an abnormal vessel that connects the portal vein to a systemic vein. The most common locations for portosystemic shunts are a patent ductus venosus or a connection between the portal vein and caudal vena cava or azygous vein. Single extraheptic shunts are most common in small-breed dogs and cats, whereas single intrahepatic shunts are most common in large-breed dogs.

2. What is the difference between congenital and acquired portosystemic shunts?

Most acquired shunts are multiple and extrahepatic. Acquired shunts develop because of sustained portal hypertension from chronic liver disease and cirrhosis. Congenital portosystemic shunts are usually single and may be intra- or extrahepatic. The most common intrahepatic portosystemic shunt is a patent ductus venosus.

3. Are certain breeds associated with portosystemic shunts?

Congenital portosystemic shunts may occur in any breed of dog but are common in miniature schnauzers, miniature poodles, Yorkshire terriers, dachshunds, Doberman pinschers, golden retrievers, Labrador retrievers, and Irish setters. There are affected lines in miniature schnauzers, Irish wolfhounds, Old English sheepdogs, and Cairn terriers. Mixed breed cats are more

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commonly affected than purebred cats, but Himalayans and Persians seem to overrepresented as purebreds. Acquired portosystemic shunts are secondary to chronic hepatic disease and so may occur in any breed.

4. Where are most portosystemic shunts located?

Single extrahepatic shunts most commonly connect the portal vein (or the left gastric or splenic vein) with the caudal vena cava cranial to the phrenicoabdominal vein. Single intrahepatic shunts can be a communication of the portal vein to the caudal vena cava which is a failure of the ductus venosus to close. Shunts in the right medial or lateral liver lobes occur with an unknown pathogenesis.

5. Why do patients with portosystemic shunts have decreased liver function?

Portal venous blood is important because it brings hepatotropic growth factors and insulin to the liver. If insulin bypasses the liver in a shunt, significant quantities are utilized by other organs and the liver receives less benefit. Portal venous blood flow is important for normal liver development as well as glycogen storage, hypertrophy, hyperplasia, and regeneration. Congenital portosystemic shunts are often associated with hepatic atrophy, hypoplasia, and dysfunction.

6. What are the most common clinical signs of portosystemic shunts?

Failure to thrive and failure to gain weight are appropriately common. Most clinical signs are referable to hepatic encephalopathy, which is defined as clinical signs of neurologic dysfunction secondary to hepatic disease. Signs include ataxia, stupor, lethargy, unusual behavior, disorientation, blindness, and seizures. Some animals display anorexia, vomiting, and diarrhea. Polyuria and polydipsia may be present. Some animals have ammonium biurate urolithiasis, which may result in pollakiuria, hematuria, stranguria, or obstruction. Increased production of saliva (ptyalism) and abdominal distention due to ascites occur in some animals. Ptyalism is more common in cats.

7. What causes hepatic encephalopathy associated with portosystemic shunts?

Products of bacterial metabolism in the intestine, such as ammonia, short-chain fatty acids (SCFAs), mercaptans, gamma-aminobutyric acid (GABA), and endogenous benzodiazepines have been suggested as mediators of hepatic encephalopathy. In addition, the ratio of aromatic amino acids to branched-chain amino acids is often increased in patients with portosystemic shunts. The aromatic amino acids may act as false neurotransmitters. Phenylalanine and tyrosine may act as weak neurotransmitters in the presynaptic neurons of the CNS. Tryptophan causes increased production of serotonin, which is a potent inhibitory neurotransmitter. The GABA receptor has binding sites for barbiturates, benzodiazepines, and substances with similar chemical structure to benzodiazepines. These agents may be responsible for depression of the CNS in hepatic encephalopathy.

8. What factors may precipitate an hepatic encephalopathy crisis?

A protein rich meal, gastrointestinal bleeding associated with parastites, ulcers or drug therapy; administration of methionine- containing urinary acidifiers; or lipotropic agents may precipitate a crisis. Blood transfusions with stored blood may also contribute to a crisis as the ammonia levels can be high in the stored blood.

9. How is hepatic encephalopathy treated?

The animal should be evaluated for hypoglycemia immediately and treated appropriately if it is present. Appropriate fluid therapy based on acid–base and electrolyte status (see chapter 81) should be initiated to correct abnormalities. LRS should be avoided. Hypoglycemia, alkalosis, hypokalemia, and gastrointestinal bleeding should be identified and corrected. Ammonia concentration and production should be decreased by administering lactulose and neomycin (10–20 mg/kg orally every 6 hr) if a swallow response is present. Oral metronidazole may be used at a dose of 10 mg/kg every 8 hr in place of neomycin. If the animal is comatose, 20–30 ml/kg of lactulose diluted 1:2 with water or a 1:10 dilution of povidone-iodine solution may be given as an

enema. Seizures may be treated initially with elimination of ammonia by enemas as listed above. Oral loading doses of potassium bromide may be useful. If seizures cannot be controlled, IV propofol as a constant rate infusion may be necessary, but respiratory support may be needed. Some animals with hepatic encephalopathy have difficulty in metabolizing benzodiazepines such as diazepam, which should be avoided. If these drugs do not control seizures, intravenous phenobarbital may be titrated slowly to effect. Patients often have decreased clearance of barbiturates.

10. What routine blood work and urinalysis abnormalities suggest portosystemic shunts?

Microcytosis is a consistent abnormality of complete blood cell count in animals with portosystemic shunts. Some animals manifest acid–base, electrolyte, and glucose disturbances (hypoglycemia). Because of vomiting and dehydration, prerenal azotemia may be present. There is no consistent finding with regard to alanine aminotransferase (ALT), aspartate aminotransferase (AST), and serum alkaline phosphatase (ALP); activities of these enzymes may be elevated, decreased, or normal in patients with portosystemic shunts. Hypoalbuminemia is common, as are coagulopathies. Some animals have isothenuric urine due to medullary wash-out; ammonium biurate crystals may be identified on microscopic examination of urine sediment.

11. What are the best ways to diagnose a portosystemic shunt?

Elevated serum pre- and postprandial bile acids in a young animal with signs of hepatic encephalopathy and stunted growth are consistent with but not diagnostic for portosystemic shunts. A nuclear medicine scan using transcolonic sodium pertechnetate Tc99m demonstrates radioactivity in the heart before the liver in an animal with portosystemic shunt. Nuclear medicine is rapid, noninvasive, and safe to the animal. The disadvantages are that the animal is radioactive for 24 hours, studies can be performed only by specially trained personnel, exact location of the shunt cannot be determined, and cases of hepatic microvascular dysplasia, which have shunting within the liver (as in Cairn terriers), may give false-negative results. When nuclear medicine facilities are unavailable, positive contrast portography may demonstrate the anomalous vessel. Portography, however, is technically demanding and invasive. Furthermore, a second surgical procedure is required to repair the shunt because of an otherwise dangerously long period of anesthesia. The major advantage of positive contrast portography is that it definitively locates the shunt.

12. What is the best way to manage a patient with portosystemic shunt?

Although medical management may be beneficial, surgical ligation of the shunt is optimal. In one study, animals that receive total ligation, even if it had to be done in two or more surgeries, showed more clinical improvement than patients with incomplete shunt ligation. In general, cats do not do as well with medical therapy.

13. Describe the preoperative management of a patient with portosystemic shunt.

In animals displaying hepatic encephalopathy, it is important to correct acid–base and electrolyte disturbances before surgery. Measures to control hepatic encephalopathy also should be performed before surgery, including a low protein diet, oral lactulose, and neomycin or metronidazole. A moderately protein-restricted diet with the bulk of calories coming from carbohydrates and fat is optimal. Vegetable and dairy proteins are better tolerated than meat and egg proteins. With each patient, the protein level should be increased to the maximum tolerated. Psyllium at 1-3 teaspoons per day has been advocated to help tolerance of proteins. Some have recommended supplementation with vitamins A, B, C, E, and K. Medical stabilization for 1–2 weeks before surgery is recommended for all patients with portosystemic shunts. A preoperative coagulation screen should be performed, and crossmatched fresh whole blood should be available. Fresh frozen plasma transfusions may be necessary for hypoalbuminemic patients. Most surgeons administer a broad-spectrum antibiotic (e.g., first-generation cephalosporin) intravenously before and during surgery.

14. What considerations must be given to drug therapy and anesthetic use in patients with portosystemic shunts?

Because liver function decreases in patients with portosystemic shunts, drugs that are potentially hepatotoxic should be avoided. In addition, hepatic clearance of drugs and anesthetic agents may be delayed.

15. What parameters should be monitored postoperatively in patients with portosystemic shunts?

After surgery, many patients with portosystemic shunts are hypoglycemic, hypothermic, and hypoalbuminemic. A postoperative database should include body weight, temperature, packed cell volume, total solids, and glucose. Additional useful information is provided by electrolytes and albumin. Maintaining hydration status and perfusion with a balanced electrolyte solution is important. Mucous membrane color, capillary refill time, pulse rate and quality, and temperature should be assessed, and the patient should be monitored for seizures. In addition, serial measurement of abdominal circumference is helpful because a number of patients develop portal hypertension and ascites postoperatively.

16. What are common postsurgical complications?

Sepsis, seizures, and portal hypertension are the most critical complications that may develop postoperatively, although pancreatitis and intussusceptions have been reported. Gastrointestinal hemorrhage also may result, which can precipitate a hepatic encephalopathy crisis. Animals with seizures should be treated with appropriate measures to normalize acid–base and electrolyte balance. Sepsis should be treated aggressively.

17. What are common signs of postoperative portal hypertension?

Portal hypertension most commonly results in abdominal distention secondary to ascites. In some cases, portal hypertension is subclinical and ascites resolves in several days. Some patients develop abdominal distention, pain, and hypovolemia; others have abdominal distention with severe pain, hypovolemia, cardiovascular collapse, hemorrhagic diarrhea, and septic or endotoxic shock.

18. How should postoperative portal hypertension be treated?

If the animal develops abdominal distention with no clinical signs of pain or discomfort, continued medical therapy is indicated. Most animals with pain and abdominal distention stabilize with colloid fluid therapy. Patients with severe pain, abdominal distention, bloody diarrhea, and cardiovascular shock should be treated for shock with fluids, stabilized as much as possible, and taken for exploratory surgery to remove the ligature or thrombus that has probably developed in a partially attenuated portosystemic shunt.

19. Why may a patient with portosystemic shunt become septic postoperatively?

A patient with portosystemic shunt may develop septic peritonitis postoperatively because of bacteremia in the portal vein. The monocyte-phagocyte system in the liver may not be fully functional. Sepsis may develop as a result of inadequate filtering of portal blood by the liver before the blood reaches the systemic circulation.

20. What is hepatic microvascular dysplasia?

Hepatic microvascular dysplasia is a congenital disorder with histologic vascular abnormalities that resemble those seen in portosystemic shunts.

21. Are there breed predispositions for hepatic microvascular dysplasia?

Cairn and Yorkshire terriers are most commonly affected with hepatic microvascular dysplasia. However, many other breeds, including dachshund, poodle, Shih Tzu, Lhasa Apso, cocker spaniel, and West Highland White terrier may be affected.

22. What are the clinical signs of hepatic microvascular dysplasia?

Clinical signs are not consistently seen, but in severe cases they are quite similar to those seen with portosystemic shunts. Hyperammonemia and ammonium biurate cystalluria rarely develop. A dog may have hepatic microvascular dysplasia with elevated bile acids but be sick for another cause.

23. When should hepatic microvascular dysplasia be considered as a differential diagnosis?

Hepatic microvascular dysplasia should be considered in a patient with clinical signs consistent with a portosystemic shunt, increased bile acid concentration, and consistent liver biopsy results. Scintigraphy is consistently normal.

24. What is the treatment for hepatic microvascular dysplasia?

Treatment should not be done if the patient is subclinical. If signs of hepatic encephalopathy are present, treatment is indicated as for patients with portosystemic shunts. It is unknown at this time whether subclinical patients will develop signs of disease.

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84. HEPATIC LIPIDOSIS AND ACUTE HEPATITIS

Cynthia Stubbs, D.V.M.

1. What is hepatic lipidosis?

Hepatic lipidosis is a common disease of cats in which excessive fat accumulates in hepatocytes and may lead to severe intrahepatic cholestasis and progressive liver failure. Most cases in cats are idiopathic. Diabetes mellitus, pancreatitis, cholangiohepatitis, hyperthyroidism, hypertrophic cardiomyopathy, renal disease, chronic cystitis, chronic upper respiratory infections, hyperadrenocorticism, and neoplasia also have been detected in some cats with hepatic lipidosis. Most dogs with hepatic lipidosis have another underlying disease process.

2. What is acute hepatitis?

Acute hepatitis refers to any condition that causes inflammation and swelling of the liver. Injury may be precipitated by drugs, trauma, toxins, and infectious agents. In addition, immune-mediated diseases, inborn errors of metabolism (copper toxicity in Bedlington terriers is an example), and neoplastic diseases may result in acute hepatitis. Acute hepatitis also accompanies acute pancreatitis in both dogs and cats.

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Clinical signs are not consistently seen, but in severe cases they are quite similar to those seen with portosystemic shunts. Hyperammonemia and ammonium biurate cystalluria rarely develop. A dog may have hepatic microvascular dysplasia with elevated bile acids but be sick for another cause.

23. When should hepatic microvascular dysplasia be considered as a differential diagnosis?

Hepatic microvascular dysplasia should be considered in a patient with clinical signs consistent with a portosystemic shunt, increased bile acid concentration, and consistent liver biopsy results. Scintigraphy is consistently normal.

24. What is the treatment for hepatic microvascular dysplasia?

Treatment should not be done if the patient is subclinical. If signs of hepatic encephalopathy are present, treatment is indicated as for patients with portosystemic shunts. It is unknown at this time whether subclinical patients will develop signs of disease.

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84. HEPATIC LIPIDOSIS AND ACUTE HEPATITIS

Cynthia Stubbs, D.V.M.

1. What is hepatic lipidosis?

Hepatic lipidosis is a common disease of cats in which excessive fat accumulates in hepatocytes and may lead to severe intrahepatic cholestasis and progressive liver failure. Most cases in cats are idiopathic. Diabetes mellitus, pancreatitis, cholangiohepatitis, hyperthyroidism, hypertrophic cardiomyopathy, renal disease, chronic cystitis, chronic upper respiratory infections, hyperadrenocorticism, and neoplasia also have been detected in some cats with hepatic lipidosis. Most dogs with hepatic lipidosis have another underlying disease process.

2. What is acute hepatitis?

Acute hepatitis refers to any condition that causes inflammation and swelling of the liver. Injury may be precipitated by drugs, trauma, toxins, and infectious agents. In addition, immune-mediated diseases, inborn errors of metabolism (copper toxicity in Bedlington terriers is an example), and neoplastic diseases may result in acute hepatitis. Acute hepatitis also accompanies acute pancreatitis in both dogs and cats.

3. What historical questions should be asked of clients with animals with suspected acute hepatitis?

Drug administration, trauma, and toxin exposure should be ruled out by history. Many drugs, including potentiated sulfonamides, carprofen, anthelmintics such as metronidazole, and benzodiazepines have been associated with acute hepatitis or acute hepatic necrosis. It should be determined whether the animal has ingested moldy food; aflatoxins produced by some fungi are potent hepatotoxins. Travel and vaccination histories are important; leptospirosis may result in acute hepatitis in dogs and is a direct zoonosis.

4. What population of cats typically develops idiopathic hepatic lipidosis?

Middle-aged cats are primarily affected, but cats of any age may develop hepatic lipidosis. There does not appear to be a breed or sex predisposition. A large percentage of affected cats are obese before onset of clinical signs.

5. What historical complaints are commonly associated with acute hepatitis or lipidosis?

Anorexia occurs in most animals. In cats with idiopathic lipidosis, a stressful episode such as surgery, boarding, moving, or a new member in the household may precede appetite loss. Lethargy, depression, icterus, ptyalism, and vomiting are also commonly reported with acute hepatic diseases. Diarrhea is uncommon with idiopathic lipidosis but occurs in some animals with acute hepatitis. Hepatic encephalopathy (HE), characterized by head pressing, stupor, and coma, occurs in some animals with acute hepatic diseases.

6. What physical abnormalities are commonly detected in animals with acute hepatitis or lipidosis?

Depression, icterus, and dehydration are common. At presentation, most cats with idiopathic hepatic lipidosis have lost as much as 25–50% of their previous body weight. Most animals with acute hepatitis have clinical signs of shock, including elevated heart rate, pale mucous membranes, increased capillary refill time, and weak pulse. Liver size may be normal, increased, or decreased, depending on the primary cause and duration of the disease process before acute presentation. Animals with chronic hepatic disease that present with an acute exacerbation may have abdominal distention due to sustained portal hypertension or hypoalbuminemia-associated transudative ascites.

7. What diagnostic tests should be considered for animals with suspected acute hepatitis or lipidosis?

Complete blood count, platelet count, serum biochemistry panel, activated clotting time, and urinalysis should be assessed on admission. Packed cell volume, total protein, blood glucose, electrolytes, and coagulation should be assessed as soon as possible and emergency treatment initiated as indicated. Coagulation should be assessed because hepatic aspiration or biopsy is often indicated and disseminated intravascular coagulation is common, particularly in animals with acute hepatitis.

8. What routine laboratory abnormalities are most consistent with acute hepatitis or lipidosis?

Although no pathognomonic changes in complete blood count are associated with hepatic lipidosis, mild nonregenerative anemia, neutrophilia, or neutropenia may be noted. Increases in liver enzyme activities are common; any combination of increased activity of alanine transferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), or gamma-glutamyl transferase (GGT) may occur. In most cats, increases in ALP and GGT activities are greater than increases in ALT and AST activities. Lack of increased liver enzyme activities does not exclude the diagnosis of idiopathic hepatic lipidosis. Hyperbilirubinemia and bilirubinuria occur in most cats with idiopathic hepatic lipidosis. Findings are similar with acute hepatitis, but increases in ALT and AST activities are usually greater than increases in ALP and GGT activities.

9. What ancillary diagnostic tests help to determine the cause of liver disease in animals with suspected acute hepatitis or lipidosis?

Fasting and postprandial serum bile acids are usually markedly increased but do not need to be measured if hyperbilirubinemia is present. Fasting serum ammonia concentrations may be elevated and can be used for indirect assessment of the presence of hepatic encephalopathy. Abdominal radiographs, hepatic ultrasound, pancreatic ultrasound and trypsin-like immunoreactivity (TLI) tests may be used to narrow the differential list in animals with acute hepatic disease.

10. Do I need to perform a hepatic biopsy for all animals with suspected acute hepatitis or lipidosis?

A presumptive diagnosis of idiopathic hepatic lipidosis in cats may be made by the combination of appropriate history, laboratory abnormalities, and vacuolated hepatocytes on cytologic evaluation of a fine aspirate of the liver. If the cause of hepatitis is determined by history (trauma, drugs, toxins) or other findings (pancreatitis), biopsy may not be needed. However, the reference test for hepatic diseases is hepatic histologic evaluation. If hepatic aspiration or biopsy is performed, samples should be cultured for aerobic and anaerobic bacteria.

11. What immediate supportive care should be provided to animals with suspected acute hepatitis or lipidosis?

Fluid, electrolyte, acid–base, coagulation, and glucose abnormalities should be corrected as discussed in other chapters. Depending on acid–base and electrolyte status, 0.45% NaCl and 2.5% dextrose or Normosol-R are appropriate fluid choices. Potassium supplementation is required for most cases. Antibiotics should be administered to all animals with suspected acute hepatitis because bacterial translocation from the intestines into the liver is common. Penicillin derivatives or first-generation cephalosporins administered parenterally are adequate if clinical findings of sepsis are not present. Enrofloxacin should be considered in animals with suspected gram-negative sepsis. Vitamin K should be given subcutaneously to animals with increased activated clotting time. Supplementation with B vitamins is suggested for most cases. Hepatic encephalopathy, if present, is managed as described for portosystemic shunts (see chapter 83). Appetite stimulants, including cyproheptadine and benzodiazepams, generally are not successful alone. Benzodiazepams may lead to severe sedation if hepatic dysfunction is severe and have been associated with liver failure.

Whether enteral feeding is indicated depends on the cause of the disease. Early, aggressive nutritional therapy is the key to successful treatment of idiopathic hepatic lipidosis in cats. Initial short-term nutritional support may be provided by a nasoesophageal tube. However, because nutritional support is required for at least 3–6 weeks in most cases, a gastrostomy tube is strongly recommended. Multiple small meals should be fed to cats to provide a total of 60–80 kcal/kg/day. Most full-grown cats can handle 50–80 ml of food per feeding when the volume of food at each meal is gradually increased over several days. Protein should not be restricted unless signs of hepatic encephalopathy are present. Food should always be offered by mouth; the tube can be pulled after eating begins and liver enzymes have returned to normal.

12. What is the prognosis for recovery from idiopathic hepatic lipidosis?

The prognosis is guarded to fair, depending on how early the disease is recognized. The conditions can be reversed with aggressive nutritional therapy. Owners must be counseled that recovery may require up to 20 weeks before spontaneous eating occurs. Without treatment, hepatic lipidosis is usually fatal, leading to progressive liver failure.

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85. TRANSFUSION TRIGGER

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is the transfusion trigger?

The transfusion trigger is the minimal hemoglobin (Hgb) or packed cell volume (PCV) value at which a red blood cell (RBC) transfusion is usually administered. (Hemoglobin concentration = ⅓ packed cell volume.)

2. What are the goals in transfusion therapy?

The goals of transfusion are to reduce mortality and morbidity and to improve the functional status that result from anemia and inadequate oxygen delivery.

3. Should the decision to transfuse a patient be based solely on laboratory values?

Anemia is commonly seen, and whole blood transfusions are often necessary. For these patients we can offer guidelines in providing a transfusion but medical judgments cannot, and should not, be determined solely by algorithms, flow charts, and packed cell volumes (PCV). These represent laboratory values at which a transfusion is usually reasonable and for which no further justification is necessary.

4. Describe the classic clinical signs of anemia.

The classic clinical signs of severe anemia include exercise intolerance, respiratory distress, lethargy, hypotension, pale mucous membranes, tachycardia, and impaired consciousness.

5. Should the decision to transfuse a patient be based on clinical signs?

Most commonly these signs appear when the PCV is dangerously low. Few data are available for animals, but in humans exertional dyspnea does not occur until the Hgb concentration falls to less than 7 gm/dl. In another study, at Hgb concentration levels < 6 gm/dl, only 54% of patients experienced tachycardia, 32% had hypotension, 35% had impaired consciousness, and 27% had dyspnea. Levels of anemia required to produce symptoms in children are even more severe. Therefore, relying on clinical signs of anemia to guide transfusion decisions probably results in significant under-transfusion of patients. Moreover, relying on clinical signs in the anesthetized animal obviously is fruitless.

6. What is the "30/10" rule?

An Hgb concentration of 10 gm/dl and PCV level of 30% are used in the decision process for receiving a transfusion. This rule is more dogma than fact and has been in use for nearly 60 years!

7. List the determinants of tissue oxygenation.

Tissue oxygenation is a function of hemoglobin concentration, oxygenation of blood by the lungs, and cardiac output.

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7. List the determinants of tissue oxygenation.

Tissue oxygenation is a function of hemoglobin concentration, oxygenation of blood by the lungs, and cardiac output.

8. What are the risks of anemia?

The level of anemia at which adverse events occur is needed to develop guidelines for transfusion, but data are limited. Healthy animals subjected to acute hemodilution, tolerate Hgb levels between 3 and 5 gm/dl. When Hgb is < 3 gm/dl, ischemic electrocardiographic, increased lactate production, depressed ventricular function, and death occur. Chronic anemia, in theory, is better tolerated than acute anemia because of the opportunity for the oxyhemoglobin dissociation curve to shift toward increased oxygen release. Whether this assumption is true is unknown.

9. List the factors that may help to determine the need for a transfusion.

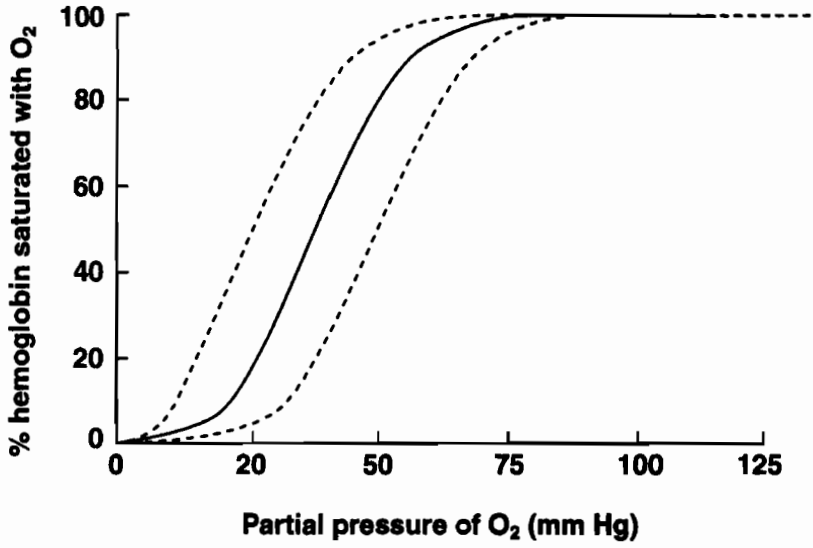
- Cause and chronicity of the anemia
- Patient's ability to compensate for decreasing oxygen-carrying capacity
- Tissue oxygen requirements

10. What factors allow an animal to compensate for anemia?

The compensatory mechanisms activated by acute blood loss include changes in oxygen transport, cardiac output, oxygen consumption, the kinetics of oxygen, and adaptive changes associated with anemia. Early in acute blood loss, compensatory mechanisms include stimulation of the adrenergic nervous system, release of vasoactive hormones, redistribution of fluid from the interstitium to the intravascular space, shift of fluid from the intracellular to extracellular compartment, renal conservation of water and electrolytes, and hyperventilation. These changes contribute to an increase in cardiac output, the primary determinant of tissue perfusion.

11. What is the oxyhemoglobin dissociation curve?

The oxygen-binding affinity of Hgb is illustrated by the sinusoidal relationship between hemoglobin oxygen saturation and PO_2. This relationship, referred to as the oxyhemoglobin dissociation curve, enables both efficient loading in the lungs at high PO_2 and efficient unloading in the tissues at low PO_2 levels. However, the oxygen-binding affinity of Hgb may be altered by various disease states and may play a significant adaptive role in response to anemia.



The oxyhemoglobin dissociation curve. The solid line represents oxygen binding affinity to the hemoglobin molecule at standard temperature (37°C) and a pH of 7.4. The dashed lines represent hypothetical shifts in the curve; to the right with increased 2,3-diphosphoglycerate (2,3-DPG) levels or decreased temperature or pH; to the left with decreased 2,3-DPG or increased temperature or pH.

12. What is oxygen content?

The content of oxygen in arterial blood (CaO_2) is described in equation 1:

$$CaO_2 = (1.34 \times [Hgb] \times SaO_2) + (0.003 \times PaO_2) \quad (1)$$

The contributions of Hgb concentration [Hgb] and the percentage of Hgb saturated with oxygen (SaO_2) are described by the first term of the equation. The second term describes the small contribution of free oxygen in the plasma. One gram of Hgb can bind 1.39 ml oxygen at full saturation. However, a small fraction of circulating Hgb is represented by forms that do not readily bind oxygen (i.e., methemoglobin and carboxyhemoglobin). Thus, 1.34 ml/gm more accurately describes the behavior of the pool of circulating hemoglobin.

13. What is oxygen delivery (DO_2)?

The amount of oxygen delivered, either to the whole body or to specific organs, is the product of the total blood flow and arterial oxygen content. For the whole body, DO_2 is the product of cardiac output (CO) and arterial oxygen content (CaO_2) (equation 2):

$$DO_2 = CO \times CaO_2 \quad (2)$$

When you substitute CaO_2 from equation 1 into equation 2, the result is equation is 3:

$$DO_2 = CO \times (SaO_2 \times 13.4^* \times [Hgb]) \quad (3)$$

CO, a measure of blood flow to the entire body, is the other major determinant of O_2 delivery. It may be quantified by multiplying the stroke volume (the difference between end-diastolic volume and end-systolic volume in ml) and heart rate (beats per minute). Stroke volume is influenced by preload (end-diastolic volume affected by filling pressure), afterload (arterial pressure and resistance encountered during each ventricular ejection), and contractility (force generated during a contraction).

14. What is oxygen consumption (VO_2)?

VO_2 from the microcirculation is a function of CO and the difference in oxygen content between arterial and venous blood (equation 4):

$$VO_2 = CO \times (CaO_2 - CvO_2) \quad (4)$$

Because CaO_2 and CvO_2 share the same term for hemoglobin binding (equation 1), the equation for VO_2 can be rewritten as equation 5:

$$VO_2 = CO \times [Hgb] \times 13.4 \times (SaO_2 - SvO_2) \quad (5)$$

In humans, the normal range for VO_2 is 110–160 ml/minute/m^2.†

15. What do all these equations have to do with a decision to tranfuse a patient?

Tissue hypoxia (and anoxia) will eventually occur if oxygen delivery is permitted to decrease to a level at which tissues no longer have enough oxygen to meet metabolic demands. From equations 1 and 3, it is apparent that tissue hypoxia may be caused by decreased oxygen delivery due to decreases in hemoglobin concentration ([Hgb]) (anemic hypoxia), CO (stagnant hypoxia), or hemoglobin saturation (hypoxic hypoxia).

16. What is known about the amount of oxygen normally delivered to tissues?

In health, the amount of oxygen delivered to the whole body exceeds resting oxygen requirements by a factor of 2–4. For example, if we assume a [Hgb] of 15.0 gm/dl, 99% saturation of Hgb with oxygen, and CO of 5 L/min, oxygen delivery is 1032 mL/min. At rest, the amount of oxygen required or consumed by the whole body ranges from 200–300 ml/min. A decrease in [Hgb] to 10 gm/dl results in an oxygen delivery of 688 ml/min. Despite this 33% decrease in

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* 10 times 1.34 converts the final results to ml/min.

† To be precise, CO is acutally cardiac index (CI), which is calculated by knowing CO and dividing by the body surface area in meters^2.

oxygen delivery, there remains a twofold excess of oxygen delivery compared with consumption. However, a further drop in [Hgb] to 5 gm/dl, with all other parameters, including CO, remaining constant, decreases oxygen delivery to a critical level of 342 ml/min. Under stable experimental conditions, this dramatic decrease in oxygen delivery does not affect oxygen consumption.

17. Describe some of the adaptive mechanisms seen in anemia.

In anemia, oxygen-carrying capacity is decreased, but tissue oxygenation is preserved at [Hgb] well below 10gm/dl. Adaptive responses include a shift in the oxyhemoglobin dissociation curve, hemodynamic alterations, and microcirculatory alterations. The shift to the right of the oxyhemoglobin dissociation curve in anemia is primarily the result of increased synthesis of 2,3-diphosphoglycerate (2,3-DPG) in erythrocytes, which enables more oxygen to be released to the tissues at a given PO_2 and offsetting the effect of the reduced oxygen-carrying capacity of the blood. This shift also occurs in vitro with decreases in temperature and pH.

18. What hemodynamic adaptations may occur in anemia?

Several hemodynamic alterations occur after the development of anemia. The most important determinant of cardiovascular response is the patient's volume status or, more specifically, left ventricular preload. The combined effect of hypovolemia and anemia often results from blood loss. Thus, acute anemia may cause tissue hypoxia or anoxia through both diminished CO (stagnant hypoxia), and decreased oxygen-carrying capacity (anemic hypoxia). The body attempts to preserve oxygen delivery to vital organs primarily by redistributing the available cardiac output through increased arterial tone. The adrenergic system plays an important role in altering blood flow to and within specific organs.

CONTROVERSIES

19. At what PCV level is oxygen delivery maximal?

In a canine model, optimal oxygen transport occurs at a hematocrit of 40–60%. Other reports have determined that maximal oxygen delivery occurs at the low end of this range (40–45%). However, one of the most widely quoted studies reported that peak oxygen transport occurred at a hematocrit of 30% ([Hgb] 10.0 gm/dl). Attempting to identify a single [Hgb] that maximizes oxygen delivery overlooks the large number of factors interfering with adaptive mechanisms in anyone with anemia other than healthy young patients.

20. What pathophysiologic processes affect a patient's response to anemia?

A number of diseases that affect either the entire body or specific organs may limit adaptive responses to anemia. Heart, lung, and cerebrovascular diseases have been proposed to increase the risk of adverse consequences from anemia. Age, severity of illness, and therapeutic interventions also may affect adaptive mechanisms.

21. What is the critical level that affects wound healing?

The critical hematocrit at which anemia may influence tissue repair appears to be approximately 15%.

22. After all of this, what is the "transfusion trigger"?

When all available studies, clinical experience, and individual options are considered, it is difficult to improve on the statement of the National Institutes of Health Consensus Development Conference on perioperative erythrocyte transfusion:

> No single measure can replace good clinical judgement as the basis for decisions regarding perioperative transfusion. However, current experience would suggest that otherwise healthy patients with hemoglobin values of 10 g/dl or greater rarely require perioperative transfusion, whereas those with hemoglobin values less than 7 g/dl will frequently require transfusion of erythrocytes.

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X. Digestive Emergencies

Section Editor: Wayne E. Wingfield, M.S., D.V.M.

86. FOREIGN BODIES IN THE DIGESTIVE SYSTEM

Howard B. Seim, III, D.V.M.

ESOPHAGEAL OBSTRUCTION

1. What is the most common cause of esophageal obstruction? Where are most obstructions located?

Foreign bodies (e.g., bones, cartilage, fish hook) are the most common cause of esophageal obstruction. Esophageal stricture and neoplasia also may cause signs of obstruction. The most common locations are the heart base and lower esophageal sphincter. Foreign bodies occasionally lodge in the cervical esophagus and thoracic inlet. Esophageal strictures generally are located in the cranial thoracic esophagus, whereas neoplasms occur at the lower esophageal sphincter.

2. Describe the most common clinical signs and physical findings in patients with esophageal obstruction.

Patients with esophageal obstruction present with various signs, depending on the duration of obstruction. Initially, regurgitation, hypersalivation, gagging, and retching are common signs. Some patients may exhibit dysphagia, distress, or slow continual swallowing. Later, these signs may disappear and become less specific (e.g,. depression, anorexia, weight loss). Physical findings are generally nonspecific. Occasionally, cervical or thoracic inlet foreign bodies are palpable. The owner saw the ingestion in 90% of animals presenting with fish hook ingestion.

3. What tests are most likely to confirm the diagnosis of esophageal obstruction?

Approximately 50% of esophageal foreign bodies are radiopaque; in such cases, survey radiographs are diagnostic. Radiographic findings suggestive of a nonradiopaque foreign body include gas in the esophagus and mediastinitis or pleuritis, which suggest a perforated esophagus. Contrast radiography should be performed if the diagnosis is in reasonable doubt. If suspicion of perforation is high, an organic iodide contrast media should be used instead of barium. Contrast radiographs also diagnose esophageal stricture and neoplasia. Rigid or flexible fiberoptic esophagoscopy is the definitive diagnostic procedure.

4. List the most common methods of removing esophageal foreign bodies.

Ninety percent of esophageal foreign bodies can be removed without surgical intervention by one of the following methods:

1. **Rigid esophagoscopy.** Advantages include dilation of the esophagus proximal to the obstruction, removal of the foreign body within the scope without trauma to the proximal esophagus, advancement of the foreign body into the stomach, relatively low cost of equipment, and low risk of pneumothorax if an esophageal perforation is present. Disadvantages include lack of clear visualization and difficulty in evaluating the esophageal wall after removal.

2. **Flexible fiberoptic endoscopy.** Advantages include precise view of the foreign body, ability to grasp the foreign body, advancement of the foreign body into the stomach, and accurate evaluation of the esophagus after removal. Disadvantages include high risk of tension pneumothorax if an esophageal perforation is present, high cost of equipment, and inability to protect the orad esophagus during removal.

5. What is the first step after removal of the foreign body?

The first step is to evaluate the esophageal mucosa for evidence of erosion, ulceration, or perforation. If perforation is present, consider surgery to repair the defect. If ulceration and erosion are present, treat for esophagitis.

6. List the components of treatment after removal of a foreign body and explain the reason for each.

1. An **H_2 receptor blocker** decreases acid content of the stomach, thus decreasing the risk of reflux of acid-rich gastric juice into the esophagus.

2. **Dietary restriction** eliminates mechanical trauma to eroded or ulcerated esophageal mucosa. Either the patient is given nothing orally for several days, or a gastrostomy feeding tube is placed.

3. **Corticosteroids** decrease the incidence of esophageal stricture formation. The esophagus is unique among bodily organs in its lack of an organized dermis; a stratified squamous epithelium lies directly on loose submucosal connective tissue. Healing, therefore, may be more simple and rapid than in complex organs such as skin, and early retardation of collagen synthesis with corticosteroids seems to make a significant difference in the quality and quantity of the final scar.

4. **Antibiotics** protect the patient against bacterial infection and possible abscess, particularly in the presence of small, undetectable perforations.

5. **Prokinetic agents** increase normograde gastric motility and pressure at the lower esophageal sphincter; both actions decrease reflux of gastric contents into the esophagus.

7. Should all patients with esophageal perforation be treated surgically?

In patients suspected of esophageal perforation after removal of a foreign body, an organic iodide esophagogram should be done. Small perforations (1–3 mm) should be treated conservatively (see question 6). Placement of a gastrostomy feeding tube should be considered. Large perforations (> 3 mm) should be surgically explored, debrided, and sutured.

SMALL INTESTINAL OBSTRUCTION

8. How are small intestinal obstructions classified?

1. **Strangulating vs. nonstrangulating (simple) obstruction.** Strangulation implies that the blood supply to the segment of obstructed bowel is compromised to some degree. Nonstrangulating obstructions do not cause vascular compromise to the affected intestinal segment. Strangulating obstruction is generally more life-threatening than nonstrangulating obstruction.

2. **Complete vs. partial obstruction.** A complete obstruction implies that gas and fluid located above the obstruction cannot pass below the obstruction. A partial obstruction implies that some gas and fluid can pass beyond the obstruction. Complete obstructions are generally more life-threatening than partial obstructions.

3. **High vs. low obstruction.** High obstructions generally imply pyloric, duodenal, and midjejunal involvement. Low obstructions generally imply distal jejunum and ileal involvement. In general, the closer the obstruction to the pyloric region and the more complete the obstruction, the greater the severity of signs.

9. What are the causes of small intestinal obstruction? Give common examples of each.

1. Luminal foreign bodies (e.g., bones, rocks, rags, socks, string)
2. Mural lesions (e.g., adenocarcinoma, leiomyoma, leiomyosarcoma, lymphosarcoma)
3. Extraluminal (e.g., intussusception, volvulus, hernia, torsion)

10. What are the most common presenting signs?

Clinical signs of small bowel obstruction include vomiting, abdominal pain, restlessness, abdominal distention, dehydration, hyporexia, and anorexia. Severity and duration of signs depend on location and completeness of the obstruction and whether vascular occlusion (i.e., strangulation) is present.

11. Describe the most common physical findings in patients with small bowel obstruction.

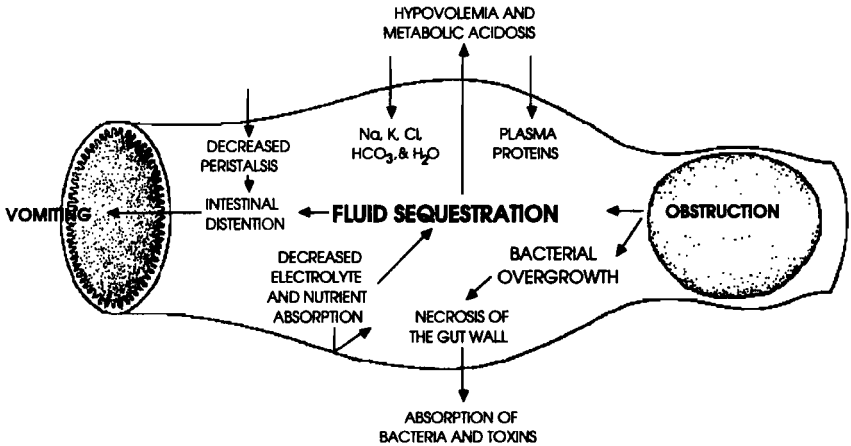
Abdominal tenderness or pain, palpation of an abdominal mass, low-grade fever, and dehydration are common physical findings. Patients with complete, high obstruction or strangulating obstruction of long duration (i.e., several days to weeks) may be severely moribund, with low body temperature, muddy mucous membranes, capillary refill time greater than 2 seconds, elevated heart rate, and variable breathing patterns, depending on acid–base status.

12. What is the single best test to establish a definitive diagnosis?

Survey and contrast abdominal radiographs are the best diagnostic tests. Characteristic findings of survey radiographs include: (1) multiple loops of gas-dilated small intestine of various diameters, (2) gas–fluid interfaces in dilated loops of small intestine on standing lateral projections, (3) visualization of a radiopaque foreign body, (4) ground-glass appearance if peritoneal fluid is present, and (5) free gas in the peritoneal cavity if intestinal perforation has occurred. Contrast radiographic examination may confirm the diagnosis by outlining the intraluminal mass with contrast, or the contrast may be compressed by a mural or extraluminal lesion.

13. What laboratory abnormalities are generally present?

Patients suspected of small bowel obstruction should have a complete blood count, biochemical profile, and urinalysis. Changes in blood parameters are influenced by location and degree of intestinal obstruction as well as presence or absence of strangulation. In general, patients have a normal or slightly elevated white blood cell count, hyponatremia, hypochloremia, hypokalemia, metabolic alkalosis, prerenal azotemia, and increased urine specific gravity. A shift to metabolic acidosis occurs as continued vomiting and dehydration cause further losses of fluid and electrolytes, resulting in hypovolemic shock. Severe fluid loss may be due to (1) vomiting, (2) intraluminal pooling, and (3) bowel wall edema.



Pathophysiology of intestinal obstruction.

14. List the steps in the initial medical management of small bowel obstruction.

1. Intravenous fluid resuscitation to correct dehydration, replace electrolyte losses, correct acid–base abnormalities, and treat hypovolemic shock.

2. Consider corticosteroid or flunixin meglumine in patients suspected of strangulating obstruction or sepsis.

3. Consider antimicrobial therapy in (1) old, debilitated patients, (2) patients with sepsis, (3) patients suspected of strangulating obstruction, and (4) patients in whom perforation is associated with the obstruction (e.g., linear foreign body, necrotic tumor). In addition, antimicrobial therapy should be considered if the surgical procedure will take longer than 90 minutes.

4. Consider adding glucose to the intravenous fluids in septic patients if the serum biochemistry profile reveals a low glucose level or a strangulating obstruction is strongly suspected.

15. What is the differential diagnosis for small bowel obstruction?

1. **Paralytic ileus.** Most patients have a history of dietary indiscretion. Physical examination reveals no palpable abdominal mass, and the abdomen is not as tender. Survey radiographs reveal generalized rather than segmental ileus.

2. **Mesenteric volvulus.** Most patients have a history of sudden, severe abdominal pain and hematochezia. Physical examination reveals severe abdominal distention and abdominal pain out of proportion with other physical findings. Survey radiographs reveal generalized ileus with abdominal distention.

16. When does the patient with small intestinal obstruction become a "stable" surgical candidate?

- *Never let the sun set on a small bowel obstruction.*
- *When a patient is unable to pass feces or flatus per rectum, he is sick and will surely die, unless surgically relieved.*

Both axioms apply to veterinary patients with signs of small intestinal obstruction. The nearer the obstruction to the pylorus, the greater the surgical urgency. Stabilization before surgical intervention is defined as the time necessary to deliver a shock dose of fluids, to ensure cardiovascular stability, to begin resolving electrolyte and acid–base abnormalities, and to institute additional shock therapy as needed (i.e., antibiotics, corticosteroids, glucose, flunixin meglumine).

17. List the surgical options at the time of laparotomy. Give examples of settings in which each option is appropriate.

1. Enterotomy (e.g., luminal foreign body, intestinal wall mass, intestinal biopsy)

2. Enterotomy with transverse closure (e.g., resection of intestinal wall mass in which linear closure will result in unacceptable lumen compromise)

3. Anastomosis (e.g., mural lesion, nonviable bowel segment, multiple mesenteric wounds)

4. Enteroplication (e.g,. after intussusception reduction or resection and anastomosis)

5. Enterostomy feeding tube (e.g,. bypass of surgical site for immediate postoperative enteral feeding)

18. What are the most reliable criteria for assessing small bowel wall viability at surgery?

The most reliable criteria include color, peristalsis, arterial pulsations, intravenous fluorescein dye injection, and a second look. Intravenous fluorescein is the method of choice in dogs and cats.

Fluorescein dye is injected via any peripheral vein. Sixty to 90 seconds after injection the lights in the operating room are dimmed and ultraviolet illumination (e.g., Wood's lamp) is provided. The affected segment of bowel is evaluated according to established criteria.

Second look refers to laparotomy 24–36 hours after the original laparotomy to reexamine the bowel in question. Less accurate methods include Doppler studies, surface oximetry, and serosal bleeding of a cut surface.

19. What is the most common postoperative complication of intestinal surgery?

Breakdown of the enterotomy or anastomosis and subsequent leakage of intestinal contents into the peritoneal cavity is the most common postoperative complication of intestinal surgery. The causes may include (1) less than 3-mm bite in the submucosa, (2) sutures spaced more than 3 mm apart, (3) traumatic handling of the cut edge of intestine, (4) improper knotting of suture material, and (5) suturing of nonviable bowel.

20. What is the most accurate test for diagnosis of postoperative intestinal leak?

Peritoneal tap and evaluation of peritoneal fluid cytology is the most sensitive diagnostic test for peritonitis secondary to anastomotic leak. Presumptive diagnosis is based on elevated body temperature, vomiting, abdominal tenderness, drainage from the incision, inflammatory leukogram, and low glucose. Survey abdominal radiographs generally are not helpful; they are difficult to assess critically because of the presence of postoperative air and fluid. Barium should not be used because it may cause peritoneal irritation. Aqueous contrast agents are not sensitive enough to pick up small perforations. If the presence of a leak is in doubt, remember the axiom, "It is better to have a negative exploratory laparotomy than a positive postmortem."

CONTROVERSY

21. Should anastomosis of small intestine be performed with 8–10 sutures?

For: Several authors have suggested that intestinal anastomosis can be successfully performed with minimal sutures (i.e., 8–10). This technique is less time-consuming and causes less trauma to intestinal tissue and blood supply.

Against: Patients with intestinal obstruction frequently have associated bowel pathology (e.g., inflammation, edema, vascular compromise). Eight to 10 sutures are likely to leave gaps of significant size that encourage leak. Sutures should be placed no further apart than 3 mm; a typical anastomosis requires 20–25 sutures.

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87. CANINE HEMORRHAGIC GASTROENTERITIS

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is canine hemorrhagic gastroenteritis (HGE)?

Canine HGE is a syndrome characterized by the acute onset of profuse vomiting and bloody diarrhea with significant hemoconcentration.

2. What is the cause of HGE?

The cause is unknown. Although the term HGE implies an inflammatory condition, the disease is more likely due to altered intestinal mucosal permeability and perhaps mucosal hypersecretion. Cultures of GI contents from HGE-affected dogs have yielded large numbers of *Clostridium perfringens*, leading to speculation that this organism or its exotoxins are the cause.

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3. Which dogs are most likely to be affected with HGE?

Toy and miniature breeds seem particularly prone to HGE, especially toy and miniature poodles and schnauzers, but the syndrome may affect any breed.

4. What are the clinical signs of HGE?

- Acute onset of vomiting
- Severe depression
- Profuse, bloody, fetid diarrhea
- Shock

5. How is the diagnosis of HGE made?

- Extreme hemoconcentration (packed cell volume > 50–60%)
- Bloody, fetid diarrhea
- No leukopenia
- Fecal cytology with increased numbers of clostridial organisms

6. Describe the treatment for HGE.

- Intensive fluid therapy until the packed cell volume is in the normal range and then continued intravenous crystalloid fluids (Normosol-R + potassium chloride) until vomiting is controlled.
- Antibiotics to control *C. perfringens* (ampicillin or amoxicillin)
- Restriction of food and water
- Antiemetic drugs (metoclopramide)

7. What is the prognosis of HGE?

- Early, aggressive fluid therapy consistently results in significant improvement within 24 hours.
- If vomiting and diarrhea are not resolved in 48 hours, a search for other causes mimicking HGE should be conducted (parvovirus, coronavirus, GI foreign bodies, intussusception, intestinal volvulus, clostridial enteritis, lymphocytic–plasmocytic enteritis).

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88. ESOPHAGEAL DISORDERS

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is the most common clinical sign of an esophageal disorder?

Regurgitation.

2. What is the difference between regurgitation and reflux?

Regurgitation refers to passive, retrograde movement of ingested material to a level proximal to the upper esophageal sphincter; usually this material has not reached the stomach. In most cases, regurgitation results from abnormal esophageal peristalsis, esophageal obstruction, or asynchronous function of the gastroesophageal junction.

Reflux refers to the movement of gastric and duodenal contents into the esophagus without associated eructation or vomiting.

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Reflux refers to the movement of gastric and duodenal contents into the esophagus without associated eructation or vomiting.

3. List the causes of regurgitation.

1. Megaesophagus
   - Idiopathic
   - Secondary
     - Myasthenia gravis
     - Polyneuropathy
     - Systemic lupus erythematosus
     - Polymyositis
     - Toxicosis (lead, thallium)
     - Hypothyroidism
     - Hypoadrenocorticism
2. Esophageal foreign body
3. Esophageal stricture
   - Intraluminal stricture
   - Extraluminal stricture due to compression
     - Abscess
     - Cranial mediastinal mass
     - Thoracic hilar lymphadenopathy
4. Vascular ring anomaly
5. Neoplasia (primary or metastatic)
6. Granuloma (e.g., *Spirocerca lupi*)
7. Hiatal hernia
8. Esophageal diverticula

4. What is megaesophagus?

Megaesophagus is a specific syndrome characterized by a dilated, hypoperistaltic esophagus.

5. What is the most common complication of megaesophagus?

Aspiration pneumonitis.

6. Does esophageal dilatation on thoracic radiographs confirm an esophageal disorder?

No. The following conditions often produce transient dilatation of the esophagus:

- Aerophagia
- Anxiety
- Respiratory distress (dyspnea)
- Anesthesia
- Vomiting

7. How is esophageal motility evaluated?

Thoracic radiography initially evaluates for evidence of an esophageal foreign body, esophageal dilatation, or thoracic mass. Ideally a barium esophagogram with fluoroscopy should be performed. It is best to mix food with the barium to observe for decreased contractility.

8. What is myasthenia gravis?

Myasthenia gravis is an immune-mediated disorder, either acquired or congenital (familial), resulting from the action of autoantibodies against nicotinic acetylcholine receptors at the neuromuscular junctions.

9. What are the most common clinical signs of myasthenia gravis?

- Premature fatigue with exercise
- Spastic pelvic limb gait
- Tetraparesis
- Collapse
- Tachypnea
- Respiratory distress
- Sialosis
- Regurgitation
- Dysphagia
- Weakness of facial muscles
- Decreased palpebral reflex

10. What is the test of choice for myasthenia gravis?

Acetylcholine receptor antibody titers (> 0/6 nM/L) in dogs. Antibodies are detectable in 80–90% of dogs with acquired disease.

11. What other tests can be used for myasthenia gravis?

- Edrophonium response test. Edrophonium (0.1–0.2 mg/kg IV) results in dramatic improvement in gait for 1–2 minutes in many but not all animals. Pretreatment with atropine (0.02 mg/kg IV) decreases salivation, defecation, urination, bronchosecretion, and bronchoconstriction. Oxygen and an endotracheal tube should be readily available.
- Ten percent or greater decremental response to the fourth or fifth compound action potential recorded from the interosseous muscle after repetitive stimulation of the tibia or ulnar nerve at 3 Hz.
- Increase in jitter on single-fiber electromyography.
- Intercostal muscle biopsy identifying acetylcholine receptor antibodies at the neuromuscular junction.

12. Describe the typical profile of a dog with myasthenia gravis.

- Breeds most commonly affected: golden retriever, German shepherd
- Bimodal age of onset: 2–4 years and 9–13 years

13. How is myasthenia gravis treated?

1. Anticholinesterase drugs—neostigmine
   - Injectable (Prostigmin [Roche]): 0.02 mg/lb IM every 6 hr
   - Oral (Mestinon [Roche]): 0.25–0.45 mg/lb every 8–12 hr
2. Corticosteroids

14. Describe the principles for management of megaesophagus.

1. Remove the cause if possible.
2. Minimize chances for aspiration of esophageal contents. (Feed the animal in an upright position so that the upper body is elevated to at least 45° above the lower body. Maintain this position for at least 10 minutes after eating and before bedtime.)
3. Maximize nutrient intake to the GI tract (if possible, feed 2–4 times/day).

15. What is an alternative means of feeding dogs with megaesophagus?

Gastrostomy tube.

16. What is the prognosis for a dog with megaesophagus?

Guarded to poor.

17. List causes of esophageal stricture in dogs.

- Esophagitis
- Reflux of gastric acid during general anesthesia (on a tilted operating table)
- Ingestion of a strong acid or alkali material
- Esophageal foreign bodies
- Thermal burns
- Hairballs (cats)

18. How is esophageal stricture diagnosed?

Esophageal stricture is diagnosed by barium esophagogram and esophageal endoscopy.

19. List the treatment options for esophageal stricture and the success rate for each.

- Surgery (esophagotomy, patch grafting, resection and anastomosis): < 50% success
- Esophageal bougienage: 50–70% success
- Balloon catheter dilatation: > 50–70% success (treatment of choice, ideally done under fluoroscopy)

20. What are the most common areas of the esophagus in which foreign bodies lodge?

- Thoracic inlet
- Base of the heart
- Hiatus of the diaphragm

21. How do you manage dogs with an esophageal foreign body?

Esophageal foreign bodies are considered an emergency. The following steps are recommended:

1. Endoscopic removal of the foreign body is usually successful. Either extract the foreign body or carefully push it into the stomach. If the foreign body is a bone, it is often best to push it into the stomach. Gastrostomy is not usually required for removal of the bone, but serial radiography should be done to ensure digestion or passage of the bone.
2. If esophagoscopy is unsuccessful, surgical removal is required.
3. Assess the esophageal mucosa for hemorrhage, erosions, lacerations, or perforations.
4. Withhold food and water for 24–48 hours, and give crystalloid fluids and parenteral antibiotics.

22. What treatments are available for esophageal reflux?

- **Metoclopramide** (Reglan) increases gastroesophageal sphincter tone and decreases gastric reflux into the stomach.
- **H_2 receptor-blocking agents** (e.g., cimetidine or ranitidine) reduce the acidity of refluxed gastric contents.
- **Sucralfate suspension** is an aluminum salt that selectively binds to injured gastroesophageal mucosa and acts as an effective barrier against the damaging actions of gastric acid, pepsin, and bile acids associated with reflux esophagitis.

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89. CANINE PARVOVIRUS

Wayne E. *Wingfield*, M.S., D.V.M., *and Dennis* W. *Macy*, D.V.M., M.S.

1. What are the common clinical signs in dogs with canine parvovirus (CPV)?

- Lethargy
- Vomiting
- Inappetence
- Fever
- Acute-onset diarrhea
- Profound neutropenia (white blood cells < 1000/mm^3)

Puppies between the ages of 6 weeks to 6 months are most commonly affected. In a Canadian study, sexually intact dogs had a 4-fold greater risk than spayed or neutered dogs, and the months of July, August, and September had a 3-fold increase in cases of CPV.

2. What systems other than the GI tract are involved with CPV?

In a study of dogs with the GI form of CPV, arrhythmia was diagnosed in 21 of 148 cases, including supraventricular arrhythmias and conduction disturbances. Some dogs developed significant enlargement of the cardiac silhouette and other radiographic cardiac abnormalities. CPV can replicate in bone marrow, heart, and endothelial cells; replication in endothelial cells of the brain produces neurologic disease.

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3. What other infectious diseases may be mistaken for CPV infection?

Infection with *Salmonella* sp., *Campylobacter* sp., or *Escherichia coli* may mimic CPV symptoms and also cause the shift in white blood cells. CPV infection also may be confused with hemorrhagic gastroenteritis (HGE), although HGE is seen most commonly in smaller breeds and usually resolves in 24 hours. Coronavirus often presents with GI signs, but neutropenia tends to resolve more rapidly than with CPV infection. Clinical signs of infection with coronavirus are usually seen only in dogs also infected with parvovirus.

4. What is the primary mode of transmission of CPV?

The number of viral particles in the feces is quite high; the fecal-oral route is the most likely means of transmission. No studies of vomitus have been done, but it probably contains viral particles.

5. How does CPV infect the intestines?

Viral replication occurs in the oropharynx during the first 2 days of infection, spreading to other organ systems via the blood. By the third to fifth day a marked viremia develops. The virus reaches the intestinal mucosa from the blood rather than from the intestinal lumen. Clinical signs are seen 4–5 days after exposure, and the incubation period ranges from 3–8 days, with shedding of the virus on day 3.

6. Where does CPV replicate in the body?

The virus replicates in rapidly dividing cells, which include lymph nodes, spleen, bone marrow, and intestines. In the intestines, viral replication kills the germinal epithelium of the intestinal crypts, leading to epithelial loss, shortening of the intestinal villi, vomiting, and diarrhea. Lymphoid necrosis and destruction of myeloproliferative cells result in lymphopenia and, in severe cases, panleukopenia. Only about one-third of CPV cases have defined neutropenia or lymphopenia.

7. How has the clinical presentation of CPV infection changed since the 1970s?

There are several strains of CPV, including the original strain, CPV-1; the minute virus; and the most severe strain, CPV-2 (with subtypes 2a and 2b). CPV-2b is now the most common strain in the United States. CPV-1, which dominated in the 1970s, caused a milder disease associated with fever and a larger window for treatment. CPV-2b causes a more explosive acute syndrome that affects young dogs 6–12 weeks of age, making the window between the first signs of GI upset and treatment much narrower and more critical. There have been no major changes in presentation in the past 6 years; lethargy, listlessness, and bloody diarrhea are the most common presenting signs. Other diseases associated with or mistaken for CPV are canine distemper virus, coccidial or giardial infection, hookworms, roundworms, or a combination of these.

8. When and how does one diagnose CPV?

CPV is most easily diagnosed with a fecal enzyme-linked immunosorbent assay (ELISA). If the test is negative but CPV is still suspected, isolate the animal and run the test again in 48 hours. The virus is not usually shed until day 3, and conscientious clients may bring the animal to the hospital at the first sign of illness. The period during which CPV is shed in the feces is brief, and the virus is not usually detectable until day 10–12 after infection. Usually the acute phase of illness has passed by this time. Modified live CPV vaccines shed in the feces may give a false-positive ELISA result 4–10 days after vaccination.

One also may use a combination of ELISA, complete blood count, and radiographs to diagnose CPV. Radiographs may help to rule out the possibility of an intestinal foreign body, and detection of generalized ileus with fluid-filled loops of intestines supports the diagnosis of CPV. Be sure to have enough antigen in the fecal sample when running the ELISA; watery stools may dilute the antigen and give a false-negative result.

Conclusive proof of CPV infection is made with electron microscope identification of the virus.

9. What are the recommendations for inpatient care of dogs with CPV?

1. **Aggressive fluid therapy.** Correct dehydration and provide intravenous maintenance fluid volumes of a balanced crystalloid solution. Make every attempt to replace continuing losses (vomitus and diarrhea) with equal volumes of crystalloid fluids. The easiest method is simply to estimate the volume lost and *double* your estimate. Continuing losses need to be replaced at the time that they occur. Use Normosol with at least 20 mEq/L of potassium chloride supplementation. Monitor glucose level. If necessary, add 2.5–5% dextrose to intravenous fluids. A 5% dextrose solution creates an osmotic diuresis, but it also allows assessment of progress in dealing with a septic case (glucose increases when the animal receives 5% dextrose if the sepsis is resolving). Low levels of magnesium chloride may be added to fluids to help correct unresponsive hypokalemia.

2. **Antibiotic therapy.** Broad-spectrum parenteral antibiotics are recommended because of disruption of the mucosal barrier and potential sepsis. Bacteremia is identified in 25% of dogs infected with parvovirus. A combination of ampicillin and gentamicin is recommended. Most veterinarians use only a first-generation cephalosporin in dogs without neutropenia or fever and reserve ampicillin and gentamicin or amikacin for dogs with signs of sepsis. One should be cautious about using an aminoglycoside because of renal toxicity.

3. **Endotoxin-neutralizing products.** Endotoxin-neutralizing products may be administered along with antibiotic therapy. The rationale for their use is based on the large population of gram-negative bacteria; by killing the bacteria, antibiotic therapy may shower the body with endotoxin, thus exacerbating the CPV condition. Studies have shown that endotoxin-neutralizing products decrease the incidence of septic shock. They may be diluted (4 ml/kg) with an equal volume of saline and administered intravenously over 30–60 minutes. Dogs who have recovered from parvovirus infections can be a good source for serum. Serum should be collected within 4 months of infection.

4. **Antiemetics.** Metoclopramide is the drug of choice. Phenothiazine derivatives should be used with caution and only after adequate volume replacement is initiated to avoid severe hypotension. Antiemetics are especially useful when continued vomiting makes it difficult to maintain hydration or electrolyte balance.

5. **Motility modifiers.** The use of motility modifiers is controversial. Anticholinergic antidiarrheal medications may suppress segmental contractions and actually hasten transit time. Narcotic analgesics and synthetic opiates are better choices but should be reserved for severe or prolonged cases because slowing the flow through the intestine may increase toxin absorption.

6. **Nothing per os (NPO).** Begin a slow return to water 24 hours after the animal stops vomiting, and slowly progress to gruel made from a bland diet.

10. What is granulocyte colony-stimulating factor (GCSF)? What role does it have in treating dogs with CPV?

GCSF selectively stimulates release of granulocytes form the bone marrow. Preliminary studies have shown that it reduces morbidity and mortality due to CPV. Unfortunately, it is available only as a human drug and is expensive, but when the positive benefits are considered, its use may be justified.

11. Does interferon benefit a dog with parvovirus infection?

Interferon given parenterally has been shown to be beneficial. The suggested dosage of human recombinant interferon is 1.3 million units/m^2 subcutaneously 3 times/week.

12. How is a dog with CPV monitored?

Monitor respiration and central venous pressure (CVP) to prevent overhydration. With osmotic diarrhea the animal loses protein. If abdominal or extremity swelling is observed or if the total solids drop by 50% from admission values or go below 2.0 gm/dl, the animal should be supplemented with either 6% hetastarch or plasma to maintain colloid oncotic pressures. Blood glucose should be monitored at least 4 times/day on the first two days. Glucose level may drop precipitously and suddenly. Most importantly, weigh the dog at least twice each day. If adequate

crystalloid replacement is provided, body weight does not decrease from initial values. Ideally body weight should increase at a rate comparable to the degree of dehydration originally assessed.

Dogs that can hold down water for 12 hours may be offered a gruel made from bland foods. Most dogs force-fed by hand will vomit. This response may be physical or psychological (association of food with vomiting). Nasogastric tubes seem to help this problem. Metoclopramide speeds gastric emptying, acts as an antiemetic, and decreases gastric distention when added to the liquid diet. Dogs that are not vomiting should be offered food even if the diarrhea has not totally stopped. A low-fat, high-fiber diet is a good choice to stimulate intestinal motility.

13. How do you know when to send a dog home?

The dog should stay in the hospital for 12 hours after it has ingested solid food with no vomiting. Clients should report immediately any vomiting in the next 7 days or refusal to eat for 24 hours. A high-fiber diet is recommended for reducing diarrhea. A recheck appointment in 1 week with a stool sample helps the clinician to assess progress.

14. What recommendations do you offer to clients who have had a CPV-infected animal in their household and now want a new pet?

Prevention involves a proper vaccination regimen, limited exposure to other animals (especially in puppies less than 12 weeks of age), cleaning contaminated areas with bleach (allowing prolonged contact time), and vacuuming all surfaces with which the previous pet came into contact (rugs, carpet, walls, furniture). Newer higher-titer vaccines (some of which may be started as early as 4 weeks) are helpful. Generally, one should wait at least 1 month before bringing the new pet into the home. It is doubtful that the environment (especially outdoors) will ever be completely free of the virus. CPV is a hardy and ubiquitous organism.

15. How long can a dog with CPV be expected to retain immunity?

A dog that has recovered from CPV can maintain life-long immunity.

16. What is the recommended vaccination schedule for dogs? Is it the same for every breed?

Some breeds are more susceptible to CPV than others. Rottweilers, American pitbull terriers, Doberman pinschers, and German shepherds are the most susceptible, whereas toy poodles and Cocker spaniels are less susceptible. The new higher-titer vaccines have a higher antigen level and a more virulent vaccine strain that can overcome maternal antibodies, unlike the older lower-titer vaccines. These vaccines narrow the window of infection, especially for susceptible breeds. The vaccination protocol for the new high-titer vaccines is 6, 9, and 12 weeks. Susceptible breeds should be vaccinated only with the high-titer CPV vaccine and then with a combination vaccine at 6–8, 12, and 16 weeks. For less susceptible breeds, the combination vaccines at 6–8, 12, and 16 weeks should be adequate. Some parvovirus vaccines are approved for use as early as 4 weeks of age.

17. How do you manage a sick puppy when the client is unwilling to pursue hospital treatment for CPV?

CPV can be treated on an outpatient basis. A combination of dietary restriction, subcutaneous fluids, and, in some cases, GI medications may be used with a follow-up appointment in 1–3 days. Outpatient recommendations include the following:

- Small, frequent amounts of fluid
- Bland food
- Oral antibiotics
- Strong recommendation to have the pet reexamined and admitted for therapy if vomiting returns or anorexia persists

Nine of ten clients bring the dog back for inpatient care shortly after taking it home. Before treating an outpatient, remember that mildly depressed dogs may have a rectal temperature of 106° F and a blood glucose of 30 mg/dl in 12 hours or less.

CONTROVERSIES

18. Should a dog with suspected CPV be hospitalized and placed in isolation?

Undoubtedly hospitalization provides the best chance for survival. Isolation is more controversial. In most veterinary hospitals, isolation means that the animal is housed in a section of the hospital that is not staffed at all times. The adage "out of sight, out of mind" has led to the demise of many CPV-infected dogs. Experience with housing dogs with CPV in the critical care unit at the Veterinary Teaching Hospital of Colorado State University has shown that nosocomial infections can be avoided with a common-sense approach to patient management. The animal is placed in the least traveled area and has its own cleaning supplies; gowns and gloves are worn each time the animal is handled; and the animal's cage is kept as clean as humanly possible. These procedures are no different from those in an isolation area. By being housed in an area where constant attention can be given, the animal receives adequate fluid replacement therapy and is monitored for changes, which occur rapidly.

19. How is nutrition provided for vomiting dogs?

Tough question! Dogs that have not eaten for 3–5 days are probably in a negative nitrogen balance, and certainly intestinal villi have undergone atrophy if not already destroyed by the CPV. The sooner patients begin receiving oral nutrition, the more rapidly they will recover. In addition, micronutrient therapy for the intestinal mucosa is required for maintenance of the mucosal barrier. Without this barrier, sepsis and bacteremia are more likely. Unfortunately, the only means to provide micronutrients is the oral route.

Glucose therapy does not provide nutritional support. It is best to think of dextrose as simply a source of water. One liter of 5% dextrose solution contains a mere 170 kcal. Increasing dextrose concentrations beyond 5% usually results in glycosuria and osmotic diuresis.

Patients that have not eaten for several days are primed for fat metabolism; thus, Intralipid (20%) may be added to fluids. It should be administered through a central IV catheter and requires strict aseptic management, which may be difficult if the patient is in an isolation area of the hospital.

For dogs that retain water without vomiting, glutamine may be added directly to the water bowl. Often placing electrolyte solutions in the water bowl is a good way to start the animal drinking. Placing dextrose in these fluids or even using commercial solutions such as Ensure-Plus in the bowl helps to provide intestinal nutrients.

20. Should parvovirus antibody levels be measured to check the immune status of the puppy?

Although antibodies to parvovirus can be measured, a negative titer does not necessarily mean that the dog is susceptible to CPV. Repeated revaccination of antibody-negative dogs usually does not result in significant titers.

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90. INTUSSUSCEPTION

Howard B. Seim, III, D.V.M.

1. What is intussusception?

Intussusception is produced by a vigorous intestinal wall contraction that forces a segment of intestine into the lumen of the adjacent relaxed segment. The invaginated segment is called the *intussusceptum*, and the enveloping segment is called the *intussuscipiens*.

2. What causes intussusception?

The cause of intussusception is unknown. It is considered a sign, not a primary disorder, and is commonly associated with various causes of gastrointestinal upset such as parvovirus infection, severe parasitic infestation, or intestinal obstruction (e.g., foreign body, neoplasia). Spontaneous intussusceptions may be caused by either a local inhomogeneity in a bowel segment (i.e., bowel wall that is either flaccid or indurated) or a mechanical linkage of nonadjacent bowel segments (i.e., pedunculated polyps, linear foreign bodies, or parasites).

3. At what age is intussusception most commonly diagnosed? What segment of bowel is most often affected?

Intussusception generally occurs in animals less than 1 year of age at the ileocecolic junction. Intussusception in older animals is most often due to an intestinal foreign body or mural neoplasm and may occur in any segment of the intestine.

4. List the cardinal clinical signs and physical findings in patients with intussusception.

1. **Vomiting.** Severity of vomiting often depends on location of the intussusception, degree of luminal compromise, and associated disorders (e.g, parvovirus, parasites). In general, the closer the obstruction to the pylorus and the greater the degree of luminal compromise, the more severe the vomiting.

2. **Abdominal pain.** Intussusception is a strangulating obstruction; the degree of strangulation and duration of intussusception play a role in the severity of abdominal pain. In general, as the degree of strangulation and duration of obstruction increase, so does the severity of abdominal pain.

3. **Melena or hematochezia.** When the wall of the intussusceptum is strangulated enough to alter its normal mucosal barrier, hemorrhage may occur in the bowel lumen. Upper intestinal intussusception (i.e., jejunal) may cause melena; lower intestinal intussusception (i.e., ileocecolic) may cause hematochezia.

4. **Palpable abdominal mass.** Intussusception produces an abdominal mass that is easily palpable, sausage-shaped, movable, and mildly painful (depending on degree of strangulation). Young animals have a relatively underdeveloped abdominal musculature, which allows unrestrained abdominal palpation.

5. What about patients with characteristic clinical signs and physical findings that seem to come and go?

Occasionally, animals present with clinical signs and physical findings that are consistent with intussusception but seem to come and go. This pattern may occur in patients with a sliding intussusception. The intussusception intermittently reduces itself, then reinvaginates, allowing clinical signs and physical findings to come and go. Sliding intussusception generally occurs in young animals with associated gastrointestinal disorders (e.g, parvovirus, parasites).

6. How do you definitively diagnose intussusception?

Definitive diagnosis is based on cardinal clinical signs and physical findings along with survey and contrast radiography and ultrasonography. Survey radiographs may reveal gas- and

fluid-filled loops of small intestine proximal to the intussusception and a fluid-dense abdominal mass. Contrast radiographs (i.e., upper GI or barium enema) reveal compression of the contrast column at the intussuscepted segment of bowel. Ultrasonography produces a pathognomonic image of the intussuscepted bowel referred to as the "concentric ring sign."

7. Barium enemas are often the definitive treatment for intussusception in humans. Are they successful in dogs and cats?

No. Barium enemas may be used for diagnostic purposes but are rarely beneficial as a definitive treatment.

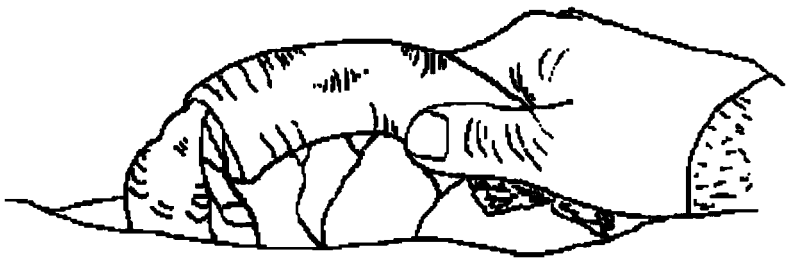
8. What is the presurgical treatment for patients with intussusception?

Preoperative treatments are generally based on presenting clinical signs, physical findings, and results of laboratory data:

1. Patients with severe abdominal pain, profuse vomiting, and bloody mucoid stools (i.e., complete, strangulating obstruction) are generally treated with intravenous fluids (i.e., shock dose), glucose, corticosteroids or flunixin meglumine, and antibiotics; they are taken to surgery as soon as fluid and medications have been given and the cardiovascular system is stable.
2. Patients with mild presenting signs are volume-expanded and taken to surgery as soon as an operating room becomes available.

9. How do you reduce an intussusception?

Reduction is attempted by grasping the intussuscipiens and squeezing out the intussusceptum as if you were squeezing a sausage from its casing. Care is taken to place minimal, if any, traction on the intussusceptum because traction forces are transmitted along the invaginated mesenteric blood supply of the intussusceptum.



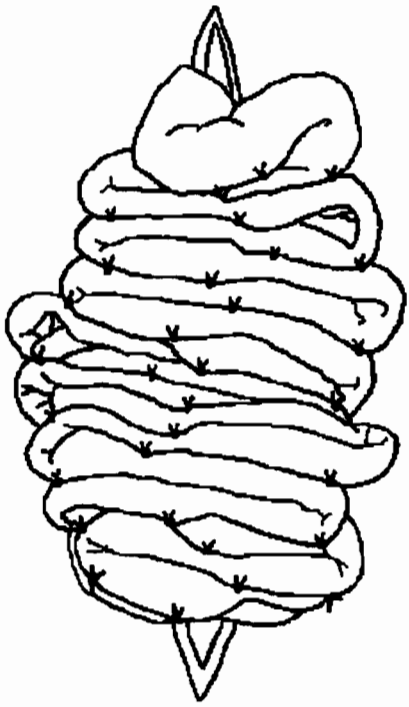
Reducing an intussusception at surgery.

10. If the intussusception does not reduce without causing seromuscular tears, what is the proper course of action?

Consider intestinal resection and anastomosis. Forced reduction of adhered, strangulated bowel may release sequestered endotoxins into the peritoneal cavity and systemic circulation. In addition, forced reduction may cause intestinal perforation and peritoneal leakage of intestinal contents.

11. If the intussusception is successfully reduced, viable bowel is present, and no cause is identified, what is the proper course of action?

Consider enteroplication. The recurrence rate of intussusception is reported to be as high as 27%. Enteroplication is performed by suturing the seromuscular layers of duodenum, jejunum, and ileum in an organized, plicated fashion (see figure at top of next page). Enteroplication effectively prevents recurrence of intussusception.



Enteroplication to prevent recurrence of intussusception.

12. If the intussusception is successfully reduced and bowel wall viability is questionable, what is the proper course of action?

The most reliable criteria for surgical assessment of small intestinal viability include color, peristalsis, arterial pulsations, and intravenous fluorescein dye injection. Intravenous fluorescein dye has been shown to be > 95% accurate for predicting bowel wall viability vs. nonviability. If the bowel wall is viable, replace the affected intestine and close routinely. If the bowel wall is nonviable, perform intestinal resection and anastomosis.

13. If the intussusception is successfully reduced and a foreign body or neoplasm is found, what is the proper course of action?

Perform an enterotomy (for a foreign body, pedunculated polyp, or intestinal biopsy) or anastomosis (i.e., foreign body causing strangulation or mural neoplasm) to remove the cause of the intussusception. Then perform enteroplication of the remaining bowel to prevent reoccurrence of the intussusception (see question 11).

14. The ileocecocolic junction is the most common location for intussusception in young dogs. What is the consequence of removing the ileocecocolic valve?

If bowel resection results in removal of the ileocecocolic valve, malabsorption syndrome and chronic diarrhea may result. The valve functions to control bacterial numbers in the small and large bowel. The small bowel has a relatively low bacterial count, whereas the large bowel has a high bacterial count. If the valve is removed, reflux of bacteria from the colon into the ileum may occur. Overgrowth of bacteria in the small intestine results in increased deconjugation of bile acids and hydroxylation of dietary fatty acids as well as production of bacterial metabolites toxic to epithelial cells. The absorptive capacity of the epithelial cells is then decreased, resulting in malabsorption. The toxic effect on villi results in inflammation and edema, causing fluid secretion into the lumen and further malabsorption that results in chronic diarrhea. Treatment with intestinal antibiotics may help to control the overgrown bacterial population in the small bowel. Most patients eventually adapt to this overgrowth. Chronic antibacterial therapy is rarely needed.

15. What suture patterns are considered acceptable for performing intestinal anastomosis in dogs and cats?

1. Simple continuous appositional sutures
2. Simple interrupted apposing sutures
3. Simple interrupted crushing sutures

16. What suture material and needles are recommended for intestinal surgery?

- Suture material: synthetic monofilament absorbable, monofilament nonabsorbable, and synthetic multifilament absorbable
- Suture size for dogs: 3–0 to 4–0; for cats: 4–0 to 5–0
- Needle: swaged-on taper point, taper-cut, or reverse cutting

CONTROVERSY

17. Is it necessary to perform enteroplication in patients that have a surgically treatable cause of the intussusception (i.e., foreign body, neoplasm)?

For: Because recurrence of intussusception is relatively high (i.e., 27%) and a second exploratory procedure is needed to reduce or repair the recurring intussusception, it seems justified to perform a prophylactic enteroplication. In addition, enteroplication does not cause abnormal side effects such as diarrhea, vomiting, weight loss, anorexia, or hyporexia.

Against: The inciting cause of the intussusception has been identified and treated. It seems unwise to perform a second procedure that is necessary in only 27% of patients. In addition, enteroplication increases total operating time and potentially jeopardizes an already debilitated patient.

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91. COLITIS

Wayne E. *Wingfield*, M.S., D.V.M.

1. What is the typical signalment for acute colitis?

- German shepherds and golden retrievers are the most commonly affected breeds.
- 1–4 years old is the most common age.
- Males are more commonly affected than females (3:2).

2. What are the common clinical signs of acute colitis?

- Diarrhea or soft stool (watery, mucus, fresh blood, frequent small amounts)
- Tenesmus
- Normal appetite with little or no weight loss
- Vomiting (30%)
- Abdominal pain

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3. What is the typical scenario for a nosocomial clostridial infection?
Acute, bloody diarrhea beginning 1–3 days after exposure to a veterinary hospital.

4. What are the possible causes of acute colitis?
The cause of acute colitis is usually unknown, but the following possibilities should be considered:

1. Mucosal injury by a foreign body or trauma
2. Infection
   - Parasitic (whipworms [*Trichuris* sp.])
   - Bacterial (*Salmonella, Campylobacter, Clostridium* spp.)
   - Fungal (histoplasmosis)
3. Systemic disease (especially uremia)

5. What differential diagnoses should be considered in patients suspected of acute colitis?

1. Other gastrointestinal problems
   - Chronic colitis
   - Neoplasia (adenocarcinoma, lymphoma, leiomyosarcoma, polyp)
   - Ileocolic intussusception
   - Cecal inversion
   - Irritable colon (diagnosis by exclusion)
   - Rectal stricture
   - Perianal fistula
   - Uremic ulcers
2. Painful abdomen
   - Hemorrhagic gastroenteritis (HGE)
   - Viral enteritis
   - GI foreign bodies
   - Bowel ischemia due to thrombi
   - Intestinal volvulus
   - Pancreatitis
   - Hepatobiliary problems
   - Urologic disorder (renal calculi, pyelonephritis, urinary tract infection)
   - Peritonitis (ruptured abdominal organ, sepsis)
   - Splenic torsion
   - Genital problems (uterine torsion or rupture, testicular torsion, prostatic abscess)
3. Thoracolumbar pain

6. Which diagnoses are most commonly confused with acute colitis?

- Neoplasia (adenocarcinoma, lymphoma, leiomyosarcoma, polyps)
- Rectal stricture

7. What are the most common physical findings?

1. Physical examination is usually normal.
2. Deep palpation may or may not produce abdominal pain.
3. Rectal examination may be painful and show fresh blood and mucus.

8. How do you approach the diagnosis of acute colitis?

- Rectal examination
- Fecal flotation for ova or parasites
- Direct and stained fecal smears
- Fecal culture
- Routine laboratory evaluation (complete blood count, biochemical profile, urinalysis)
- Abdominal radiographs and barium enema

- Colonoscopy
- Mucosal biopsy via colonoscopy

9. Describe the appropriate symptomatic treatment.

1. Withhold food for 24–48 hours or until diarrhea resolves. If lymphocytic-plasmocytic enteritis is suspected, withholding food will not resolve the problem.
2. Give crystalloid fluids with potassium chloride.
3. Give medication to decrease fecal water and increase colonic motility (loperamide).

10. What cause-specific treatments may be used for acute colitis?

- Correction of underlying cause if known (e.g., foreign body removal)
- Reduction of clostridial overgrowth (tylosin preferred; also metronidazole)
- Treatment of inflammatory bowel disease (i.e., chronic colitis) with tylosin, mesalazine, sulfasalazine (oral, enema, or foam), or prednisone (antiinflammatory doses)
- High-fiber diet (often supplemented with Metamucil)

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XI. Reproductive Emergencies

Section Editor: Lori A. Wise, D.V.M., M.S.

92. PYOMETRITIS

Donald A. Ostwald, Jr., D.V.M.

1. What is pyometritis?

Pyometritis is the accumulation of pus within the lumen of the uterus. It is one of the few life-threatening conditions of the female reproductive tract. The resulting extragenital effects may include shock, septicemia, toxemia, glomerulonephritis that leads to renal dysfunction, and uterine rupture with secondary peritonitis. Pyometras are loosely defined as open-cervix or closed-cervix based on the amount of vaginal discharge, which depends in part on the degree of cervical patency. Many animals presenting with slight-to-no vaginal discharge (closed pyometras) are in a more advanced stage of disease and often in more serious clinical condition. Pyometritis has been reported in many species, including dogs, cats, rabbits, ferrets, and guinea pigs.

2. How are progesterone and estrogen involved in the pathogenesis of pyometritis?

Cystic endometrial hyperplasia results from an inappropriate response of the endometrium to progesterone. Pyometritis develops when opportunistic bacteria from the vagina (most commonly *Escherichia coli*) ascend into a uterus affected by cystic endometrial hyperplasia. Progesterone also suppresses the local immune system, stimulates the endometrial glands to provide secretions favoring bacterial growth, decreases myometrial contractility, and closes the cervix, preventing drainage of the ensuing uterine exudate. The endometrial hyperplasia caused by progesterone occurs with or without estrogen. Estrogen, however, profoundly increases the severity by increasing the number of progesterone receptors in the endometrium. Thus pyometritis develops in 25% of bitches given estradiol as an abortifacient (mismate shot) during diestrus. The incidence of pyometritis is lower in queens than in bitches because queens are induced ovulators and therefore progesterone usually is secreted only after mating.

3. Describe the presenting signs and symptoms of pyometritis.

Pyometritis is more common in middle-aged to older females that have had an estrus within 2 months before the onset of clinical signs. Presenting complaints include vulvar discharge, lethargy, anorexia, vomiting, polydipsia/polyuria, and weight loss. The most common physical findings include vulvar discharge, abdominal distention, enlargement of the uterus, and dehydration. A fever is present in less than one-third of the cases. Vulvar discharge may be less obvious in cats because of their fastidious grooming habits.

4. Explain why polyuria with polydipsia is a common symptom.

Approximately 50% of dogs with pyometritis present with polyuria/polydipsia. These renal manifestations are poorly understood but may result from prerenal azotemia secondary to dehydration and/or shock; antigen–antibody complex glomerulopathy; endotoxin interference with renal tubular function (renal diabetes insipidus); or a combination of the above. Although many dogs with pyometritis develop renal dysfunction, few have lesions severe enough to produce renal failure.

5. List the differential diagnoses for pyometritis.

- Pregnancy
- Fetal abortion
- Postpartum endometritis
- Normal estrus
- Vaginitis
- Vaginal neoplasia
- Renal failure
- Diabetes mellitus
- Hepatic failure
- Hypoadrenocorticism

6. How is pyometritis diagnosed?

Diagnosis is strongly suggested by a history of recent estrus and a clinical presentation of vaginal discharge. Laboratory findings include leukocytosis with a left shift and mild-to-moderate normocytic, normochromic anemia. Some patients may be consuming white blood cells and present with a leukopenia. Serum alkaline phosphatase levels are elevated in 50–75% of the bitches. Azotemia is seen in fewer than one-third of the cases. Most bitches with pyometritis present with concurrent urinary tract infections.

7. What is the role of ultrasound in diagnosing pyometritis?

Although abdominal radiographs may reveal an enlarged uterus, they cannot distinguish between pyometritis and a gravid uterus in the first two trimesters (before fetal calcification is detectable). Ultrasonography is the best tool to demonstrate uterine enlargement and to visualize uterine contents.

8. How do you treat a patient with pyometritis?

Treatment of pyometritis should be prompt and aggressive. Intravenous fluid therapy should be administered first to correct dehydration, improve renal function, and maintain adequate tissue perfusion. Intravenous, broad-spectrum, bactericidal antibiotics should be administered until culture and sensitivity results are known. Surgical ovariohysterectomy is the recommended treatment for pyometritis unless the owner strongly desires to breed the animal.

9. When should you perform surgery?

According to an old adage, don't let the sun set on a pyometra. Surgical removal of the uterus should be performed within 6–12 hours or even sooner if the uterus is thought to have ruptured. Patients should be stabilized before surgery. Dehydration, azotemia, hypotension, shock, acid-base imbalance, and electrolyte abnormalities should be corrected before anesthesia.

10. Is there a medical alternative to surgery?

Yes. Open-cervix pyometras have been successfully treated with prostaglandin F_2-alpha (PGF_2-alpha) and long-term, broad-spectrum antibiotics. Medical treatment of pyometritis with PGF_2-alpha should be reserved for clinically stable bitches who will be bred in the next heat cycle. A closed-cervix pyometra should be treated cautiously with PGF_2-alpha because of the greater risk of rupturing the uterus. Natural PGF_2-alpha (Lutalyse) is given at a dose of 0.05–0.25 mg/kg subcutaneously once or twice daily for 3–5 days. Synthetic PGF_2-alpha (Fluprostenol, Cloprostenol) is more potent than natural PGF_2-alpha and should not be used. PGF_2-alpha is not labeled for use in small animals in the United States, and informed consent should be obtained before it is used.

11. Describe the methods of action of PGF_2-alpha.

PGF_2-alpha stimulates uterine motility, forcing the excretion of uterine contents through the cervix. Its relaxing effects on the cervix are inconsistent; therefore, its use is restricted to treatment of open-cervix pyometras. Because PGF_2-alpha is luteolytic, it reduces progesterone levels in both bitches and queens. In bitches, however, the luteolytic effect may not be a factor in treatment because it occurs late in diestrus. The response to PGF_2-alpha likely depends on underlying uterine pathology rather than dosage. The lower dose should be used first and increased only if there is no initial response.

12. What are the side effects of PGF_2-alpha?

Side effects of PGF_2-alpha include panting, salivation, vomiting, defecation, and micturition. These effects are transient and disappear within the first hour after treatment. Subsequent injections result in progressively less severe side effects.

13. What is the prognosis for pyometritis?

The prognosis for surgical treatment of pyometritis is good for patients surviving the perioperative period. Medical management of open-cervix pyometras with prostaglandins resolves clinical signs and illness in over 90% of bitches and queens. Breeding during the next estrus after treatment should be recommended strongly. More than 70% of bitches successfully treated with PGF_2-alpha redevelop pyometritis within 2 years. Fewer than 30% of patients with closed-cervix pyometras recover when treated with prostaglandins.

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93. PARAPHIMOSIS

Adam J. Reis, D.V.M.

1. What is paraphimosis?

Paraphimosis is the inability of a male animal to retract the penis into normal position within the prepuce.

2. With what is paraphimosis most commonly associated?

Paraphimosis is most commonly associated with the formation of a constrictive band of preputial hair that becomes wrapped around the base of the penis during coitus.

3. What are the clinical signs of paraphimosis?

Engorged penis protruding from the prepuce
Excessive licking of the exposed penis
Drying or necrosis of the exposed penis
Stranguria, hematuria, and anuria

12. What are the side effects of PGF_2-alpha?

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4. What factors predispose to paraphimosis?

The following factors, in conjunction with sexual excitement, often precede the development of paraphimosis:

- Reduced size of the preputial opening secondary to congenital malformation or trauma
- Penile strangulation caused by preputial hair or foreign bodies (e.g., string or hair)
- Penile swelling secondary to trauma, infection, neoplasia, or priapism
- Chronic balanoposthitis

5. What other conditions are associated with paraphimosis?

Paraphimosis has been reported as a sequel to inefficient preputial muscles, which result in the inability of the prepuce to be pulled forward to cover the penis. The condition is unrelated to stenosis of the preputial opening, erection, or coitus.

6. How is abnormal preputial muscle function corrected?

Surgical correction can be achieved by shortening both preputial muscles

7. Describe the pathophysiology of paraphimosis.

The pathophysiology of paraphimosis is related to the blood flow dynamics of the penis. Paraphimosis results from a decrease or blockage of venous drainage of the engorged penis that prevents shrinkage and retraction into the prepuce. Prolonged exposure eventually causes desiccation, trauma, and necrosis, which increase existing swelling, tighten constrictive forces, and further inhibit venous drainage and retraction.

8. What other conditions may appear similar to paraphimosis?

- Chronic priapism
- Paralysis of the retractor penis muscles
- Malformation or fracture of the os penis
- Abnormally large preputial opening
- Congenital shortening of the prepuce

9. How is paraphimosis differentiated from similar-appearing conditions?

Differentiation is often made by a good history. Paraphimosis is acute in onset and associated with coitus, whereas similar-appearing conditions are often chronic.

10. What advice can you give to owners over the telephone to prevent further damage before presentation?

- Do not let the dog lick or bite his penis.
- Lubricate the penis with jelly or ointment.
- Keep the dog calm and quiet.

11. How do you treat paraphimosis?

Dogs that present with paraphimosis are in pain, agitated, and potentially in shock. Cardiovascular status must be evaluated and addressed first. Sedation or general anesthesia is required for replacement of the penis. Before manipulation, the exposed penis should be cleansed, freed of hair and foreign material, debrided if necessary, and generously lubricated. Gentle manipulation is often all that is required to replace the penis in its proper position. Cold packs and hyperosmotic solutions help to reduce swelling and ease replacement. A ventral preputial incision may be required to replace the penis. If penile viability is in question, a Doppler examination may be used to search for active blood flow.

12. What are the potential sequelae of paraphimosis? How can they be prevented or treated?

- Penile necrosis and urethral obstruction are the most serious sequelae. Penile resection and urethrotomy are required in cases of necrosis and urethral obstruction.

- Preputial adhesions to the penis also may occur. Adhesions are best prevented by daily extrusion of the penis and infusion of steroid/antibiotic ointments into the prepuce.

13. How can recurrence of paraphimosis be prevented?

- Correct congenital malformations
- Address underlying musculoskeletal or neurologic problems
- Preputial hygiene and regular trimming of preputial hair
- Castration

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94. ECLAMPSIA

Teresa Dye, D.V.M.

1. What is eclampsia?

Eclampsia is a hypocalcemic tetany associated with pregnancy in bitches or queens.

2. What other terms are used for eclampsia?

- Puerperal tetany
- Lactation tetany
- Periparturient hypocalcemia

3. Are certain animals predisposed to eclampsia?

Eclampsia is seen most commonly in small-breed dogs and is uncommon in cats and large-breed dogs. Bitches with a previous history of eclampsia may have recurrence with subsequent litters.

4. What are the common causes of the hypocalcemia associated with eclampsia?

Calcium is lost to fetuses during gestation and through milk during lactation. Improper perinatal nutrition may result in limited calcium intake. The stress of lactation may result in a decreased appetite and poor intake of calcium even when an adequate diet is provided. Excessive supplementation of calcium during gestation may lead to atrophy of the parathyroid gland and inhibit release of parathyroid hormone, thus interfering with mobilization of calcium stores and utilization of dietary calcium after parturition. Metabolic factors, such as alkalosis, that promote

- Preputial adhesions to the penis also may occur. Adhesions are best prevented by daily extrusion of the penis and infusion of steroid/antibiotic ointments into the prepuce.

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increased protein binding of calcium and therefore decreased levels of ionized calcium also may contribute to development of eclampsia.

5. What are the clinical signs of eclampsia?

Initial signs of eclampsia are restlessness, anxiety, irritability, and panting. These signs may progress within minutes to hours to early signs of tetany, including hypersalivation, stiffness of gait, and ataxia. Severe tetany is characterized by tonic-clonic muscle spasms, which may be provoked by auditory or tactile stimuli, recumbency, and seizures. Such signs are generally accompanied by tachycardia, miosis, and pyrexia. Death may result from severe respiratory depression, hyperthermia, and cerebral edema.

6. What is the pathophysiology of eclampsia?

Hypocalcemia alters cell membrane potentials, allowing spontaneous discharge of nerve fibers and induction of tonic contractions of the skeletal muscles. Both degree of hypocalcemia and rate of decline in calcium level determine the onset and degree of clinical signs.

7. When does eclampsia occur?

Eclampsia is typically seen within the first 2 weeks postpartum but also may occur in late pregnancy or during parturition when hypocalcemia may be a contributing factor to uterine inertia.

8. How is eclampsia diagnosed?

Diagnosis is typically based on history, clinical signs, and response to treatment. Pretreatment calcium level should be assessed, but treatment should not be delayed for laboratory confirmation. Serum calcium levels are usually less than 7 mg/dl. Serum glucose levels also should be evaluated for concurrent hypoglycemia.

9. What is the initial treatment for eclamptic patients?

Treatment consists of slow (over 15–30 minutes) intravenous infusion of 10% calcium gluconate to effect. A total dose of 2–20 ml may be required. Heart rate and electrocardiogram should be monitored during infusion. If bradycardia or arrhythmias develop, the infusion is discontinued until the heart rate and rhythm normalize and is then resumed at one-half of the initial infusion rate. The initial required dose of calcium gluconate can be diluted with an equal volume of saline and injected subcutaneously to prevent recurrence of clinical signs. Once the animal is stable, oral calcium carbonate supplementation is initiated. Concurrent hypoglycemia, hyperthermia, and cerebral edema should be treated if present. Corticosteroids should be avoided because they lower serum calcium levels through promotion of calciuria, decreased intestinal absorption of calcium, and inhibition of osteoclasis.

10. What is the expected response to treatment?

The clinical signs should regress immediately after correction of hypocalcemia. If clinical signs do not resolve despite calcium infusion, diazepam or phenobarbital may be used to control seizures. Other causes for seizure activity should be considered, including concurrent hypoglycemia, cerebral edema, toxicosis, or primary neurologic disorder.

11. What instructions are given for the patient at the time of discharge from the hospital?

The patient should be placed on oral supplementation with calcium carbonate tablets, 100 mg/kg, divided into 3 doses/day. Over-the-counter antacid products may be used to provide calcium carbonate. A well-balanced growth formula diet should be fed. The diet should contain at least 1.4% calcium in the dry matter.

Puppies older than 3 weeks should be weaned. If puppies are younger, they may be allowed to nurse but should be supplemented with hand-feeding to reduce lactational demands on the bitch. If a relapse occurs, puppies should be weaned, regardless of age, and hand-fed.

12. What steps can be taken to prevent development of eclampsia in pregnant bitches?

A balanced growth formula diet should be fed during the second half of gestation and through lactation. Calcium should not be supplemented during gestation but may be desirable during lactation in bitches with a previous history of eclampsia. Calcium carbonate may be used at a dosage 100 mg/kg, divided into 3 doses/day.

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95. DYSTOCIA

Adam J. Reiss, D.V.M.

1. What is dystocia?

A dystotic animal is unable to expel fetuses from the uterus.

2. What are the stages and signs of eutocia (normal parturition)?

Stage 1. Stage 1 consists primarily of behavioral changes. The commonly seen signs are restlessness, nesting, panting, and shivering. Such signs may occur up to 48 hours before parturition but are not reliable indicators of parturition.

Stage 2. The second stage of labor consists of strong, externally visible contractions that result in expulsion of the fetus through the birth canal. This stage may last up to 24 hours in large canine litters and up to 36 hours in cats.

Stage 3. The passage of the placenta is the hallmark of the third stage of labor. Stages 2 and 3 may occur alternatively. Stage 3 may not be observed if the bitch or queen is allowed to ingest the placenta. This stage is completed with uterine involution.

3. What common signs may help pet owners and veterinarians to recognize a dystotic animal?

- Prolonged gestation (concern should be raised in dogs and cats after the 68th day of gestation, as determined by the last breeding date)
- No active stage 2 labor within 24 hours of temperature drop below 100°F
- Visible abdominal contractions for 30 minutes or more without passage of a fetus
- Visible fetal membranes for 15 minutes or longer
- Weak, nonproductive abdominal contractions for 4 hours after onset of stage 2 labor
- More than 3 hours between puppies without signs of labor
- Abnormal vulvar discharge (foul-smelling, purulent, green, without production of a puppy or kitten)
- Crying or biting of flanks or vulvar area, with repeated attempts to urinate

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- Crying or biting of flanks or vulvar area, with repeated attempts to urinate

- Depressed or obtunded bitch or queen
- Failure to deliver all puppies in 24 hours or all kittens in 36 hours

4. What is the most reliable and available indicator of impending parturition?

The most reliable and available indicator of impending parturition is a drop in body temperature below 100°F (97–99°F). This drop usually occurs within 24 hours of parturition. Owners should monitor temperature twice daily for the last 7–10 days of the predicted date. Temperature drop in the queen is not as reliable an indicator as in the bitch.

5. Are there any unreliable indicators of parturition?

Nesting behavior, mucoid vaginal discharge and lactation have been described as unreliable indicators of impending parturition. Milk secretion may begin 1–2 weeks prior to birthing, and vaginal discharge and nesting behavior may occur days before the onset of labor.

6. What steps should be taken to diagnose a dystotic animal?

1. Obtain a complete history. Important questions to ask:
   - When is the predicted date of parturition?
   - What was the last breeding date?
   - Was vaginal cytology done?
   - What was the first day of diestrus?
   - What signs of labor have you seen?
   - How long ago were they observed, and how long did they last?
   - When was the last puppy delivered?
   - Has the bitch or queen had dystocia previously? If so, how was she treated?
   - Did you record a temperature drop?
2. Perform a complete physical exam. Address dehydration, shock, and toxemia quickly. Perform a sterile vaginal exam and relieve obstructions, if possible.
3. Take abdominal radiographs (two views). Abdominal radiographs may be helpful and do not harm the fetuses. Gestational length (fetal calcification at 45 days), number in litter, orientation, size of the fetus vs. size of the birth canal, and fetal viability can be assessed. Radiographic evidence of fetal death includes gas in the uterus, overlapping of skull and spinal bones, fetal bone resorption, and abnormal positions.

7. What is the correct terminology to describe fetal position when viewed radiographically?

- **Presentation** indicates the relation of the long axis of the fetus to that of the bitch. Presentation can be described as anterior, posterior or transverse. Both anterior and posterior presentations are normal in the bitch.
- **Position** describes which surface of the uterus the fetal vertebral column is in contact with. Terms used to indicate position include dorsal, ventral, right or left lateral, and oblique. The dorsal position is normal.
- **Posture** refers to the location of the head and extremities of the fetus. Only the fully extended posture is normal.

8. How is fetal viability best determined?

Fetal viability is best determined by ultrasonographic identification of a heartbeat.

9. Are veterinary obstetrical devices available to monitor fetal distress and uterine activity during parturition?

Yes. The Veterinary Division of Biomedical Systems (888-717-2341) has both fetal heart monitors (Doppler) and uterine activity monitors available for practitioners to lease or purchase. Remote interpretation of data is offered with these monitors and can be used to detect the onset of labor, abnormal uterine activity associated with dystocia, and fetal distress.

10. Once the animal has been diagnosed as dystotic, how is the type of dystocia classified?

Dystocia can be broadly divided into maternal (60–75%) and fetal causes (25–40%). Dystocia of maternal origin may be divided into anatomic, physiologic (primary uterine inertia), or combined (secondary uterine inertia) anatomic and physiologic etiologies.

Uterine inertia (failure of the uterine musculature to expel the fetus with an open birth canal) is the physiologic cause of dystocia. Primary uterine inertia also may be divided into two groups, complete and partial. Animals suffering from complete primary uterine inertia do not reach the second stage of labor. Animals experiencing partial primary uterine inertia reach the second stage of labor, but attempts to expel the fetus are weak and unsuccessful.

Anatomic causes imply obstruction of the birth canal. Birth canal obstructions may be due to narrowing of the pelvis (congenital or acquired), uterine malposition, mass lesions, vaginal stricture or bands, and vulvar hypoplasia and mucosal hyperplasia.

Secondary uterine inertia is a combination of anatomic and physiologic causes. Persistent uterine contractions against a closed or obstructed birth canal result in exhaustion of the uterine musculature and secondary inertia.

Fetal causes of dystocia include oversized fetus (single pup litters), developmental abnormalities (monsters, ascites, hydrocephalus, and hydropic conditions), faulty orientation, deficiency of fetal fluids, and fetal death.

11. Why is it important to know the underlying cause of dystocia?

It is essential to know the underlying cause to determine the best course of therapy. Ecbolic drugs, such as oxytocin, administered to animals with obstructive causes of dystocia may lead to uterine rupture and placental separation, resulting in fetal death.

12. What types of dystocia are most likely to respond to medical therapy? What is the best course of medical treatment?

All nonobstructive causes or obstructive dystocias that respond to manual manipulation or episiotomy can be addressed medically. It has been reported that 60–70% of medically managed dystocias require surgical intervention. Animals that are toxic should not receive medical management for dystocia but should be stabilized first.

Most authors recommend the use of oxytocin, 10% calcium gluconate, and dextrose in various combinations and dosages. No single combination is necessarily right or wrong. Oxytocin should be administered initially at a dose of 1.1–2.2 U/kg IM, with the dosage not to exceed 20 U. This dosage may be repeated at 30-minute intervals as long as it is working. Oxytocin also may be administered intravenously (10 U of oxytocin per liter of fluids). The initial fluid rate of oxytocin should be slow, 1/8–1/4 maintenance. The rate of administration should be adjusted every 15–30 minutes until effective abdominal contractions are visualized.

If no response is seen after 2–3 repeated dosages of oxytocin, 10% calcium gluconate and/or dextrose should be administered intravenously. Ten percent calcium gluconate may be administered at a dosage of 1cc/3–5 kg of body weight. Calcium should be given slowly, and the animal's heart rate and rhythm should be monitored during administration. Dextrose also may be added to the treatment regimen. The recommended dosage of 50% dextrose is 0.5 ml/kg, which should be diluted minimally (1:1) with sterile saline before administration. If oxytocin is given intravenously, it may be added to a liter of 5% dextrose.

If productive abdominal contractions are not stimulated by the above protocols surgical intervention should be pursued.

13. Can oxytocin be overdosed?

Yes. If the IM dose of oxytocin is too large or if the rate of IV administration is too fast, tetanic uterine contractions result. Such contractions do not contribute to expulsion of the fetus and may lead to uterine tears and placental separation. Tetanic uterine contractions appear as extremely strong, intense contractions persisting for several minutes or longer. Oxytocin dosages must be decreased by at least 50% before normal contractions will return.

11. What other ecbolic drug is available? What are its advantages and disadvantages?

Ergonovine maleate is the other available ecbolic drug. The recommended dose is 0.125–0.5 mg/15 kg IM or PO. Advantages include longer duration of action, stronger uterine contractions, and less cervical contraction than oxytocin. The advantages also may be disadvantages; overdose is more likely as well as uterine rupture.

13. What are the indications for cesarean section?

- Uterine inertia not responsive to medical management
- Pelvic or vaginal obstruction nonamenable to manipulation
- Fetal oversize
- Fetal death
- Planned surgery
- Malpresentations not amenable to correction
- Fetal monstrosities
- Deficiency or excess of fetal fluids

14. What preanesthetic protocols may be instituted to ensure maternal and fetal survival?

The goal should be to minimize the time from anesthetic induction to removal of the fetuses. The following suggestions may help:

- Prepare surgical site prior to induction.
- Preoxygenate to prevent maternal and fetal hypoxia. Because of the physical and physiologic changes of pregnancy, maternal lung volumes, diaphragmatic function, and oxygen-carrying capability may be decreased, whereas oxygen consumption is increased.
- Fluid therapy. Dehydration and shock should be corrected before anesthesia. Removal of the uterus from the peritoneal cavity during surgery results in a large increase in vascular space and potential secondary hypovolemia.
- Drug dosages. Pregnant animals are prone to overdosage because they have decreased requirements based on weight. Anesthetics should be administered in titrated doses until the desired effect is achieved. Most drugs cross the placenta to the fetus, which has immature organ systems; thus, drug excretion is prolonged.

15. The most controversial issue related to dystocia is the anesthetic protocol used during cesarean section. Which anesthetic drugs are right, and which are wrong?

Many anesthetic protocols are available for pregnant animals; no single protocol is right or wrong. Each method has advantages and disadvantages. Factors in deciding which protocol to use include condition of the animal, expertise and familiarity of the practitioner, and availability of certain drugs. The three basic approaches are as follows:

1. Administration of a tranquilizer and subsequent local block
2. Use of epidural regional anesthesia with or without sedation
3. Use of general anesthesia

Although local and epidural blocks have minimal effects on the fetus, many animals require sedation or tranquilization to ensure their cooperation and to provide some degree of visceral anesthesia. All sedatives and tranquilizers cross the placental barrier, but narcotics depress the central nervous system and respiratory function of the fetuses. A combination of narcotic and tranquilizing agents to produce neuroleptanalgesia may be a useful supplement to regional techniques as well as appropriate premedication for general anesthesia.

16. What anesthetic combinations are commonly used?

- Acepromazine (0.05–0.1 mg/kg) with morphine (0.1–0.2 mg/kg) or oxymorphone (0.025–0.05 mg/kg) IV
- Butorphanol (0.45 mg/kg) with diazepam (0.45 mg/kg) IM

For both combinations reversal agents are available, such as naloxone for opioids and flumazenil for benzodiazepines. Because both combinations may result in severe hypotension, animals

should receive intravenous fluids simultaneously. Other drugs, such as propofol and etomidate, are useful but should be used only by practitioners with experience in their administration.

Lidocaine used for local anesthesia in doses that exceed 5 mg/kg may result in systemic toxicity. Bupivacaine (1 ml/3.5 kg) and/or morphine (0.1 mg/kg) may be administered epidurally to provide regional anesthesia.

Halothane and isoflourane may be delivered with or without preanesthetics. Inhalant anesthetics are generally considered the safest for bitches or queens, and fetal exposure to sedatives, tranquilizers, and narcotics may be avoided. Although these anesthetic agents are fairly safe, standard protocols should be followed—i.e., premedication with anticholinergics and intravenous fluids.

17. What are the advantages and disadvantages of each of the above anesthetic protocols?

The advantage of a local block is its minimal effect on the fetus. The disadvantages are the need for concurrent tranquilization, possible systemic effects of the drug, and lack of visceral anesthesia. Epidural anesthesia does not affect the fetus and provides better visceral analgesia and immobilization of the hind end than local blocks. The disadvantages of epidural anesthesia include difficulty of technique, regional vasodilatation, and subsequent hypotension and need for tranquilization. The main advantages of general anesthesia include ease of administration, avoidance of fetal exposure to narcotics and tranquilizers, rapid recovery, and complete analgesia and immobilization. Disadvantages include depression of the fetus and dam, restraint during induction, and possible catecholamine release during the excitement stage.

18. What breed or type of pregnancy has increased susceptibility to dystocia?

Dystocia has been reported in almost all breeds of dog. The most common include miniature and small breeds and dogs with large heads and wide shoulders. The breeds at increased risk include chihuahuas, dachshunds, Pekinese, Yorkshire terriers, miniature poodles, Pomeranians, bulldogs, pugs, Boston terriers, and Scottish terriers. Persians have been reported to have an increased incidence of dystocia. In addition, primigravid, single-pup litters have been reported to have a higher incidence of dystocia. Single fetal litters are suspected to contribute to dystocia by allowing increased fetal size and inadequate fetal hormonal stimulation to initiate parturition.

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96. ABORTION

Lori A. Wise, D.V.M., M.S.

1. How common are abortions in dogs and cats?

The true incidence of abortion is unknown because early fetal resorption may occur in animals not known to be pregnant. In addition, cats and dogs may consume aborted fetuses before they are noticed by the owner.

2. What are the common causes of abortion?

Causes can be divided into three main categories:

1. Fetal problems: abnormalities of development or chromosomal defects.

2. Maternal problems: systemic diseases such as uterine disease (infection, neoplasia, cystic endometrial hyperplasia), hypoluteoidism, or failure to maintain progesterone levels above 2.0 ng/ml, hypothyroidism in bitches, nutritional deficiencies, or exposure to certain drugs or compounds.

3. Infectious agents: *Brucella canis, Escherichia coli,* streptococci, canine herpesvirus, canine parvovirus, canine distemper virus, *Mycoplasma* sp., *Ureaplasma* sp., *Campylobacter* sp., *Toxoplasma gondii, Neospora caninum* in bitches; panleukopenia, feline leukemia virus infection, rhinotracheitis, toxoplasmosis, and various bacteria in queens.

3. What medications may cause abortion in dogs or cats?

Corticosteroids have been incriminated in bitches as well as doxorubicin, methotrexate, xylazine, and misoprostol. In general, try to avoid giving any medications or vaccinations during pregnancy.

4. What signs may indicate impending abortion?

The animal may vomit; become anorectic, listless, or febrile; show abdominal pain; or have abdominal contractions. A vaginal discharge that is purulent, bloody, black, dark green, or fetid is abnormal and may signify abortion. A portion of a litter may be aborted, with viable fetuses remaining.

5. Should anything be done to manage an animal that may be aborting?

The animal should be evaluated, and a thorough reproductive history should be taken. Include breeding dates, results of previous pregnancies, vaccination history, results of *Brucella* sp. testing, and information about diet, husbandry, and medications. Complete laboratory evaluation should include a complete blood count, biochemical profile, urinalysis, thyroid hormone level, and serologic tests for *Brucella canis, Toxoplasma gondii,* and canine herpesvirus. Plasma may be collected for a progesterone level. The progesterone level will drop once abortion has occurred but should not be low at the time of abortion. Exercise should be limited, and antibiotic treatment should be given if infection is suspected.

6. What if the animal presents after abortion has occurred?

Using physical examination (palpation), radiography, and possibly ultrasound, the animal should be evaluated for pyometra, retained fetuses, and retained placenta. If uterine infection is suspected, antibiotic therapy plus prostaglandin treatment may be necessary. An ovariohysterectomy should be considered if there are no future breeding plans. In bitches, a *Brucella* titer should be obtained. If possible, the owner should collect aborted fetuses and placentas and keep them refrigerated until they can be examined.

7. What specific tests help to diagnose the cause of abortion?

Fetal lung and liver should be cultured for *Brucella* sp. and herpesvirus. Fetal stomach contents should be cultured for other bacterial species. *Campylobacter* sp. requires specific culture techniques. Fetal and placental tissues should be submitted for histopathologic examination. Collect vaginal samples from bitches for cytologic examination and culture. In addition to routine bacterial culture, samples should be placed in Aimes media for *Mycoplasma* sp. and *Ureaplasma* sp. culture. Results of vaginal cultures should be interpreted with caution because various organisms may be isolated from healthy animals. Serum should be collected from bitches to test for *Brucella canis*, canine herpesvirus, and *Toxoplasma gondii*.

8. If abortion is recurrent, what should be done?

First, document the pregnancy with ultrasound (as early as 16 days) or radiography (at 42–45 days). Collect a Brucella titer of the bitch, dog, and previous mates. Perform a physical examination, vaginal examination, vaginal culture, and cytology. Perform titers for various infectious diseases. A progesterone assay should be done during pregnancy. Finally, uterine biopsy and culture may be indicated.

9. Hypoluteoidism is a common cause of early abortion in humans. Is this condition common in dogs and cats?

Hypoluteoidism, or inadequate secretion of progesterone for maintenance of pregnancy, has not been confirmed in dogs and cats. The diagnosis is made by confirming pregnancy in conjunction with an abnormally low (< 1.0 ng/ml) level of circulating progesterone. If the value is low, then supplementation can be considered.

10. Is deliberate termination of an unwanted pregnancy safe?

If an animal is presented following an unwanted mating, try to determine the real risk of pregnancy. Take a history to ascertain whether breeding occurred. Confirm the stage of the cycle with vaginoscopy, cytology, and plasma progesterone. If pregnancy is likely, medical induction of abortion may be considered. In past years, estrogens were used; however, because of side effects such as pyometra and bone marrow toxicity, their use is not recommended.

Prostaglandins have been used both in early diestrus and in mid-gestation as an abortifacent. After the fifth day of diestrus, PGF_2-alpha or cloprostenol can cause luteal arrest and eventual resorption. Abortion is induced more easily and reliably after day 30 with prostaglandins.

A newer regimen has been described using dopamine agonists bromocriptine or cabergoline. These compounds inhibit prolactin, which results in luteolysis if given after day 30–35. A combination of cabergoline and closprostenol used at day 25 is reportedly safe and effective.

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XII. Urologic Emergencies

Section Editor: India F. Lane, D.V.M., M.S.

97. ACUTE BACTERIAL PROSTATITIS AND PROSTATIC ABSCESS

Cary L. Matwichuk, D.V.M., M.V.Sc., and India F. Lane, D.V.M., M.S.

1. What organisms are commonly implicated in prostatic infections in dogs?

Organisms commonly implicated in prostatic infections in dogs are the common pathogens of the urinary tract. *Escherichia coli* is the most frequently isolated organism. Other commonly identified organisms include staphylococci, streptococci, and *Proteus, Klebsiella,* and *Pseudomonas* spp. Anaerobic infections are uncommon but may occur with prostatic abscesses. Prostatic infections also may be caused by *Mycoplasma* or fungal organisms.

2. What historical and clinical findings are suggestive of acute bacterial prostatic infection?

Historical and clinical signs reflect systemic illness; examples include lethargy, anorexia, and vomiting. Affected dogs may walk with a stiff rear limb gait. Physical findings include fever; caudal abdominal pain, which may be localized to the prostate gland on digital rectal examination; and hemorrhagic or purulent urethral discharge. Some dogs with severe depression do not react dramatically to palpation, however. Vague abdominal pain or "splinting" of the abdomen may be detected instead. Bacterial prostatitis should be considered a primary differential diagnosis in intact male dogs presented for vomiting, lethargy, back pain, or fever.

3. How do signs of prostatic abscess differ from signs of acute bacterial prostatitis?

Clinical findings in dogs with prostatic abscess include those associated with acute bacterial prostatitis as well as signs of generalized peritonitis and septic shock. The prostate gland may be enlarged and asymmetric. Dogs may exhibit stranguria or tenesmus due to pressure placed on the urethra or colon by the enlarged prostate gland. With prostatic abscess caused by *E. coli,* polyuria and polydipsia may be included in the preliminary complaints. Just as in female dogs with pyometra, *E. coli* endotoxin may interfere with responsiveness to antidiuretic hormone and urine concentrating ability.

4. Formulate a plan to confirm the diagnosis of acute bacterial prostatic disease.

A presumptive diagnosis of acute bacterial prostatitis is usually made on the basis of history, physical examination, complete blood count, urinalysis, and urine culture. Dogs presenting with historical signs suggestive of acute bacterial prostatic disease should have a complete physical examination, including digital rectal examination. Leukocytosis, with or without a left shift, may be observed in a complete blood count. Hematuria, pyuria, and bacteriuria may be observed in urine sediment examination. A urine sample, preferably collected by cystocentesis, should be submitted for culture and sensitivity testing. In the case of suspected prostatic abscess, abdominal radiographs and ultrasound are indicated. An enlarged asymmetrical prostate gland may be visible on radiographs; hypoechoic or anechoic areas within the prostate may be observed sonographically.

5. Should prostatic fluid samples be obtained from dogs with suspected acute bacterial prostatitis?

All intact male dogs with a urinary tract infection should be considered to have prostatic involvement. Analysis of prostatic fluid probably provides no additional information in a dog with an inflammatory urine sediment, positive urine culture, and clinical and physical signs compatible with acute bacterial prostatitis. Dogs are usually in too much pain to produce an ejaculate. Urethral brushings or prostatic massage should not be performed because of the possibility of producing bacteremia.

6. Should prostatic cysts or abscesses be aspirated for cytologic evaluation and culture?

Ultrasound may be used to guide collection of fluid by fine-needle aspiration. Complications include seeding of bacteria along the needle tract and peritonitis. Fine-needle aspiration is probably contraindicated in dogs with fever or leukocytosis. With guided technique and a 22-gauge needle, the benefit of obtaining cyst fluid for cytologic evaluation, culture, and confirmation of diagnosis may outweigh the risk associated with aspiration. Fine-needle aspirates can be obtained sequentially to assess therapy. If an abscess is inadvertently aspirated, antibiotic therapy should be instituted.

7. What considerations are important in selecting an antimicrobial agent for acute bacterial prostatitis? For long-term antimicrobial therapy?

Identification of the causative organism, its antimicrobial sensitivity pattern, the ability of the antimicrobial to reach effective concentration within the prostate gland, and the animal's clinical condition should be considered in choosing an antimicrobial treatment for acute bacterial prostatitis. The choice should be based on the results of urine culture and sensitivity testing. While awaiting culture results, the clinician should initiate therapy with a broad-spectrum antibiotic with good activity against gram-negative bacteria. Gram stain results may be helpful for guiding initial therapy. During acute inflammation the blood–prostate barrier is not intact, and most antimicrobials penetrate the prostate gland. In a severely ill dog, antibiotics should be administered intravenously.

For chronic therapy, it is essential to choose an antibiotic that crosses the blood–prostate barrier. A highly lipid-soluble antibiotic that is weakly basic with a high pKa is desired. Trimethoprim-sulfadiazine, chloramphenicol, erythromycin, and clindamycin are good choices for gram-positive infections. Recommended antimicrobials for treatment of gram-negative infections include trimethoprim-sulfadiazine, enrofloxacin, and chloramphenicol. Ciprofloxacin is reported to have greater activity than enrofloxacin against *Pseudomonas* sp. Regardless of which is chosen, susceptibility testing should be done using the specific fluoroquinolone selected. Ciprofloxacin is commonly used in susceptibility testing to represent the fluoroquinolones but does not appear to be a satisfactory representative for in vitro susceptibility testing of other antimicrobials in this class. Commonly used antibiotics such as penicillins, cephalosporins, and aminoglycosides penetrate the prostate poorly and are not recommended.

8. Formulate a treatment plan for acute bacterial prostatitis.

Supportive care, including intravenous fluids, should be initiated in ill patients. Choice of initial antibiotic before culture and sensitivity results are available should be based on Gram stain results. If the dog is very ill, parenteral antibiotic therapy is indicated initially. Antimicrobial choices for the acute phase of disease include trimethoprim-sulfadiazine, ampicillin, cephalosporins, chloramphenicol, and enrofloxacin. The dog then may be switched to oral therapy with an antimicrobial chosen on the basis of culture and sensitivity results and predicted prostatic penetrance. Antibiotic therapy should be continued for 21–28 days.

9. After resolution of the acute episode, how should the patient with acute bacterial prostatitis be monitored?

A follow-up evaluation should be performed 5–7 days after completion of antimicrobial therapy. The evaluation should include a complete physical examination, urinalysis and urine culture, and cytologic evaluation and culture of prostatic fluid. Urethral brushings or fine-needle aspirates of intraprostatic cysts are useful methods for obtaining prostatic samples. An assumption that the

infection has been eliminated should not be based solely on resolution of clinical signs. Castration is strongly recommended after resolution of acute disease to facilitate clearance of bacteria and to prevent recurrence of prostatic disease.

10. What surgical options are available for management of prostatic abscesses?

Surgical drainage of prostatic abscesses may be accomplished by needle aspiration, placement of drains over the prostate gland, marsupialization of the abscess, subtotal prostatectomy, or prostatic omentalization. Complications of needle aspiration include septic shock and absorption of bacterial toxins. Complete drainage and resolution of the abscess are difficult with this method alone, although clinical signs can be minimized with intermittent drainage and antimicrobial treatment. Complications of prostatic drains include fistula formation, ascending infection, and recurrence of the abscess. Marsupialization creates a draining stoma to the exterior. If the stoma closes too early, the abscess may recur. On the other hand, a chronic draining tract may develop. More extensive prostatic surgery is associated with a high incidence of postoperative urinary incontinence. Complete excisional prostatectomy is not recommended because of high morbidity, but subtotal prostatectomy may be required in severely abscessed glands. Prostatic omentalization entails introducing omentum into the prostate to act as a "physiologic drain." In one study, long-term success was achieved with this technique in the majority of dogs, with a low incidence of serious complications. In general, however, because of the numerous potential complications of medical or surgical treatment, prostatic abscess carries a guarded prognosis.

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98. URINARY TRACT INFECTION AND ACUTE PYELONEPHRITIS

Cary L. *Matwichuk*, D.V.M., M.V.Sc., *and India* F. *Lane*, D.V.M., M.S.

1. What are the differential diagnoses for acute pollakiuria, hematuria, and dysuria?

The clinical signs of pollakiuria (frequent urination), hematuria (blood in the urine), and dysuria (difficult urination) indicate lower urinary tract inflammation but are not specific for a particular disorder. Differential diagnoses for an animal exhibiting lower urinary tract signs include bacterial urinary infection, urolithiasis, neoplasia, trauma, feline lower urinary tract disease, and prostatic disorders.

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2. What clinical signs suggest involvement of the upper urinary tract (kidneys, renal pelves, ureters)?

Determining the extent of infection along the urinary tract is important because more aggressive treatment is indicated with involvement of the upper urinary tract. Localization of infection may be difficult. However, animals with disorders confined to the lower urinary tract do not exhibit systemic signs of illness. Fever, lethargy, anorexia, vomiting, polyuria and polydipsia, and lumbar pain are suggestive of upper urinary tract infection, neoplasia, or injury. If pyelonephritis is secondary to ascending infection from the lower urinary tract, concurrent lower urinary tract signs may be observed.

3. How can the origin of hematuria be localized?

Hemorrhage from the kidney, ureters, urinary bladder, urethra, or external genitalia leads to microscopic or macroscopic hematuria. Clinical signs, physical examination (including digital rectal and vaginal examination), timing of hematuria during urination, comparison of a voided urine sample with a sample collected by cystocentesis, and identification of urinary tract pathology on radiographs or ultrasound help to localize the source of the hematuria.

Blood observed at the beginning of urination suggests bleeding from the bladder neck, urethra, or genital tract (uterus, vagina, prostate, prepuce). Blood observed throughout urination is most consistent with diffuse bladder disease or upper urinary tract hemorrhage (kidneys, ureters); hemorrhage due to coagulopathy also may lead to this pattern of hematuria. With focal (especially ventral or cranioventral) lesions of the urinary bladder or large dependent cystouroliths, blood may enter urine primarily at the end of voiding. Bleeding or discharge from the genital tract may occur independently of urination and may be detected only in voided samples. Hematuria in the absence of other lower urinary tract symptoms (pollakiuria, dysuria, stranguria) may indicate upper urinary tract disease, genital hemorrhage, or coagulopathy.

4. List differential diagnoses for acute changes in urinary volume (polyuria or oliguria).

Urine concentration and volume vary in response to water and solute intake in normal animals. Changes in urine output may simply represent homeostatic mechanisms of body water balance; however, dramatic changes in urine output may signify pathologic states. Acute polyuria may be associated with increased sodium or water intake, hypoadrenocorticism, pyometra, nonoliguric acute renal failure, pyelonephritis, urinary tract or prostate infection with *Escherichia coli*, or diabetes mellitus. Most of these disorders can be differentiated by physical evaluation and minimal database. An abrupt decline in urine output may indicate physiologic urine concentration (dehydration), acute oliguric renal failure, urine retention, or urinary tract rupture or obstruction.

5. When is cystocentesis contraindicated for the diagnosis of urinary tract infection (UTI)?

Cystocentesis is the preferred method for urine collection. Urine collected by free flow or catheter may be contaminated by cells or normal bacterial flora residing in the distal urethra and genital tract, whereas urine obtained by cystocentesis should be sterile. Performed correctly, cystocentesis is a safe procedure. Contraindications to cystocentesis include thrombocytopenia or other coagulopathies, suspected or confirmed pyometra, major abdominal trauma, or severe skin infection at the needle entry site. A relative contraindication is a distended urinary bladder secondary to urethral obstruction because of the possibility of leakage of urine into the abdomen with puncture of a compromised bladder wall.

6. What urinalysis findings are suggestive of acute UTI?

Urinalysis findings suggestive of UTI include hematuria, pyuria, and bacteriuria. Hematuria and proteinuria may be noted on urine dipstick examination. Urine dipstick leukocyte assays are generally unreliable and should not replace urine sediment examination for detection of inflammatory cells. Urine pH may be increased with infection by urease-producing bacteria (staphylococci, Proteus sp.). However, alkaline urine in the absence of compatible clinical signs or urine sediment findings does not necessarily suggest a diagnosis of UTI.

7. What is the significance of crystals in patients with acute pollakiuria, polyuria, hematuria, or dysuria?

Crystals are formed when urine is oversaturated with mineral and other substrates. In normal dogs and cats, crystals often are insignificant findings and are readily shed in urine without causing clinical signs. Magnesium ammonium phosphate (struvite) crystals may be a component of idiopathic lower urinary tract disease or urolithiasis in cats. Other crystals are more suggestive of metabolic (cystine, urate) or pathologic (calcium oxalate monohydrate) disorders. Identification of crystals in urine, however, may aid in the detection, classification, and management of urolithiasis in dogs and cats.

8. What is the significance of casts in patients with acute polyuria or oliguria?

Casts are cylindrical structures formed in the tubular lumen and shed into urine. They are molds of cells and Tamm-Horsfall protein, which is secreted by tubular epithelial cells in the loops of Henle, distal tubules, and collecting ducts. Casts may contain epithelial cells, bacteria, inflammatory cells, bilirubin, or fat globules. A few hyaline or granular casts may be observed in the urine of normal animals. In significant numbers, casts indicate an active pathologic process with renal tubular involvement, usually acute tubular injury. Cellular casts indicate hemorrhage or inflammation within renal tubules. Casts are shed into urine intermittently; the absence of casts does not rule out acute renal injury.

9. Why should urine cultures be completed in patients with suspected UTI?

The findings of hematuria and pyuria indicate only urinary tract inflammation, for which there are many differential diagnoses. Urine culture should be completed in all patients with inflammatory urine sediment to distinguish between infectious and noninfectious causes of inflammation. With a negative urine culture, investigation for other causes of lower urinary tract disease may be initiated earlier in the course of evaluation. In many patients with UTI, overt bacteriuria may not be observed in the urine sediment, and culture is used to confirm infection. Bacterial culture and sensitivity testing are the only methods to identify antibiotic sensitivity patterns of individual organisms and to ensure that appropriate antimicrobial therapy is instituted.

Urine culture in especially important in animals with recurrent UTIs to distinguish between relapse (infection with the same organism) and reinfection (infection with a different organism or different susceptibility pattern). This distinction is important because patient evaluation and follow-up differ. In patients with relapse, a persistent nidus of infection is likely or antimicrobial treatment was ineffective, whereas reinfection is more likely due to an abnormality of the urinary tract predisposing to infection.

10. How are urine samples best handled for urinalysis? For urine culture?

To ensure reliable results, urinalysis should be performed immediately after collection. Allowing urine to sit at room temperature may result in lysis of red and white blood cells and changes in crystal composition. Urine may be refrigerated but should be analyzed within 12 hours. Urine culture is best initiated within 30 minutes after collection, because at room temperature bacterial counts may double rapidly. If culture cannot be done immediately, urine may be refrigerated for up to 6 hours. Urinalysis and urine culture should be performed before administration of antimicrobials or radiographic contrast agents.

11. How can in-house urine cultures be initiated?

If a laboratory is not readily available, urine cultures can be performed easily in the practice setting. Calibrated loops or mechanical pipettes may be used to apply a known quantity of urine to blood agar and MacConkey plates and incubated at 37°C for 18–30 hours. Plates demonstrating significant bacterial growth may be sent to a commercial laboratory for identification of the organism and antimicrobial sensitivity testing.

12. What clinicopathologic findings support a diagnosis of upper UTI?

Bacteria are inconsistently observed in urine of patients with upper UTI. Additional urinalysis findings that suggest upper UTI include isosthenuric or suboptimally concentrated urine

(urine specific gravity of 1.008–1.029 in dogs, 1.008–1.034 in cats), inflammatory urine sediment (pyuria and hematuria), and casts (especially white blood cell casts). An inflammatory leukogram may be detected in acute pyelonephritis, and azotemia may be evident with severe bilateral pyelonephritis. The absence of these findings does not preclude a diagnosis of pyelonephritis, however; chronic pyelonephritis may be associated with minimal hematologic and biochemical abnormalities.

13. How can a tentative diagnosis of upper UTI be confirmed?

Supportive evidence for pyelonephritis may be obtained by imaging the kidneys with intravenous urography or ultrasound. Findings consistent with pyelonephritis include dilation, blunting or asymmetry of the renal pelves, and dilation of the ureters. A definitive diagnosis of pyelonephritis requires isolation of bacteria from the kidneys via pyelocentesis or renal biopsy. Because these diagnostic tests are moderately invasive, a tentative diagnosis of upper UTI is usually based on identifying urinary tract infection in the presence of clinical, laboratory, and radiographic/ultrasonographic signs consistent with upper urinary tract involvement.

14. What are reasonable first-line antimicrobial agents for suspected lower UTI?

Antimicrobial selection is best based on results of antimicrobial sensitivity testing. Ideally, minimal inhibitory concentrations (MICs) are determined; an antimicrobial that reaches urine concentrations of at least 4 times the MIC is likely to be effective in vivo. Before culture and sensitivity results are available, initial therapy may be based on Gram stain of urine and knowledge of best choices for the urinary tract. In general, ampicillin or amoxicillin is a good choice for gram-positive infection, and trimethoprim-sulfonamide combination is usually effective for gram-negative infections. Cephalosporins are appropriate choices for treatment of *Klebsiella* sp.; tetracyclines or fluoroquinolones are effective against *Pseudomonas* sp. Ciprofloxacin is reported to have greater activity than enrofloxacin against *Pseudomonas* sp. Regardless of which is chosen, susceptibility testing should be done with the specific fluoroquinolone selected. Ciprofloxacin is commonly used in susceptibility testing to represent the fluoroquinolones but does not appear to be a satisfactory representative for in vitro susceptibility testing of other antimicrobials in this class.

15. What are reasonable first-line antimicrobial agents for suspected upper UTI?

An antimicrobial that concentrates well in serum and renal tissue is desired for treatment of upper UTIs. Good initial choices include trimethoprim-sulfonamide or chloramphenicol. Aminoglycosides also may be used, although in renal patients they should be used only with extreme caution and appropriate monitoring. With the advent of fluoroquinolones, aminoglycosides are now rarely indicated for upper UTIs.

16. What supportive treatment is indicated in patients with suspected upper UTI?

Patients with acute pyelonephritis may be severely ill. Appropriate supportive care includes intravenous fluid therapy, parenteral antibiotic therapy, pain management, and nutritional support if needed. Fluids should be administered to replace volume deficits quickly (over 6–8 hours) and to maintain moderate diuresis. With effective antimicrobial treatment, most patients improve clinically and can support hydration requirements orally within a few days.

17. When should surgical therapy be considered in patients with pyelonephritis?

If long-term therapy with an appropriate antimicrobial fails to eliminate renal infection or if a nidus of continued infection remains (e.g., nephroliths), surgical intervention may be necessary. Surgical treatment does not, however, result in resolution of pyelonephritis in all cases. Nephrectomy is indicated if the infection appears to be unilateral, if the kidney becomes abscessed, and if the remaining kidney is able to maintain adequate function. Nuclear scintigraphy may be used to measure glomerular filtration rate in individual kidneys and is therefore a useful tool for documenting function in the remaining kidney. Nephroliths may be removed by nephrotomy, or using extracorporeal shock wave lithotripsy.

18. What follow-up recommendations should be made for small animals with simple lower UTI?

A simple or uncomplicated UTI is defined as a single or rare infection in an animal in which no underlying cause can be identified. Such animals usually respond quickly to an appropriate course of antimicrobial therapy. Appropriate therapy includes treatment for 10–14 days with an antimicrobial to which the identified organism is susceptible. Ideally urinalysis or urine culture is performed 3–5 days after completion of therapy to ensure that the infection has been eliminated.

19. What conditions suggest that an animal with UTI should be followed more aggressively?

An animal in which an underlying condition predisposing to UTI has been identified requires more careful follow-up to ensure successful eradication of the infection. Every effort should be made to identify and remove reversible complicating factors. Factors that compromise host defenses include conformational or anatomic abnormalities, urine retention or voiding dysfunction, changes in urine composition, urolithiasis or neoplasia, and immunocompromising diseases or treatments. Animals with an identifiable compromise in host defenses are said to have a complicated infection and should be treated with an appropriate antimicrobial for no less than 4 weeks. A negative urine culture 3–5 days after initiation of therapy indicates that the chosen antibiotic is efficacious. A urine culture should be performed 3–5 days before discontinuing therapy and 5–7 days after completion of therapy to ensure that the infection has been eliminated. Urinalysis with or without urine culture is indicated 30 and 60 days after completion of antimicrobial therapy. Upper UTIs, UTIs in intact male dogs, and UTIs in cats should be considered complicated and treated as such.

20. What emergency patients may be at increased risk for development of UTI?

Any factor that impairs normal host defenses predisposes an animal to development of nosocomial (hospital-acquired) infections. Common predisposing factors include prolonged hospitalization, immunosuppression, indwelling urinary catheter placement, intravenous catheters, chronic debilitating disease, previous antibiotic therapy, and burns or skin wounds. In veterinary medicine, urethral catheterization (obstructed cats, urethral surgery), dysfunctional voiding (neurogenic disorder, bladder atony), and immunosuppression (diabetes mellitus, glucocorticoid or chemotherapy administration) are the most common scenarios in which nosocomial infections occur.

21. How can nosocomial infections be prevented?

Because nosocomial infections are often caused by bacteria exhibiting multidrug resistance, every effort should be made to prevent their development. Guidelines for minimizing the risk of nosocomial infections include awareness of factors predisposing to infection, minimizing the duration of hospitalization, placement of indwelling urinary catheters only when necessary, strict attention to cleanliness when handling intravenous or urinary catheters, frequent hand washing, disinfection of equipment, maintaining environmental cleanliness, and judicious use of antimicrobials.

22. How common are catheter-induced UTIs?

Catheterization of the urinary tract predisposes animals to UTIs both by providing a direct route of entry for bacteria into the bladder and by allowing bacteria to bypass many normal host defense mechanisms. Catheter-induced infections are common, with the reported incidence ranging from 20–75% in small animals. The risk of infection increases with duration of catheterization, open indwelling catheters, concurrent administration of glucocorticoids, and immunocompromising disease. Because of the potential for UTI, careful consideration should be given to the necessity of urinary catheterization; catheterization should be avoided in patients particularly susceptible to infection. Intermittent urinary catheterization is preferred over indwelling catheters whenever possible; however, the risks of repeated catheterization (trauma, introduction of infection) must be weighed against the potential benefit in individual patients.

23. When should antimicrobial treatment be given to catheterized patients?

Antimicrobial therapy is initiated in patients with an indwelling urinary catheter only after the catheter has been removed and infection has been documented. Prophylactic antimicrobial

treatment while the catheter remains in place does not prevent infection and increases the likelihood of development of resistant infection. To minimize the possibility of catheter-induced UTI, indwelling urinary catheters should be kept in place for as short a duration as possible. Urine culture or culture of the catheter tip should be performed at the time of catheter removal to identify the current causative organisms and antimicrobial sensitivity pattern.

Antimicrobial therapy is indicated while an indwelling catheter is in place in the presence of clinical signs of systemic illness suggestive of upper UTI. If antibiotic therapy is instituted in a patient with an indwelling catheter, urine culture and sensitivity testing should be performed when the catheter is removed to identify resistant infections that may have developed during therapy.

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99. ACUTE RENAL FAILURE

India F. *Lane*, D.V.M., M.S.

1. What pathophysiologic events lead to the abrupt decline in glomerular infiltration rate characteristic of acute renal failure (ARF)?

Glomerular filtration rate (GFR) and nephron function are maintained by the balance of afferent and efferent blood flow, glomerular capillary pressure, and intratubular pressure. Disruption of vascular flow, glomerular capillary function, or intratubular dynamics causes reductions in GFR.

2. What are the major mechanisms that initiate or perpetuate ARF?

- Failure of afferent arteriolar blood flow, usually afferent arteriolar vasoconstriction
- Reduced functional glomerular capillary surface area
- Efferent arteriolar vasodilation leading to a drop in glomerular capillary pressure
- Tubular epithelial damage leading to backleak of filtrate into peritubular capillaries
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treatment while the catheter remains in place does not prevent infection and increases the likelihood of development of resistant infection. To minimize the possibility of catheter-induced UTI, indwelling urinary catheters should be kept in place for as short a duration as possible. Urine culture or culture of the catheter tip should be performed at the time of catheter removal to identify the current causative organisms and antimicrobial sensitivity pattern.

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- Tubular obstruction with cellular debris, cellular edema, casts, or crystals

3. What are the most common causes of ARF in small animals?

The most common causes of ARF are nephrotoxicant, infectious and ischemic injury. Nephrotoxicity, especially ethylene glycol intoxication, is a more common environmentally acquired cause of ARF than ischemic injury in small animals. Hospital-acquired ARF also may be due to nephrotoxicant therapeutic agents or iatrogenic ischemic injury. Toxicant-induced ARF may be precipitated by drugs such as amphotericin B, aminoglycosides, chemotherapeutic agents, or nonsteroidal antiinflammatory agents. Infectious agents including bacteria (acute pyelonephritis), *Leptospira* organisms, rickettsial organisms, *Borrelia bergdorferi*, and feline infectious peritonitis cause ARF by direct inflammatory means or via an extensive vasculitis.

Ischemic injury is associated with hypovolemia and hypotension, which lead to diminished renal blood flow. Trauma, cardiopulmonary failure, and hyperthermia may lead to ischemic renal injury. Iatrogenic causes include hypotension associated with surgery or anesthesia and vasodilatory therapy (especially angiotensin-converting enzyme inhibitors).

A third category of patients with ARF includes dogs and cats with acute-on-chronic renal failure, in which an acute exacerbation of azotemia develops in an animal with established renal insufficiency or failure. Acute renal dysfunction also may result from renal neoplasia, hypercalcemia, systemic lupus erythematosus, or trauma.

Common Causes of Acute Uremia in Veterinary Medicine

Prerenal or hemodynamic	**Renal**
Shock	Leptospirosis
Anesthesia	Pyelonephritis
Trauma	Borreliosis
Heat stroke	Lymphosarcoma
Diuretics	Hypercalcemia
Pancreatitis	
Sustained Addisonian crisis	**Postrenal**
Vasculitis	Nephrolith or ureterolith
Thromboembolic	Urethral obstruction
Sustained hypertension	Uroabdomen
Nephrotoxicant	
Ethylene glycol	
Antimicrobial agents	
Antifungal agents	
Chemotherapeutic agents	
Nonsteroidal antiinflammatory agents	
Angiotensin-converting enyme inhibitors	
Ethylene glycol	
Heavy metals	
Radiocontrast agents	
Mushrooms	
Snake and bee venom	
Hemoglobinuria	

4. Can chronic renal failure patients develop ARF?

Yes. Acute on chronic or prerenal on chronic types of acute azotemia are possible in patients with chronic renal failure, especially after dehydration, toxicant, or ischemic insults. Illness may appear similar to other causes of ARF, but the kidneys are often small, soft tissue mineralization may be observed, and previous signs of renal failure are detected in the history. In many cases, severe decompensation of renal function suggests end-stage disease; however, some patients experiencing a minor acute on chronic crisis can be returned to a stable degree of azotemia with treatment.

5. What patients are at highest risk for acquired ARF?

Patients with preexisting renal disease, major trauma, or major systemic disease such as pancreatitis, diabetes mellitus, cardiovascular disease, and hepatic disease are at increased risk for development of acquired ARF. In addition, clinical conditions such as volume depletion, electrolyte disturbances, hypotension or hypertension, fever, and sepsis are contributing risk factors. For patients at risk, administration of nephrotoxic drugs, anesthesia, surgery, or administration of radiographic contrast media may precipitate ARF.

6. How can at-risk patients be protected from development of ARF?

Volume deficits, electrolyte disturbances, and major medical problems should be addressed before the use of anesthetics, radiographic contrast media, or potentially nephrotoxic agents. During required procedures, anesthesia, or surgery, systemic blood pressure should be monitored and maintained above 60–80 mmHg by fluid support or pharmacologic means. Potentially nephrotoxic agents should be discontinued, avoided, or used only with appropriate therapeutic drug monitoring. Pretreatment with saline diuresis or mannitol infusion may be protective.

High-risk patients should be monitored for early deterioration of renal function by frequent monitoring of hydration status, body weight, blood urea nitrogen, serum creatinine, and serum electrolyte concentrations. Urine output should be estimated or measured, and urine should be monitored for blood, casts, protein, or cellular debris. Urinary enzymes may be useful parameters for monitoring aminoglycoside and chemotherapeutic treatments.

7. Describe the historical and physical clues that suggest ARF.

ARF is defined as an abrupt decline in GFR, leading to rapid development of azotemia and clinical signs of uremia. Anorexia, depression, vomiting, diarrhea, and sudden changes in urine output (either polyuria or oliguria) may be clinical indicators of ARF. Patients with acute nephrotoxic injury without preceding illness are usually in good condition and active, with minimal preliminary signs. Young intact males are predisposed to environmentally acquired ARF. Ethylene glycol intoxication is characterized by an early stage of ataxia, vomiting, and polyuria and polydipsia, followed first by a transient period of apparent recovery, then by established renal failure. At this stage, minimal outward signs of intoxication or ARF may be observed.

On physical examination, uremic breath odor may be detected. Oral ulcerations develop in some cases and may lead to severe stomatitis or tongue-tip necrosis. Pallor, weakness, and dehydration are common findings. Subnormal body temperature often is detected. Kidneys may become enlarged or painful if intracapsular swelling occurs. Bruising or peripheral edema may be noted in animals with vasculitides and ARF.

8. Describe the clinicopathologic abnormalities that suggest a diagnosis of ARF.

Rapid development of azotemia is the hallmark of ARF. Increases in urea and creatinine are usually parallel. Hyperphosphatemia and metabolic acidosis accompany azotemia. Hyperkalemia is most common in oliguric patients, patients with postrenal azotemia, and patients with severe metabolic acidosis. Anemia develops relatively rapidly over the course of established ARF but is usually not evident at diagnosis. Urine specific gravity often is isosthenuric but varies and may be normal with acute glomerular injury. Proteinuria, glucosuria, and urinary casts or cellular debris may be observed in urinalysis samples.

9. With acute azotemia, how is renal azotemia distinguished from prerenal causes?

In prerenal azotemia associated with volume depletion or hypotension, urine concentrating ability should reflect body water conservation, with urine specific gravity measurements > 1.030 (dogs) or > 1.035 (cats). Many nonrenal disorders influence urine concentrating ability, however, and distinction of prerenal azotemia may be complicated in the face of hypoadrenocorticism, hyperadrenocorticism, diabetes mellitus, or diuretic or steroid therapy. Other findings suggestive of prerenal azotemia include urinary sodium concentration < 20 mEq/L, fractional excretion of sodium < 1.0%, urine osmolality:plasma osmolality ratio > 5, and urine creatinine:plasma creatinine ratio > 20. Without the availability of these quantitative measurements, response to fluid

therapy may be used to distinguish the prerenal component of azotemia. Prerenal azotemia should resolve rapidly with correction of volume deficits and restoration of renal perfusion.

10. What other methods can be used to characterize renal function?

In some referral hospitals and veterinary teaching hospitals, nuclear scintigraphy is used for rapid quantification of renal function. Individual kidney filtration and excretory function can be assessed. Serial assays provide an assessment of disease severity, progression, and response to therapy. If scintigraphy is not available, excretory urography may be used for a subjective assessment of individual kidney function and to rule out postrenal obstruction; however, the large dose of contrast agent required for adequate renal opacification increases the risk of further renal damage. In patients with urine collection systems in place, timed measurements of endogenous creatinine clearance may be completed to monitor GFR objectively.

11. What is oliguric ARF? How does it differ from polyuric ARF?

Oliguria has been defined as urine production < 0.27 ml/hr/kg, but urine production < 0.5–3.0 ml/hr/kg should be considered inappropriate in rehydrated patients with ARF. Oliguria or anuria signifies severe renal dysfunction or bilateral postrenal obstruction. In oliguric renal failure, management becomes more difficult because fluid administration may be dramatically attenuated, making it difficult to resolve azotemia and hyperkalemia. Oliguric ARF also involves a greater potential for overhydration and volume overload. Most medically managed ARF patients quickly become overhydrated and hypertensive. In nonoliguric ARF the degree of azotemia and hyperkalemia tends to be blunted in nonoliguric ARF, and the potential for overhydration is reduced.

12. What extrarenal complications may develop with ARF?

Nausea, anorexia, diarrhea, and oral ulcerations are common gastrointestinal signs that accompany ARF. A caustic effect of ammonia produced locally by bacterial ureases may lead to oral ulceration. Gastritis and enteritis are attributed to local ammonia production, impairment of the gastric mucosal barrier, and reduced renal clearance of gastrin. Nausea and vomiting also may be centrally mediated, because uremic toxins affect the chemoreceptor trigger zone. Malnutrition develops quickly from the combination of metabolic demands and lack of food intake. Animals with severe gastroenteritis may develop high vagal tone, bradycardia and cardiac arrest after protracted vomiting (Cowgill and Elliott, 2000).

Impaired leukocyte function and cellular immunity increase the risk of concurrent infection or sepsis. A bleeding tendency characterized by platelet dysfunction is occasionally observed with severe uremia. Uremic encephalopathy, manifested as altered mentation, bizarre behavior, tremors, head bobbing, or seizures, is observed with severe renal dysfunction. Systemic hypertension is another cause of visual or neurologic disturbances in ARF. Rare complications of ARF include uremic pneumonitis, uremic pericarditis, pulmonary edema, myopathies, and cardiac arrhythmias.

13. What are the major objectives in the treatment of ARF?

Specific treatment of underlying disease (obstruction, hypercalcemia, lymphoma, leptospirosis) should be undertaken when possible. Supportive treatments should be formulated to correct fluid, electrolyte, and acid–base disorders, initiate diuresis, and manage systemic complications. Drugs commonly used in the management of ARF, along with their specific actions, recommended dosages, adverse effects, and contraindications, are listed in the table on the next page.

14. How should infectious causes of ARF be addressed?

Infectious etiologies should be investigated in any animal presenting with non–hospital-acquired acute azotemia, especially if fever, thrombocytopenia, lymphadenopathy, multisystemic disease, or vasculitis is observed concurrently. Leptospirosis should be strongly considered in dogs with concurrent hepatic disease. High single titers or rising serum titers to nonvaccinal strains of leptospirosis confirm the disease. Lyme nephritis should be considered if thrombocytopenia, severe proteinuria, and peripheral edema are observed.

Drugs Used in the Management of Acute Renal Failure

AGENT	ACTIONS	DOSAGE	ADVERSE EFFECTS	CONTRA-INDICATIONS
Agents to enhance urine production				
Furosemide	Loop diuretic ↑ RBF	2–3 mg/kg IV q 6–8 hr 2–6 mg/kg IV q 30–60 min 1 mg/kg/hr IV CRI	Volume depletion Hypokalemia	Gentamicin nephrotoxicity
Dopamine	↑ RBF, ↑ GFR ↑ Natriuresis	1–5 mcg/kg/min IV CRI	Arrhythmias Hypertension Vomiting	
Mannitol	Osmotic diuresis ↓ Cellular edema Free radical scavenger	0.5–1.0 gm/kg IV slow bolus (as a 10–20% solution	Pulmonary edema GI upset	Overhydration Cardiac disease
Dextrose (10–20%)	Osmotic diuresis Caloric support	25–50 ml/kg IV slow infusion q 8–12 hr	Volume expansion Hyperglycemia Hyperosmolality	
Agents to treat hyperkalemia				
Calcium gluconate (10% solution)	Cardioprotection	0.5–1.0 ml/kg IV slow bolus	Arrhythmias	
Sodium bicarbonate	Alkalinization of ECF	0.5–2 mEq/kg IV slow bolus	Hypernatremia ↓ Ionized calcium Hypokalemia	Hypocalcemia
Dextrose	↑ Insulin	0.1–0.5 gm/kg IV (1–2 ml/kg 25% solution)	Hyperglycemia Hyperosmolality	
Insulin/ dextrose	Intracellular movement of potassium	0.25–0.5 U/kg insulin with 1–2 gm dextrose per unit insulin	Hypoglycemia	
Agents to treat metabolic acidosis				
Sodium bicarbonate	Alkalinization	See text for dosage	Hypernatremia Hypokalemia ↓ Ionized calcium	
Agents to treat nausea and vomiting				
Cimetidine	H_2 antagonist	2.5–5.0 mg/kg IV q 8–12 hr	Altered drug metabolism	Severe renal or hepatic failure
Ranitidine	H_2 antagonist	1–2 mg/kg IV q 8–12 hr		Severe renal or hepatic failure
Metoclopramide	Dopamine antagonist	0.2–0.4 mg/kg IM, IV or 1–2 mg/kg/24 hr IV CRI	CNS signs Interference with dopamine Constipation	GI obstruction Seizures
Misoprostol	Prostaglandin analog	1–5 µg/kg PO q 6–12 hr	GI upset Uterine contraction	Pregnancy Hypertension ? Seizures ?

RBF = renal blood flow, GFR = glomerular filtration rate, CRI = constant-rate infusion, ECF = extracellular fluid, CNS = central nervous system, GI = gastrointestinal.

15. What fluid composition is appropriate in the initial treatment of ARF?

In polyuric ARF, sodium and chloride are usually lost in concert with water losses. Sodium and extracellular fluid losses are exacerbated by gastrointestinal losses. Potassium may be retained

because of poor excretion or lost by renal or gastrointestinal routes. In most patients with ARF, normal (0.9%) saline is an appropriate initial fluid choice because it is isotonic to plasma and contains no potassium. Normosol-R and lactated Ringer's solution are other isotonic replacement fluids that contain minimal potassium and are suitable alternative fluids. In patients with cardiopulmonary disease, half-strength (0.45%) saline in 2.5% dextrose or half-strength lactated Ringer's solution may be preferable, as long as hypotension and hyponatremia are not evident. In hypernatremic patients, isotonic fluids are used for volume replacement, followed by judicious administration of low sodium fluids (0.45% sodium chloride or 5% dextrose in water) to drop serum sodium concentrations slowly.

16. How is the initial fluid rate calculated for patients with suspected ARF?

Volume deficits are estimated (estimated percentage hydration × body weight in kg = liters required) and replaced within 4–6 hours. Fluids for maintenance requirements (40–60 ml/kg/day) and ongoing losses associated with polyuria, vomiting, and diarrhea should be added to the daily total and replaced over 24 hours. Ongoing losses can be estimated at 10–20 ml/kg/day; alternatively, 1.5–2 times maintenance requirements can be added to fluids calculated for volume replacement. Ideally, fluids are administered via a jugular catheter while urine output and serial central venous pressures are measured.

17. When is specific correction of hyperkalemia or metabolic acidosis indicated?

Correction of fluid deficits and initiation of diuresis are usually sufficient to reverse mild-to-moderate hyperkalemia and metabolic acidosis. Occasionally specific treatment may be required to prevent or counteract cardiotoxic effects of hyperkalemia (see chapter 78). Effects of pharmacologic treatment are short-lived, however, and urinary excretion must be restored or dialytic therapy considered. Bicarbonate therapy is indicated in patients with severe metabolic acidosis (blood pH < 7.2, bicarbonate or total CO_2 < 12–15 mmol/L). Partial correction of bicarbonate deficits over a period of 12–24 hours is advised (see chapter 82).

18. When is pharmacologic manipulation indicated to enhance urine output?

Urine production should be measured with an indwelling urinary catheter and closed collection system, metabolic cage, or serial weighing of litter pans or absorbent padding. After replacement of the estimated volume deficit, urine production should exceed 1 ml/kg/hr. If urine production is inadequate, mild volume expansion may be considered (administer an additional 3% body weight in fluid) and urine production reassessed. If urine production remains inadequate, pharmacologic treatment with furosemide and dopamine or mannitol is warranted.

19. What pharmacologic agents are available for enhancing urine output?

Diuretics and vasodilatory agents have been used to enhance urine output in ARF. Furosemide, mannitol, and hypertonic dextrose are used as diuretics. Dopamine at subpressor doses leads to renal vasodilation. For the most part, little change in GFR or clinical outcome is documented despite improvement in urine flow.

20. How can furosemide be useful in the treatment of ARF?

Furosemide is readily available and easy to administer as an intermittent IV bolus (2–3 mg/kg IV every 6–8 hr) or constant-rate infusion (1 mg/kg/hr). As a loop diuretic, furosemide helps to increase tubular flow and to improve renal blood flow but does not significantly affect GFR. Furosemide also may protect tubular epithelial cells in the thick ascending loop of Henle by reducing active transport at this site. The effectiveness of furosemide is enhanced by concurrent administration of dopamine. Furosemide may lead to excessive potassium losses, and it is contraindicated in the treatment of gentamicin nephrotoxicity.

21. What are the potential advantages of dopamine in the treatment of ARF?

Dopamine is a norepinephrine precursor that at low doses (1–5 μg/kg/min) causes dilation of splanchnic and renal arterial beds and acts at specific renal receptors to enhance sodium

excretion. In cats, dopamine (5–10 μg/kg/min) appears to stimulate alpha-adrenergic receptors, leading to increased blood pressure and natriuresis. Effects on urine production may be significant, but effects on GFR are modest.

22. What are the potential advantages of mannitol in the treatment of ARF?

Mannitol is a safe and effective osmotic diuretic when used in rehydrated, normovolemic patients with ARF and normal cardiopulmonary function. As an osmotic diuretic, mannitol creates volume expansion and increases tubular flow and urine production. A renal vasodilatory effect is also observed, perhaps mediated by enhanced prostaglandin activity or release of atrial natriuretic peptide. By virtue of volume expansion and vasodilatory effects, mannitol results in mild improvements in renal blood flow and GFR. Mannitol also may exert a cytoprotective action in ARF because the osmotic agent helps to minimize swelling of injured or hypoxic cells. Weak free radical scavenging activity also may help to minimize ischemic and reperfusion injury.

23. When is maintenance fluid therapy initiated?

Once volume deficits have been restored, electrolyte concentrations are stabilized, and diuresis has been established, fluid therapy should be tailored to match urine volume and other sensible and insensible losses. Insensible losses (e.g., water loss due to respiration) are estimated at 13–20 ml/kg/day. Urine output (the most variable sensible loss) is quantitated during 6- or 8-hour intervals; the amount lost is replaced during an equivalent period, along with measured or estimated gastrointestinal losses.

Fluid composition during maintenance therapy should be tailored to the individual patient. Polyionic replacement solutions that provide buffering activity and electrolyte replacement may be administered during the first few days of treatment, especially if gastrointestinal or electrolyte losses are great. For longer-term therapy, lower sodium solutions designed to meet maintenance fluid needs are preferred.

24. How are fluid requirements managed in ARF with oliguria or anuria?

Fluid requirements in oliguric patients must be based on urine output. As with typical maintenance fluid therapy, insensible losses are calculated at 13–20 ml/kg/day and urinary losses are measured and replaced. The fluid rate is adjusted frequently as hydration status is assessed. Serial measurements of central venous pressure are valuable for detecting early fluid overload.

25. When is dialytic therapy indicated in ARF?

Dialytic therapy should be considered in patients with ARF caused by dialyzable nephrotoxicants; patients with life-threatening fluid overload, hyperkalemia, or metabolic acidosis; oliguric or anuric patients that do not respond to pharmacologic manipulation; and patients that do not respond to medical management within 24–48 hours.

26. How are patients with ARF monitored?

Body weight, hydration status, blood pressure, food and fluid intake, and urine output should be monitored frequently. Clinicopathologic monitoring should include records of packed cell volume, total protein measurements, and concentrations of blood urea nitrogen, serum creatinine, sodium, potassium, and phosphorus as well as acid–base status. Frequency of monitoring is based on the severity and phase of illness; once- to twice-daily monitoring is ideal in critical patients.

27. How can progress and recovery be monitored in ARF?

Stabilization of azotemia, resolution of electrolyte and acid–base disturbances, and maintenance of polyuria are favorable signs in the management of ARF. Slow improvement of azotemia may be expected during fluid support in the maintenance phase if recovery is likely. Recovery of renal function and histologic renal repair may require several weeks before the animal is able to be weaned from fluid or dialytic support. Serial percutaneous kidney biopsies (at initiation of therapy and 3–4 weeks later) are most helpful in establishing accurate prognosis and monitoring recovery.

28. What factors affect prognosis and survival in patients with ARF?

Established ARF carries a guarded-to-grave prognosis unless an underlying disease process can be rapidly reversed (e.g., early treatment of leptospirosis or tick-borne disease, successful movement or removal of a nephrolith). Prognosis of acute intrinsic renal failure is affected by severity of dysfunction, extent of histologic damage, and response to therapy. Nonoliguric ARF generally has a more favorable prognosis than oliguric ARF, and patients with complete anuria are unlikely to survive. Nephrotoxicant-induced ARF (except ethylene glycol toxicosis) may have a better prognosis than ischemia-induced ARF because tubular basement membranes frequently remain intact. Preexisting cardiac disease, renal disease, neoplasia, pancreatitis, and major trauma as well as development of oliguria, respiratory failure, coma, or sepsis are poor prognostic indicators in human patients with ARF.

Early use of diuretics or renal vasodilators and early application of dialytic support may ultimately improve the outcome in ARF in veterinary medicine. Dialysis provides extended time for renal repair but is fraught with complications. In animals that survive or are maintained by dialysis, partial renal recovery is expected in 3–6 weeks (up to 3–6 months in patients that are initially oliguric).

CONTROVERSIES

29. When should renal biopsy be considered in ARF?

Renal biopsy is more likely to be clinically useful in ARF than in CRF. Biopsy is indicated with large, acutely diseased kidneys, significant proteinuria, and when the diagnosis remains in doubt after noninvasive methods (history, imaging, urine culture, serology, toxicologic analyses) have been exhausted. Renal biopsy also can be helpful when acute renal disease is part of an ambiguous multisystemic disease. Renal biopsies are contraindicated in patients with severe hypertension or coagulopathies and when imminent hemodialysis is considered (heparinization associated with hemodialysis may increase risk of hemorrhage).

30. Is dopamine harmful in ARF?

The efficacy of dopamine in improving renal blood flow is questionable (especially in cats). Improved renal function or survivability is not documented in dogs or cats. Higher doses required to affect diuresis and sodium excretion in cats may create systemic hypertension, increase renal vasoconstriction, and decrease GFR. Additional concerns when dopamine infusions are implemented include the potential for tachycardia, arrhythmias, or damage from extravasation. Dobutamine infusion has been suggested as a more effective means of increasing cardiac output and renal perfusion; however, the same caveats regarding systemic and intrarenal vasoconstriction must be considered.

31. Is metoclopramide harmful in ARF?

Many gastrointestinal protectants, including H_2-receptor antagonists and metoclopramide, undergo significant renal elimination, and dosages should be reduced in severe renal failure. As a D_2-dopaminergic antagonist, metoclopramide theoretically can reduce renal blood flow or the effects of endogenously administered dopamine. Currently, however, these effects are unproved. After volume expansion, centrally acting phenothiazine derivatives may be preferable to metoclopramide for management of protracted vomiting.

32. How should acute ureteral obstruction be managed?

Acute ureteral obstruction by calcium oxalate nephroliths or ureteroliths is becoming a common cause of acute or chronic renal failure in cats. Bilateral uroliths or uroliths obstructing the more functional kidney can create an acute uremic crisis. Surgical removal or manipulation of the urolith is possible, but potential complications may dramatically worsen renal or excretory function. Some ureteroliths are passed with time and conservative medical treatments, usually including fluid diuresis. In general, nephroliths and ureteroliths should be monitored to determine their mobility and their lasting effects on renal morphology and function. Referral for surgical or other intervention is indicated if persistent dysfunction is documented.

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100. OBSTRUCTIVE FELINE LOWER URINARY TRACT DISEASE

Kristi L.*Graham*, D.V.M., M.S., *and India* F. *Lane*, D.V.M., M.S.

1. What are the most common causes of urethral obstruction in cats?

The two most common causes of urethral obstruction include mucoproteinaceous plugs and urethroliths. Urethral plugs are composed of minerals embedded in a proteinaceous matrix. The mineral composition within urethral plugs varies but often includes magnesium ammonium phosphate (struvite), calcium oxalate, calcium phosphate, or a mixture of these crystals. The matrix is a proteinaceous substance suspected to consist primarily of Tamm-Horsfall mucoprotein. Uroliths are a less common cause of urethral obstruction but are found in 15–22% of cats with clinical signs of hematuria, pollakiuria, and dysuria. The composition of feline uroliths most frequently consists of magnesium ammonium phosphate or calcium oxalate. Other, less frequent causes of urethral obstruction include bladder neck or urethral neoplasia, luminal strictures, extraluminal compression, and functional urethral obstruction or detrusor-urethral dyssynergia.

2. Obstructive uropathy is most frequently associated with what metabolic abnormalities?

Metabolic derangements associated with postrenal azotemia include volume depletion, hyperkalemia, and metabolic acidosis. Volume depletion may be a result of adipsia, anorexia, and vomiting; it is often underestimated by physical examination. The urethral blockage impairs excretion of potassium and hydrogen ions, leading to hyperkalemia and metabolic acidosis. With time, increased pressure within the bladder and ureters impairs glomerular filtration, renal blood flow, and tubular function, leading to postrenal azotemia.

3. What is the typical clinical course of complete urethral obstruction over 24–72 hours?

A urethral plug or urolith initially leads to clinical signs of dysuria, stranguria, and pollakiuria. Distention of the bladder and associated inflammation of the bladder and urethra contribute to hematuria and pain. Cats may become irritable, vocalize, or groom the perineum incessantly. Within 12–48 hours, the cat becomes anorectic, lethargic, and depressed. Postrenal uremia usually develops within 24 hours of complete obstruction. Vomiting and weakness are observed as uremia progresses. With prolonged obstruction, cats may become recumbent, shocky, or comatose. Without treatment, death usually occurs within 3–6 days of complete urethral obstruction.

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4. What are the primary goals of medical therapy when complete urethral obstruction is suspected?

The immediate therapeutic goals are relief of the obstruction and reversal of concurrent metabolic abnormalities. The status of the patient directs priorities in management. Relieving the obstruction is required for ultimate resolution of azotemia and hyperkalemia. However, hypovolemia and hyperkalemia may be life-threatening in more compromised cats; thus, fluid support and cardioprotective treatments become top priorities. In more severely affected cats, intravenous fluid treatment is initiated while preparations are made for urethral catheterization. In alert and stable cats, urethral catheterization may be completed first.

5. What is the appropriate fluid therapy for obstructive lower urinary tract disease (LUTD)?

Goals of fluid therapy are to replace volume needs, to reduce hyperkalemia and uremia, and to minimize acid–base imbalance. Normal saline (0.9% sodium chloride) is a safe and efficacious initial choice. As a potassium-free solution, saline corrects volume deficits and promotes diuresis of retained potassium, urea, and hydrogen ions. Alkalinizing solutions such as Normosol-R or lactated Ringer's solution may be preferable for reversing acidemia and hyperkalemia, although these fluids contain minimal amounts of potassium. Improvements in tissue perfusion, acidosis, and potassium excretion often outweigh the risk of a small added potassium load. As urinary excretion of potassium is restored and diuresis ensues, hypokalemia is likely to develop, depending on duration of therapy and composition of the fluid. Fluids may then need to be supplemented with potassium. Serial serum potassium concentrations should be used to guide supplementation.

6. How should cats be restrained for urethral catheterization?

Urethral obstruction is an extremely painful condition, and patients often need chemical restraint to facilitate urethral catheterization. However, risks associated with anesthetic or analgesic administration in compromised cats must be considered. The choice of sedative agents is dictated by the clinical condition of the cat. Severely depressed and obstructed cats often require no anesthesia. In more clinically stable cats, ketamine and diazepam are the most common agents chosen. Ketamine alone often provides adequate depth and duration for most catheterization. However, it is unlikely to provide analgesia. Ketamine must be used judiciously because it is excreted by the kidneys. Repeated doses are not advised. Additional muscle relaxation may be gained with the addition of diazepam. If cardiac stability is a concern or if urethral catheterization was unsuccessful with injectable agents, masking the cat with isoflurane may be a safer choice for restraint. Isoflurane provides adequate depth and duration for the procedure, and its effects can be removed quickly by discontinuing inhalation.

Approximate Doses of Pharmacologic Agents Used in Obstructed Cats

DRUG	APPLICATION	DOSE	COMMENTS
Ketamine	Chemical restraint	3–5 mg/kg	No analgesia No muscle relaxation
Ketamine with diazepam	Chemical restraint	K: 3–5 mg/kg D: 0.25–0.5 mg/kg	
Calcium gluconate	Cardioprotective in hyperkalemia	2–10 mg in 10% solution IV	Give slowly, monitor ECG
Sodium bicarbonate	Hyperkalemia	1–2 mEq/kg	
Glucose	Hyperkalemia	5–10% dextrose in water or 1–2 ml/kg 50% dextrose bolus (diluted to 25% with saline)	
Glucose with insulin	Hyperkalemia	I: 0.5–1 U/kg G: 2 gm dextrose per unit insulin	Monitor serum glucose levels

Table continued on next page.

Approximate Doses of Pharmacologic Agents Used in Obstructed Cats (Continued)

DRUG	APPLICATION	DOSE	COMMENTS
Bethanechol	Detrusor contraction	1.25–7.5 mg/cat orally every 8 hr	
Prazosin	Urethral smooth muscle relaxant	0.03 mg/kg IV	Hypotension
Phenoxybenzamine	Urethral smooth muscle relaxant	2.5–7.5 mg/cat orally every 12–24 hr	Hypotension
Diazepam	Urethral smooth muscle relaxant	1–5 mg/cat orally every 8 hr or 1 mg/kg IV	Sedation possible

7. What methods are available for relieving difficult urethral obstruction?

The urethra may be catheterized with a sterile, open- or closed-tip, 3.5-French "tomcat" catheter (Sherwood Medical, St. Louis). Minnesota olive-tipped catheters (Ejay International, Glendora, CA) also are available in several different lengths and diameters; they are composed of steel and designed to be minimally traumatic to the urethra. If the obstruction is not easily dislodged, flushing the catheter with sterile saline occasionally forces the plug back into the bladder or breaks up the obstructive material sufficiently to allow passage of the urinary catheter into the bladder. If simple reverse flushing is ineffective, retropulsion with a closed urethral orifice may dilate the urethra around the plug and release it. If bladder size and intraluminal pressure are excessive, hindering retropulsion and passage of the catheter, a decompressive cystocentesis may be cautiously performed (see controversies). Occasionally, a small amount of lidocaine (solution or gel) instilled through the catheter helps to decrease urethral spasm and facilitates catheter placement. Large quantities of anesthetic solutions should be avoided because they may be readily absorbed through inflamed urinary bladder mucosa. Injection of pharmacologic agents that may decrease urethral pressure (alpha antagonists, skeletal muscle relaxants) has been investigated as a means of facilitating urethral catheterization. The magnitude of change in urethral pressure with these drugs, however, is unlikely to enhance catheter passage dramatically.

8. Does flushing the bladder help to minimize dysuria or reobstruction?

After the obstruction is relieved, flushing the bladder with a sterile saline solution has been recommended. Justification for this practice is based on the assumption that removal of crystals, "sand," or mucoid precipitate remaining in the bladder decreases the chance of reobstruction. Saline hydrodistention and flushing also may promote release and excretion of inflammatory mediators that contribute to feline LUTD. Hydrodistention provides temporary relief in some women with interstitial cystitis, probably by exhausting sensory nerve firing, promoting release of inflammatory mediators, and creating epithelial trauma, which heals over time. However, patients usually have more pain for several weeks after the procedure before improvement is appreciated. In cats, the effects of aggressive bladder flushing have not been established. If this technique is performed, care should be taken not to overdistend the bladder.

9. What are the main criteria for maintaining an indwelling urinary catheter?

The decision to leave an indwelling catheter is based on the condition of the patient and postobstructive bladder and urethral function. With severe azotemia or metabolic acidosis, the catheter is often maintained to assess urine output during postobstructive diuresis. An indwelling catheter also averts immediate reobstruction, which compromises recovery in critically ill cats. Indwelling catheters also may be maintained to minimize reobstruction in cats after difficult, traumatic catheterization or early reobstruction or in cats with heavy crystalluria, hematuria, or urine debris. Finally, temporary indwelling catheters are indicated when detrusor atony or functional urethral obstruction is likely to interfere with voiding. Ideally, the polypropylene catheter is removed, and urine stream is assessed by gentle bladder expression. The catheter may then be replaced, if necessary, with a soft flexible alternative. With difficult catheterization, the original

catheter is usually left in place for short-term use (12–24 hours) to avoid additional trauma and to allow urethral inflammation and spasm to subside.

10. How are indwelling catheters maintained?

Soft polyvinyl ("red-rubber") catheters are preferred to minimize iatrogenic urethral and bladder irritation during longer-term urethral catheterization. A 5-French catheter is usually needed to maintain good urine flow. Alternatives include infant feeding tubes (Argyle feeding tube, Sherwood Medical, St. Louis) and recently available silicone or Teflon-based products (Slippery Sam catheter, Cook Veterinary Products, Bloomington, IN). Soft catheters can be stiffened in the freezer to facilitate placement. The tip of the catheter is ideally situated within the bladder neck so that drainage is effective but excessive catheter material does not remain in the bladder. The catheter is then secured by tape, which is attached to the catheter and sutured to the prepuce. Tension is avoided by taping the catheter or drainage tubing to the cat's tail.

Indwelling urinary catheters may be maintained as an open system or a closed collection system. Open systems ensure that the urethra remains open but allow easy bacterial colonization of the urinary bladder and do not allow quantification of urine output. A closed urinary catheter system can be created by using a fluid infusion line to connect the catheter to an empty, sterile collection bag (usually a recently emptied fluid bag). Commercial urine collection systems also are available. A closed system initially minimizes bacterial colonization. With increased time, however, ascending infection becomes more likely as bacteria gain access by migrating along the outside of the urinary catheter.

11. Why does postobstructive diuresis occur?

The dramatic diuretic effect after relief of urinary obstruction probably results from appropriate physiologic responses and residual tubular concentrating defects. The homeostatic response to retained loads of urea, sodium, potassium, phosphate, and hydrogen ions is an increase in excretion. An accumulation of atrial natriuretic factor during obstruction also may promote natriuresis and diuresis. Intrarenally, residual tubular defects may impair concentrating ability. The medullary gradient and tubular responsiveness to antidiuretic hormone also may be ineffective after periods of obstruction.

12. How can measured urine production help to direct fluid therapy?

Urinary losses during the postobstructive phase may be great. Because maintenance fluid requirements include both sensible (primarily urinary) and insensible losses, urine output may be used to prepare fluid therapy in previously obstructed cats. Insensible losses are estimated at 13–20 ml/kg/day. Urinary losses are measured over 6- or 8-hour intervals and replaced over intervals of similar duration. With this "ins-and-outs" method, fluid replacement more equally matches true requirements. Over 24–72 hours, fluids may be tapered to prevent ongoing diuresis.

13. When is removal of the indwelling catheter indicated?

Because of the risk of urinary tract infection and iatrogenic trauma, urinary catheters should be removed as soon as the cat is clinically and metabolically stable and likely to urinate voluntarily. Postobstruction voiding function is difficult to predict but is more likely when hematuria is resolving and when the bladder is small and tonically contracted around the catheter tip. A decision to remove the catheter is usually made within 24–48 hours of placement.

14. Are antimicrobials necessary? If so, when are they indicated?

Primary bacterial infections are rarely documented in obstructive or nonobstructive LUTD in cats. However, iatrogenic introduction of bacteria into the urinary tract is possible during the placement and maintenance of urinary catheters. Prophylactic antimicrobial administration is not recommended while an indwelling urinary catheter is in place unless symptomatic infection or urosepsis develops (excessive straining, lethargy, fever). Prophylactic antimicrobial treatment often leads to development of complicated infections with a resistant species of bacteria.

Ascending infections of the upper urinary tract are also possible. Urinary tract colonization increases over time; use of sterile technique and a closed collection system may delay the development of urinary tract infection. Ideally, antibiotic therapy is based on urine culture obtained after removal of the urinary catheter.

15. List possible reasons for persistent voiding dysfunction in previously obstructed cats.

In the early postobstructive period, inability to void is usually attributable to physical reobstruction, functional outlet obstruction (urethral spasm), or detrusor atony. Outlet resistance and bladder function can be assessed by attempting manual expression of a moderately full bladder. If a good urine stream can be produced with gentle sustained compression, detrusor atony is the most likely cause of urine retention. If voiding is not stimulated and an appropriate urine stream cannot be generated, physical or functional outlet obstruction is likely. Physical reobstruction is common as a result of persistent mucocrystalline debris, small uroliths, or urethral edema. Resistance to urethral catheterization may be used to distinguish physical from functional obstruction; however, small uroliths can be easily bypassed or pushed back into the urinary bladder. Development of dysuria several weeks to months after obstruction may indicate urethral stricture, an uncommon complication of urethral trauma, caused by either the plug, urolith, or catheter.

16. How can functional urethral obstruction be detected?

Excessive urethral outlet resistance is commonly observed after urethral obstruction in cats. Cats usually strain to void, producing minimal amounts of urine. Expression of the bladder is difficult or impossible, whereas urethral catheterization is usually easy. Some cats demonstrate detectable perineal contractions while straining to void. Extensive urethral spasm may make withdrawal of a urinary catheter difficult.

17. What treatments are effective for voiding dysfunction attributed to functional outlet obstruction?

Smooth and striated muscle of the urethra may be manipulated pharmacologically. Alpha-adrenergic antagonists (prazosin, phenoxybenzamine) are useful in modulating smooth muscle of the urethra in dogs and have been effective experimentally in reducing urethral pressures in cats. However, in cats striated muscle relaxants may be more effective in reducing outlet resistance in the distal urethra, which is the usual site of injury in recently obstructed cats. Diazepam and dantrolene have been investigated for this purpose. In clinical usage, diazepam appears to facilitate bladder expression and may be most helpful when initiated early after relief of obstruction. In most cases, however, patience and tincture of time are the only effective treatments for restoring normal voiding function.

18. When is surgical intervention indicated?

Perineal urethrostomy has been used to avert urethral obstruction. Emergency perineal urethrostomy may be necessary when repeated attempts to catheterize the urethra fail, although decompressive cystocentesis may be used to provide additional time for medical attempts to succeed in dislodging the obstruction. Urethrostomies are most commonly performed in cats with frequent reobstruction. Because of the short clinical course typically associated with feline LUTD, surgery should be performed only when all attempts at medical control fail. Surgery helps to prevent future urethral obstruction, but owners should be advised that signs of idiopathic inflammation (hematuria, pollakiuria, dysuria) are still likely to occur.

CONTROVERSIES

19. Should corticosteroids be used in obstructive feline LUTD?

The decision to use glucocorticoids in obstructive feline LUTD should be given careful consideration. Certainly inflammation plays a role in the development of dysuria, pollakiuria, and hematuria associated with urethral obstruction. The antiinflammatory properties of glucocorticoids help

to minimize clinical signs and reduce the possibility of reobstruction. However, the immunosuppressive and catabolic effects of glucocorticoids may be detrimental in obstructed cats with postrenal azotemia and associated metabolic abnormalities. Furthermore, the efficacy of glucocorticoids in nonobstructive disease remains unproved. Glucocorticoids are contraindicated in cats with indwelling urinary catheters or bacterial urinary tract infection.

20. Should decompressive cystocentesis be used in urethral obstruction?

Decompressive cystocentesis may be indicated when the urethral obstruction cannot be immediately removed. Advantages of a carefully performed cystocentesis include rapid decompression of an overly distended bladder, relief from pain, temporary attenuation of renal compromise, and facilitation of reverse flushing and retropulsion of urethral plugs. Samples obtained via cystocentesis are suitable for initial urinalysis and culture. However, cystocentesis may be dangerous, especially if the bladder wall is compromised. Urine may extravasate around the needle, or the bladder wall may be further injured, occasionally leading to rupture. Thus, the decision to perform decompressive cystocentesis is based on immediacy of need for decompression and assessment of likely bladder wall integrity.

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101. PERITONEAL DIALYSIS AND HEMODIALYSIS

India F. *Lane*, D.V.M., M.S., *Leslie Carter*, M.S., C.V.T., V.T.S., *and Denise* A. *Elliott*, B.V.Sc.

1. How does dialysis work?

All forms of dialysis are based on the interaction of plasma water with a solution across a semipermeable membrane that allows movement of selected substances from plasma into removable dialysate or vice versa. Movement of water and solute is directed by principles of **diffusion** (the movement of molecules from areas of high concentration or activity to areas of low concentration or activity), **osmosis** (the movement of water toward increasing solute concentration), and **solute drag** (the movement of substances en masse in response to diffusion or osmotic forces). In peritoneal dialysis, the peritoneum serves as the membrane for transfer of solute or water, and movement is driven predominantly by osmotic gradients. In hemodialysis, an artificial membrane within the dialyzer allows transfer, which is driven by artificially generated hydrostatic forces as well as diffusion gradients. The ultimate goal of dialysis in renal failure is transfer of undesirable solutes and excessive fluids from blood of the uremic patient to the dialysate.

to minimize clinical signs and reduce the possibility of reobstruction. However, the immunosuppressive and catabolic effects of glucocorticoids may be detrimental in obstructed cats with postrenal azotemia and associated metabolic abnormalities. Furthermore, the efficacy of glucocorticoids in nonobstructive disease remains unproved. Glucocorticoids are contraindicated in cats with indwelling urinary catheters or bacterial urinary tract infection.

20. Should decompressive cystocentesis be used in urethral obstruction?

Decompressive cystocentesis may be indicated when the urethral obstruction cannot be immediately removed. Advantages of a carefully performed cystocentesis include rapid decompression of an overly distended bladder, relief from pain, temporary attenuation of renal compromise, and facilitation of reverse flushing and retropulsion of urethral plugs. Samples obtained via cystocentesis are suitable for initial urinalysis and culture. However, cystocentesis may be dangerous, especially if the bladder wall is compromised. Urine may extravasate around the needle, or the bladder wall may be further injured, occasionally leading to rupture. Thus, the decision to perform decompressive cystocentesis is based on immediacy of need for decompression and assessment of likely bladder wall integrity.

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101. PERITONEAL DIALYSIS AND HEMODIALYSIS

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2. What are the indications for dialytic therapy in veterinary medicine?

Dialysis is most commonly used in veterinary medicine for the management of refractory acute intrinsic renal failure. Dialysis is indicated when clinical signs, azotemia, acidosis, or hyperkalemia is unresponsive to appropriate medical management (see chapter 99). Guidelines for severity of azotemia that warrants dialysis include blood urea nitrogen > 100 mg/dl or serum creatinine > 10 mg/dl. Dialysis is chosen early in treatment of acute renal failure if life-threatening hyperkalemia or fluid overload cannot be medically reversed or if oliguria is persistent for more than 12–24 hours. Ideally, dialysis is initiated for reversible acute renal disease but may be useful in acute intoxications, acutely decompensated chronic renal disease, perioperatively for renal transplantation or postrenal disorders, or temporarily while awaiting renal biopsy results. In chronic renal failure, intermittent dialysis may be undertaken for selected patients to minimize signs of uremia and to improve overall quality of life. Although azotemia worsens between dialysis periods, maximal urea concentration and time-averaged urea concentration are reduced. Other indications for dialysis include acute intoxicoses or refractory fluid overload due to nonrenal causes.

PERITONEAL DIALYSIS

3. What factors affect peritoneal clearance of a solute?

Although the peritoneal surface area is large, the capillary surface area for fluid movement is relatively small. Transport may be intercellular, transcytoplasmic, or via vesicle formation. Movement of solute depends not only on diffusion gradients but also on molecular size and weight, charge, and protein binding. Interstitial and vascular hydrostatic pressures, peritoneal permeability, and dwell time also influence transfer. Use of warmed dialysate, increased dwell time, or hypertonic dialysate solutions may enhance diffusion and solute drag.

4. How does peritoneal dialysis compare with hemodialysis?

Peritoneal dialysis is effective for removal of most retained uremic toxins, acids, and potassium. Peritoneal dialysis may be more effective than hemodialysis in the removal of larger-molecular-weight substances (middle molecules of uremia) because of larger pore size, but hemodialysis is generally more efficient than peritoneal dialysis. Peritoneal dialysis may be preferred for perioperative management of postrenal disorders (e.g., uroabdomen) and can be useful for severely hypothermic or hyperthermic patients. In its simplest form, peritoneal dialysis is practical for any veterinary practice; however, dialysis is labor-intensive and fraught with complications. Hemodialysis requires additional technical equipment, reliable vascular access, and specially trained personnel. In the dedicated laboratory, intermittent hemodialysis requires less time and labor than continuous peritoneal exchanges.

5. How do you perform a peritoneal dialysis exchange?

After surgical placement of the dialysis catheter, the tail of the catheter tubing is aseptically connected to a transfer tubing set that previously has been attached to and primed with a prewarmed bag of dialysate. With a single-spike system, exchanges are made as follows:

1. After a fresh bag of dialysate is prepared, the collapsed empty dialysate bag is unrolled and placed below the level of the animal for drainage.
2. The roller clamp on the transfer tubing is opened to allow slow drainage of fluid from the peritoneal cavity.
3. The fresh dialysate bag is connected to the transfer set spike, and dialysate is infused by gravity flow.
4. Dialysate remains in the peritoneal cavity for 1–6 hours (depending on the intensity of dialysis required), and the process is repeated.

With a Y-set system, the Y-set is attached to the catheter tubing or transfer set, with a fresh dialysate bag and collection container attached to either segment of the Y. For exchanges, a small amount of fresh dialysate is first flushed into the drainage bag so that any contaminants introduced during the connection procedures are flushed into the drainage bag and not into the peritoneal

cavity. The peritoneal cavity is then drained, and fresh dialysate is infused for the next dialysis cycle. If desired, the Y-set can be disconnected between exchanges and the caps protected with disinfectant (alcohol disinfectant of catheter connections is most effective). Details of dialysis procedures are reviewed in works listed in the bibliography.

6. How is dialysate prepared for peritoneal dialysis?

Dialysate solutions are buffered, slightly hyperosmolar crystalloid solutions designed to pull fluid, potassium, urea, and phosphate from the plasma into dialysate while providing diffusible buffer and other needed compounds such as magnesium and calcium. Potassium-free commercial dialysate solutions are available with dextrose concentrations of 1.5%, 2.5%, or 4.25% and lactate as the primary buffer. Potassium supplementation may be required during long-term dialysis of normokalemic or hypokalemic patients. Similar solutions can be prepared by adding dextrose to lactated Ringerís solution; however, bicarbonate and magnesium supplementation may be necessary. Acetate-based solutions may damage the peritoneum and are not recommended.

7. Why are hypertonic solutions used for peritoneal dialysis?

Hypertonic dextrose-containing solutions are effective for minimizing edema in overhydrated patients and for enhancing ultrafiltration (removal of water) in all patients. Hypertonic dextrose appears to favor capillary vasodilation and increased pore size in the peritoneum and enhances solute drag. Dialysate containing 1.5% dextrose is used in dehydrated or normovolemic patients, whereas 2.5% and 4.25% solutions are used in mildly to severely overhydrated patients. Intermittent use of 4.25% dextrose solution may increase the efficiency of dialysis in all patients.

8. What is the recommended volume for dialysis exchange?

The recommended infusion volume for small animals is 30–40 ml/kg per exchange. For the first 12–24 hours after catheter placement, exchange volumes should be one-half of the calculated ideal volume to assess the degree of abdominal distention, effect on respiratory function, and potential for dialysate leakage.

9. How can small exchanges be facilitated in cats or small dogs?

Multiple exchanges can be completed with a single bag of dialysate. The exchange volume is calculated and administered by weighing the bag during infusion (1 liter of fluid equals 1 kg). Dialysate can be drained into a separate collection container using a Y-infusion set or directly back into the infusion bag. Dilution of drained effluent with fresh dialysate still allows infusion of effective dialysate for several exchanges.

10. What catheters are available for long-term peritoneal dialysis?

Peritoneal dialysis catheters are available in straight, curled, and column-disk designs. The column-disk design is preferred for veterinary patients, because it appears to be less easily obstructed than other designs. However, column-disk catheters are no longer available commercially. A T-shaped catheter (Ash Advantage Peritoneal Dialysis Catheter, Medigroup, IL) offers hope for adequate long-term dialysis in small animals. The T shape provides an access/infusion line connected to two transverse cylinders that lie within the abdomen. The cylinders contain small fluted openings along their length for diffusion and are less likely to become occluded by omental attachment.

11. How can acute peritoneal dialysis be practically accomplished?

Acute peritoneal dialysis can be accomplished with instruments as simple as a 14–18-gauge needle, trocar or cannula inserted along the ventral midline caudal to the umbilicus. Infusion and drainage of dialysate can be done through sterile intravenous administration sets. To avoid multiple intermittent punctures with this technique, a sterile fenestrated feeding tube, thoracostomy tube, or acute peritoneal dialysis catheter can be placed in a paramedian or flank position. Penrose drains exiting the abdomen or open abdominal drainage also can be used to augment drainage in a postoperative patient. However, the risks of pericatheter leakage and peritoneal infection increase

with these methods. Curled catheters may be adaptable to small animals for long-term dialysis. Straight catheters designed for human use are readily available and satisfactory for acute dialysis in dogs and cats. Without immediate access to specially designed peritoneal catheters, thoracostomy tubes and other sterile fenestrated tubing may be used temporarily while preparations are made for long-term dialysis.

12. How can catheter occlusion be prevented?

A full or partial omentectomy at the time of catheter placement may minimize physical occlusion of catheter pores. Heparin (1000 U/L initially, tapered to 250 U/L) is added to dialysate solution during the first few days of dialysis to minimize fibrin formation and obstruction by blood clots.

13. What measures should be taken if the effluent is not draining effectively?

Less fluid may be recovered from the abdomen than was delivered for the first few exchanges. As dialysis proceeds, outflow should approximate or exceed inflow. If drainage persistently lags behind infusion, excessive fluid is being resorbed by the patient, fluid is leaking around the catheter, or catheter outflow is obstructed. If the patient appears to be resorbing most of the dialysate fluid, a higher dextrose concentration may be chosen for a few exchanges. Leakage into bandage material or subcutaneous leakage can be detected by examination of the catheter site. Significant leakage impedes effective dialysis. Dwell volume may be decreased temporarily. Corrective sutures may be necessary to resolve persistent leakage. If dialysate is retained in the peritoneal cavity (progressive abdominal distention and discomfort), the integrity of the catheter system must be evaluated.

14. What measures should be taken if effluent exceeds dialysate input?

Fluid losses from the patient into the dialysate may be excessive. On the other hand, this scenario may be desirable if the patient is fluid-overloaded or receiving large volumes of parenteral fluid supplementation. Deviations from ideal exchange efficiency can be monitored to demonstrate inappropriate fluid loss or gain. If effluent production is inappropriately excessive, the osmolality of the dialysate solution should be reduced to minimize osmotic pull. Intravenous fluid supplementation is adjusted to prevent dehydration or fluid overload.

15. What findings suggest the development of peritonitis?

Bacterial peritonitis is a serious complication of peritoneal dialysis and usually results from touch contamination of catheter tubing or bag spikes. Clinical findings or effluent characteristics may be the first indicator of peritonitis. Abdominal pain, vomiting, depression, and fever may indicate peritonitis; however, most of these signs may be difficult to differentiate from signs of uremia. Cloudy or bloody effluent may suggest peritonitis; periodic cytologic evaluation of effluent is recommended regardless of gross appearance. Peritonitis is diagnosed if two of the following three criteria are met: (1) cloudy dialysate fluid with neutrophilic inflammatory cells (> 100/ml); (2) detection of organisms in effluent by Gram stain or culture; and (3) clinical signs of peritonitis.

16. How is peritonitis managed in peritoneal dialysis?

When peritonitis is suspected, effluent is cultured for aerobic and anaerobic organisms. Broad-spectrum antimicrobial treatment (e.g., parenteral cephalosporin) is initiated pending culture and antimicrobial susceptibility results. Antimicrobial agents are often added to dialysate in human patients but are probably best administered systemically in veterinary patients, especially when dosing becomes difficult because multiple or partial exchanges will be made from a single dialysate bag.

17. What are other complications of peritoneal dialysis?

Complications of peritoneal dialysis include catheter complications, metabolic complications, and other miscellaneous problems. Catheter occlusion, exit site and subcutaneous tunnel infections, and leakage of dialysate are the most common catheter complications. Metabolic

complications include blood and protein losses, hyponatremia, hypokalemia, and hyperglycemia. Dialysis dysequilibrium is an uncommon complication of early dialysis. Rapid removal of urea and other osmotic products from the plasma creates an osmotic gradient with subsequent movement of water into cells and the potential for cerebral edema. Symptoms include restlessness, vomiting, dementia, seizures, or death.

18. When should peritoneal dialysis be terminated?

Ideally, dialytic support is continued until renal function recovers sufficiently to maintain a clinically acceptable level of azotemia with infrequent or no dialysate exchanges. In reversible acute renal failure, this phase may require several weeks or longer. For acute toxicoses or corrected postrenal azotemia, dialysis may be required for a much shorter period. In other patients, dialytic support and remaining renal function are insufficient to support a reasonable quality of life. The decision to terminate treatment is usually made when clinical signs of uremia are not managed by dialysis, biochemical abnormalities are not corrected, or refractory peritonitis is encountered.

HEMODIALYSIS

19. How does hemodialysis work?

In hemodialysis, blood is removed from the body, circulated through an artificial kidney that simulates the excretory and regulatory functions of the kidney, and returned to the body. Undesirable uremic toxins are removed by transfer across a membrane into the dialysate. Water removal (ultrafiltration) is regulated by manipulating hydrostatic pressures generated in the extracorporeal circuit.

20. How does hemodialysis compare with peritoneal dialysis?

Hemodialysis is 10–20 times more efficient than peritoneal dialysis for management of acute and chronic azotemia and intoxication. Although the equipment and personnel costs for hemodialysis exceed those for peritoneal dialysis, the procedure can be completed efficiently and conveniently in specialized centers. With experience and dedicated personnel, hemodialysis is a practical option for aggressive management of renal failure and intoxications. Hemodialysis also is more practical for prolonged renal support (4–6 months) in patients with slowly reparable renal injury.

21. What are the characteristics of a suitable hemodialyzer?

The ideal artificial kidney must be able to remove small- and medium-molecular-weight waste products while preventing loss of blood proteins, cells, and needed solutes. The system must be able to regulate ultrafiltration (water removal) independently and must be biocompatible.

22. Describe the typical construction of a hemodialyzer.

Hemodialyzers are classified based on construction design and composition of the limiting membrane. The most common type of dialyzer in current use is the hollow-fiber design. The dialyzer is constructed of bundles of small-diameter capillary fibers with multiple tiny pores for diffusion. Blood flows through the hollow fibers in one direction while dialysate is distributed around the fiber bundle in a countercurrent direction. This design provides a large surface area for exchange and minimizes resistance to blood flow while retaining compact size. Membranes are comprised of disposable natural cellulosic material or more expensive but reusable durable synthetic plastic polymers.

23. What are the other components of the hemodialyzer unit?

In addition to the dialyzer, reliable vascular access, an adjustable dialysis delivery system, ultrapure water, and miscellaneous monitoring equipment are required for safe and effective hemodialysis. Dialysis delivery can be prepared and completed manually, but automated systems have simplified this laborious process and minimized the supervision required during dialysis. The delivery system creates the appropriate dialysis composition, temperature, and pH in addition

to regulating the dialysate flow, blood flow, anticoagulant delivery, and the rate of ultrafiltration. Alarms are incorporated into the system to alert operators to blood and air leaks, disconnections, alterations of conductivity, pH, temperature, or pressure changes in the circuit. Neonatal and pediatric systems have advanced sufficiently to be readily adaptable to dogs and cats.

24. How is vascular access maintained for hemodialysis?

Arteriovenous shunts created by cannulating the femoral artery and vein or carotid artery and jugular vein have been traditionally used for vascular access. During dialysis, blood is shunted from the arterial limb into the dialyzer and returned to the vasculature via the venous limb. Between dialysis periods, the limbs of the shunt are connected, leaving a permanent, flowing arteriovenous shunt. Unfortunately, shunts require surgical placement, easily become clotted, and are difficult to maintain in active veterinary patients. Double-lumen transcutaneous vascular catheters have replaced shunts for short- and long-term dialysis in dogs and cats. The catheter tip is placed in the right atrium via the jugular vein, and blood is removed from and returned to this compartment using the two lumens of the same catheter.

25. What is a typical hemodialysis plan for a patient with acute renal failure?

Patients with acute renal failure are initially dialyzed once daily to slowly reduce the predialysis blood urea concentration by 40–50% per treatment. Once the predialysis blood urea nitrogen concentration is below 90 mg/dl, treatments can be extended to every 2–3 days until sufficient renal function has been reestablished to discontinue dialysis. The intensity of the dialysis treatment may be altered by the choice of hemodialyzer, dialysis time, blood flow rate, and ultrafiltration pressure.

26. What is a typical hemodialysis plan for a patient with chronic renal failure?

Dialysis times and prescription are modified in patients with chronic renal failure to provide an acceptable inter-dialysis quality of life with minimal treatments. In moderately azotemic dogs and cats (serum creatinine 6–8 mg/dl), twice weekly dialysis may be sufficient. In more severely affected animals (serum creatinine > 8 mg/dl), dialysis is required three times per week. Dialysis sessions for animals with advanced chronic renal failure are designed to achieve an acute drop in urea concentrations by 85-90% of the pre-dialysis value and to maintain a time-averaged urea concentration of 60 mg/dl or less.

27. What are the common complications of hemodialysis?

Complications that may occur during the dialysis procedure include transient hypotension, vomiting, seizures, clotting in the extracorporeal circuit, and blood loss. These complications can be minimized by using sophisticated dialysis delivery systems, tailoring the dialysis prescription to the patient and fine tuning anticoagulant delivery. Dialysis dysequilibrium may occur with the rapid osmotic shifts of early dialysis and can be avoided by the appropriate selection of hemodialyzer, blood flow rate, dialysate flow rate, and sodium delivery. The most common interdialytic complications include clotting or infection of the vascular access, thrombosis, sepsis and bleeding associated with heparinization.

28. Where is hemodialysis available?

Currently there are three active dialysis centers: (1) the Companion Animal Hemodialysis Unit in Davis, CA (530-752-1393); (2) the Animal Medical Center in New York, NY (212-838-8100); and (3) Veterinary Referral Associates, Inc., in Gaithersburg, MD (301-340-3224). Additional units may become active at teaching hospitals, including Michigan State University and Tufts University.

29. How does one make an appropriate referral for hemodialysis?

For most dialysis centers, telephone consultations are available 24 hours a day to assess the appropriateness of dialysis for individual patients. Dialysis centers encourage early consultation if

dialysis is being considered as a therapeutic modality for acute renal failure or acute intoxication. The earlier an acutely uremic patient is referred, the greater the likelihood of a positive outcome as many of the complications of severe uremia (uremic pneumonitis, encephalopathy, acute respiratory distress syndrome, disseminated intravascular coagulation) and fluid overload can be avoided.

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XIII. Toxicology

Section Editor: I. Michael McFarland, D.V.M.

102. GENERAL TOXICOLOGY AND APPROACHES

Tam Garland, D.V.M., Ph.D.

1. What is toxicology?

Toxicology is the knowledge of poisons, including their chemical properties, identification, biologic effects, and treatment.

2. How is poison defined?

A poison is any substance in any state, whether solid, liquid, gas, ionic, or nonionic radiation, that when placed into or applied to the body interferes with the life processes of the cells by its own inherent qualities without mechanical action and with regard to temperature.

3. Are there natural toxicants?

Yes. Many herbs, plants, mycotoxins, and microbial agents are toxic, although they are natural. Biotoxins from snakes and spiders are natural but are also toxic. The fact that a substance is "all natural" does not mean that it is safe.

4. How is acute toxicity defined?

Acute toxicity refers to the effects of a single dose or multiple doses during a 24-hour period. The toxic effects may become obvious over several days or weeks.

5. What is a chronic toxicity?

Chronic toxicity refers to the effects produced by prolonged exposure of 90 days or longer.

6. What factors should be considered in evaluating potential toxicity?

The physiologic factors, such as breed, species, age, sex, pregnancy, and lactation, are considerations. Also consider the environmental factors such as season, temperature, humidity, and air circulation. Other environmental factors may include the quality and quantity of water, diet, caging size and material used in the cage, and presence of other animals.

7. Is duration of exposure important?

Yes. The duration greatly affects the toxicity. The animal may survive a single exposure but multiple exposures over time may prove lethal. Likewise, multiple exposures may produce a type of tolerance, as with rodents and rodenticides. Both duration of exposure and dose are important.

8. Is the route of exposure important?

Yes. Most common are dermal, oral, and inhalation routes. However, toxicities also occur through intravenous, intraperitoneal, and subcutaneous routes.

9. How much of a substance does it take to poison an animal?

The amount depends on the substance, size of the animal, and even species.

10. What clinical signs may a poisoned animal exhibit?

Poisoned animals exhibit a full range of clinical signs, including vomiting, diarrhea, trembling, shaking, convulsing, coma, problems with the heart, difficulty with breathing, clotting problems, muscle weakness, and muscle stiffness. Poisonings may mimic a number of diseases and can affect all body systems.

11. Are species and breed important in dealing with toxicities?

Yes. Physiologic factors are always a concern. Some species are more sensitive than others. For example, cats may be more sensitive to some insecticides than dogs. Likewise, some breeds may be more sensitive than others. For example, collie and collie-cross dogs may be more sensitive to some heartworm products.

12. Is it possible for more than one animal to be involved?

Yes. Always ask the owners if other pets could have been exposed.

13. Is it important to know immediately if an animal was poisoned?

Sometimes. Some toxic substances, such as cyanide or strychnine, require immediate attention. Other situations are not as critical, and stabilizing the animal may be more important.

14. What is the first thing to do once it is known that an animal has been poisoned?

Make sure that the animal is in stable condition. Treat with appropriate antidote, if available. Treat the clinical signs, and do not harm.

15. Does the length of time between the incident and the time the animal is seen by a veterinarian make a difference?

Yes. The sooner an animal is seen by a veterinarian, the better the prognosis, in most cases.

16. What substances are best to induce emesis?

Apomorphine is the most reliable and most effective. However, it may cause protracted emesis. Apomorphine may be controlled by appropriate narcotic antagonists administered intravenously. It was at one time withdrawn from the market but is now available from pharmacies with the capability to compound substances.

17. Do other products besides apomorphine induce emesis?

Syrup of ipecac is available but it is only 50% effective in dogs. It can be repeated only once within 20 minutes. If emesis does not occur after the second dosage, the syrup of ipecac must be removed by gastric lavage. Syrup of ipecac may be toxic. Copper sulfate is occasionally effective, but it is dangerous. Table salt is dangerous but has been known to cause emesis. Hydrogen peroxide is not highly effective in companion animals, although it does occasionally work. Rompun (xylazine) also has been used as an emetic and is usually effective.

18. When is emesis contraindicated?

Emesis is contraindicated if the animal is unconscious or shows signs of central nervous system (CNS) depression. Respiratory depression may be an indication of CNS depression. If the animal has been intoxicated with a petroleum distillate, emesis is contraindicated. If more than 4 hours have passed since ingestion, emesis is contraindicated. At more than 4 hours after ingestion, probably no toxic substance remains in the stomach, and to cause emesis is to put undue stress on the animal. If you suspect that the animal has ingested an acid or an alkali, the stomach wall may be weakened. Retching may rupture the stomach and allow the substance to reinjure the esophagus and oral cavity.

19. When has it been too long after consumption to consider inducing emesis?

The general rule is that when it is longer than 4–5 hours since ingestion, emesis will probably not benefit the animal.

20. What is the mechanism of activated charcoal?

Charcoal is activated by increasing the surface area of the charcoal and heating it. It provides a surface onto which the substance is absorbed.

21. How much activated charcoal should be given?

Make a slurry with water and activated charcoal. Use 1 gm charcoal/5–10 ml of water, and calculate the dose at 2–8 gm of charcoal/kg of body weight. Administer through an orogastric tube using a funnel or large syringe. Administer a saline cathartic 30 minutes after the charcoal. For best results, the activated charcoal should be readministered 4 times/day for several days after intoxication.

22. What type of activated charcoal is best?

Use an activated charcoal of vegetable or petroleum origin. Do not use activated charcoal of animal origin.

23. Why is syrup of ipecac not recommended if charcoal is used?

Syrup of ipecac renders the charcoal inactive and incapable of adsorbing toxic particles. Likewise, the charcoal binds the syrup of ipecac and renders it unable to produce vomition.

24. What is a saline cathartic?

A cathartic is a substance causing evacuation of the bowels. Sometimes evacuation results from increasing bulk, sometimes from stimulating peristaltic action. A saline cathartic increases fluidity of the intestinal contents by retention of water by osmotic forces and indirectly increases motor activity. Sodium sulfate is a salt, and saline refers to a salt.

25. How is a saline cathartic made? How is it administered?

A saline cathartic is made by mixing either sodium sulfate or magnesium sulfate with enough water to form a thin paste, similar to the consistency of Milk of Magnesia or slightly thinner. The mixture should be administered orally or through a gavage tube or esophageal tube, if the animal is anesthetized. Sodium sulfate is generally preferred and should be administered at approximately 1 gm/kg of body weight. Magnesium sulfate is an alternative to sodium sulfate.

26. Why is a cathartic, especially a saline cathartic, recommended after treatment with activated charcoal?

Activated charcoals are adsorbents. Substances adsorbed to the charcoal also may desorb; hence, the use of a cathartic hastens elimination of the substance while it is still adsorbed to the surface of the charcoal. The mechanism of a saline cathartic is to increase fluid in the bowel osmotically and cause emptying. It does not interfere with other physiologic processes within the body that result from treatment or poisoning.

27. Why is pentobarbital better for a seizing animal than phenobarbital when the seizure is not epileptic?

Pentobarbital allows much faster control of the seizing animal. In cases such as strychnine poisoning, it is important to give the patient relief as quickly as possible because the respiratory muscles are paralyzed. Phenobarbital has a latent period between administration and action. This latent period may be as long as 20 minutes, in which time a seizing patient can die. Therefore, it is appropriate to use an agent that relieves the seizure activity quickly.

28. If I suspect that my patient has eaten a toxic plant, can the diagnosis be confirmed before the patient dies?

Yes, sometimes. History and access to vomitus are the most useful tools. The easiest method is a complete history. Some animals shred a plant without actually consuming it. If portions of the plant can be brought to the clinic, they should be carefully examined to ascertain whether the plant

was shredded or eaten. The vomitus can be inspected in a laboratory, usually by a toxicologist competent with microscopic plant particles, to determine what plant was consumed. If the stomach is gavaged, then resulting fluid may be examined.

29. What is the best way to treat an animal suspected of having a poisonous plant intoxication?

If the plant is identified and specific treatment is available, that is the best treatment. If the plant does not have a specific treatment or the plant is unknown, symptomatic treatment is best. Emesis may be indicated to remove as much of the plant from the animal's system as possible.

30. What is the best approach when an animal is believed to have been poisoned?

The first step is to stabilize the animal. If it is seizing, control the seizures; otherwise it is important to follow the ABC rule. That is, establish an airway that is not blocked by some structure; make sure the animal is breathing; and make sure that cardiac output is sufficient to sustain life. Treat the signs exhibited by the animal. Often an owner is convinced that the animal was poisoned by some other substance that may not be consistent with the clinical picture.

31. What information should be recorded in case of litigation in relation to a poisoned animal?

With any case, it is important to keep accurate and detailed records. Records should indicate what procedures were performed and the results. If you are suspicious that the case may involve a legal issue, notify the laboratory. You can always save some samples of vomitus or other tissues in a refrigerator—not a freezer. Your records are legal documents and can be subpoenaed.

32. How can I really find out if the animal has been poisoned?

A thorough history is important. It is probably the best start to solving the mystery. However, at times a toxic diagnosis is the only thing left. Many cases of toxicosis mimic other diseases and situations and may be difficult to definitively diagnose. Others are highly specific, and there is no question. Submitting the proper samples to a diagnostic laboratory can be helpful in determining whether the animal has been poisoned.

33. Why are some substances classified as more toxic than other substances?

Classification is based primarily on how much of the substance is required to induce an intoxication. Perhaps it is best explained by the chart below:

Toxicity Rating Chart

CLASS	TOXICITY
Extremely toxic	≤ 1 mg/kg
Highly toxic	1–50 mg/kg
Very toxic	50–500 mg/kg
Moderately toxic	0.5–5 gm/kg
Slightly toxic	5–15 gm/kg
Practically nontoxic	> 15 gm/kg

34. What is a dose-response relationship?

For every dose of a substance there is a response, even if the response is death. The dose-response relationship is defined as the level of exposure vs. the magnitude of the biologic reaction. It is possible for a veterinarian to induce toxicity by administering an improper dose of a pharmacologic agent or for an inappropriate amount of time. Pharmacologic agents can cause toxicities, and veterinarians may be responsible for toxicities if proper procedures are violated.

35. Is there a difference between tolerance and action level?

Tolerance level is the maximal quantity of chemical or drug that can legally appear in food for human consumption or in animal feeds. This level is legally set by regulatory agencies and is

published in the Code of Federal Regulation or Federal Register. An action level is similar, but it is a guideline and is not legally established. However, regulatory agencies use it in a similar manner as a tolerance.

36. Is there a difference in first-order and zero-order toxicokinetics?

In zero-order kinetics a fixed quantity is excreted during a given time, e.g., 10/mg/kg/day. First-order kinetics is a constant fraction or percentage of a chemical excreted per unit time. First-order kinetics is most common.

37. Why is it important to know if a substance is first-order or zero-order kinetics?

This information allows an estimate of how long the animal may have a potentially dangerous amount of a substance in the body, particularly pharmaceutical products that pets occasionally consume, usually in an accidental setting.

38. When I take a history of an animal, what factors may help to determine whether the animal has been poisoned?

A thorough history is informative and helpful. Histories of particular interest include prior consumption of nonfood items. Sometimes a plant is shredded without consumption. Clues to toxicities are often found in the vomitus or urine. A toxicologic or diagnostic laboratory study is most useful. How attentive the owner is to the animal and its surroundings may give clues to the health status of the animal. Animals that are prone to investigate garbage are more likely to experience toxicities of various natures. Indications from the owner concerning new additions to the surroundings are important. For example, new rugs, new plants, or recent insect treatment to the yard or home are important clues.

39. What are the goals of therapy in treating a poisoned animal?

Goals of therapy always involve emergency intervention and prevention of further exposure. Delay further absorption, whether by bathing or emesis. Application of specific antidotes and remedial measures is important. If possible, hasten the elimination of the absorbed toxicant. Be sure to institute appropriate supportive therapy. If possible, determine the source of the toxicant, and educate the client.

40. Describe the procedure of gastric lavage.

Gastric lavage may be an important way to remove a substance from an animal's stomach. The animal should be unconscious or under light anesthesia with a cuffed endotracheal tube that extends beyond the teeth. Measure the orogastric tube from muzzle to xiphoid cartilage, and mark the tube. The orogastric tube should be the same size as the endotracheal tube. Slightly lower the head and thorax of the animal. Use 5–10 ml/kg of lavage solution for infusion. Aspirate the solution from the stomach using a large aspirator bulb or 50–60-ml syringe. Repeat the cycle 10–15 times. Activated charcoal increases efficiency. It is important to use low pressures and not to force the fluid. Reduce the volume if there are signs or suspicion of a weakened stomach. Do not rupture the esophageal or gastric walls.

41. Is it important to rid the body quickly of a toxin?

Yes. The more quickly a toxicant is removed, the less damage is likely to be done.

42. How can I hasten the elimination of a toxic substance from the body?

Activated charcoal followed by a cathartic, especially a saline cathartic, is one of the best methods to hasten elimination. Always follow activated charcoal with a cathartic. If the substance is water-soluble and can be excreted in the urine, fluid diuresis and ion trapping may be helpful.

43. What methods of eliminating a toxicant from the body are important to consider?

Animals eliminate waste by defecating and urinating. Vomiting may on occasion be a method of elimination as well as gastric lavage. Exhalation and lactation are also routes of

elimination. Lactation may intoxicate nursing animals also. If a substance is not water-soluble and is not absorbed by the body, it is likely to be passed in the feces or enter the enterohepatic circulation, which may prolong exposure to a toxic substance. If the substance is water-soluble, it may be excreted in the urine. Fluid diuresis and ion trapping may be helpful.

44. Describe the mechanism of ion trapping. Where in the body can it be used?

The pH of urine may be manipulated so that the substance in question is not reabsorbed. By alkalinizing the urine, products that are acidic are trapped and not reabsorbed; therefore, they are excreted. Likewise, basic substances may be trapped in the bladder by acidifying the urine. This phenomenon is known as ion trapping. Ion trapping may also occur within the stomach.

45. What is the best way to submit stomach contents to a veterinary diagnostic laboratory?

Stomach contents should be submitted in a clean glass jar or clean plastic bag. Stomach contents should be refrigerated, not frozen. If you must ship them to a laboratory, be sure to include adequate ice to keep the sample cool.

46. What is the best tissue to test for organophosphate? How should the tissue be submitted to a veterinary diagnostic laboratory?

The best tissue to test for organophosphates is the brain. Testing the brain for organophosphates is a bit of a misnomer. The brain is actually tested for depressed acetylcholine activity, which indicates probable exposure to organophosphates. If the brain is autolyzed, acetylcholine activity is depressed also. Be sure to keep the brain well chilled, but not frozen.

47. How do you treat a cat that presents with aspirin or acetaminophen intoxication?

Methylene blue has been controversial. It has been maintained for years that it is toxic to cats. However, current work suggests that it may be acceptable, if given with care. The standard treatment has been acetylcysteine (Mucomyst) in a sterile 1–20% solution given at 140 mg/kg orally every 8 hours. Ascorbic acid also may be given at the rate of 200 mg orally 3 times/day.

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103. ETHYLENE GLYCOL INTOXICATION

J. Michael McFarland, D.V.M.

1. What is the lethal dose of ethylene glycol?

In dogs the minimal lethal dose is approximately 4.4–6.6 ml/kg or less than ½ cup for a 10-kg dog. Cats are considerably more sensitive, requiring only 1.4 ml/kg of the full strength solution or 1½ tsp for a 5-kg cat.

2. What is the pathophysiology of ethylene glycol intoxication?

The effects of ethylene glycol are dose-dependent. When a large volume is ingested, the patient may progress to coma and death within a few hours, primarily because of the direct effect of ethylene glycol on the central nervous system (CNS). If the patient survives this initial phase, oxidation via alcohol dehydrogenase in the liver leads to the production of metabolites capable of

elimination. Lactation may intoxicate nursing animals also. If a substance is not water-soluble and is not absorbed by the body, it is likely to be passed in the feces or enter the enterohepatic circulation, which may prolong exposure to a toxic substance. If the substance is water-soluble, it may be excreted in the urine. Fluid diuresis and ion trapping may be helpful.

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causing severe metabolic acidosis and renal tubular epithelial damage. The ethylene glycol metabolites include glycoaldehyde, glycolate, glyoxalate, and oxalate. Oxidation of glycolate is the rate-limiting step in ethylene glycol metabolism and allows accumulation of glycolate in the serum. CNS depression from the effects of glycoaldehyde may be accentuated by metabolic acidosis and a high osmolal gap. The other metabolites, particularly glycolate, can cause severe damage to the renal tubular epithelium. If left untreated, anuric renal failure may develop within 1–4 days.

3. How does formation of calcium oxalate crystals contribute to the development of renal failure in dogs and cats exposed to ethylene glycol?

Oxalic acid (oxalate) combines with calcium in the serum and eventually crystallizes in the renal tubules. Although the damage caused by calcium oxalate crystals is thought to be relatively minor, the exact mechanism of renal tubular damage is unknown. The presence of calcium oxalate crystals in the urine may have a more important role in diagnosis than pathogenesis.

4. Describe the clinical signs and symptoms associated with ethylene glycol intoxication.

The initial symptoms are similar to those of alcohol intoxication, including depression, stupor, ataxia, knuckling, hypothermia, and vomiting. Unfortunately, these symptoms occur within a few hours of ingestion and frequently go unnoticed by the owner. If the quantity ingested is sufficient, polyuria, polydipsia, and dehydration develop within 12 hours. Thereafter symptoms are associated primarily with oliguric renal failure. Ethylene glycol-intoxicated cats may develop renal failure in 12–24 hours. Dogs usually experience renal failure within 24–72 hours. Nonspecific signs include oral ulceration, hypersalivation, vomiting, oliguria with isosthenuria, and eventually (within 4 days) anuria.

5. How can serum osmolality be used in diagnosis?

Ethylene glycol is an effective antifreeze due to its low-molecular-weight osmotic activity. After ingestion, ethylene glycol significantly raises serum osmolality within 1 hour. Hyperosmolality usually peaks within 6 hours and remains elevated for up to 24 hours. Normal serum osmolality in the dog and cat is 280–310 mOsm/kg. The normal osmolal gap is less than 10 mOsm/kg. Osmolal gap is the difference between measured serum osmolality and calculated osmolality. A formula for calculating serum osmolality (in mOsm/kg) is as follows:

$$1.86\ (Na + K) + glucose/18 + BUN/2.8 + 9$$

where N = sodium, K = potassium, and BUN = blood urea nitrogen. Ingestion of ethylene glycol can cause characteristically high osmolar gaps (> 30 in cats and > 50 in dogs). Discovering a high osmolar gap in an acutely depressed or vomiting animal may be an effective way of diagnosing ethylene glycol intoxication. However, because of the potential delay in presentation, a low serum osmolality does not rule out ethylene glycol exposure.

6. What other common laboratory findings are associated with ethylene glycol intoxication?

The metabolites of ethylene glycol are potent organic acids. Therefore, severe metabolic acidemia develops within a few hours of ingestion. The presence of these organic acids increases the anion gap (AG) significantly. Anion gap (normal = 10–15 mEq/L) is calculated as follows:

$$AG = (Na + K) - (HCO_3 + Cl)$$

Urinalysis is important in the diagnosis of ethylene glycol intoxication. Calcium oxalate crystalluria is a consistent finding. These crystals occur in several forms. The most common associated with ethylene glycol ingestion is the monohydrate (6-sided prism) crystal. In addition, urine specific gravity decreases by 3 hours after ingestion to the isosthenuric range (1.012–1.014). Another consistent finding is a low urine pH. Hematuria, proteinuria, and glucosuria are less common findings. With the onset of renal failure, azotemia and hyperphosphatemia develop. As renal failure progresses, hyperkalemia occurs. Consumption of calcium by chelation with oxalic acid leads to hypocalcemia.

7. Are any other reliable diagnostic tests available?

In-house ethylene glycol test kits are readily available, but they are not reliable 18 hours after ingestion. False-positive results may occur if substances containing propylene glycol (e.g., some forms of activated charcoal) are administered before testing. In addition, presence of glycerol or metaldehyde (snail bait) may lead to a positive result. However, a positive result in conjunction with appropriate history and clinical signs is a strong indication for treatment. The test may not be sensitive enough to identify exposure in cats.

Renal ultrasonography also may be a tool in early diagnosis. Within 4–6 hours of ingestion an increase in cortical echogenicity may be observed.

8. Describe the goals of treatment in ethylene glycol intoxication.

As with most other types of intoxication, the first goal of treatment is to prevent absorption. Vomiting should be induced if ingestion has occurred within 2 hours. However, care should be taken with severely depressed patients. Gastric lavage and administration of activated charcoal also are indicated.

The metabolites of ethylene glycol are primarily responsible for the life-threatening damage. Nearly all of the ethylene glycol ingested is excreted or metabolized within 48 hours. Therefore, it is extremely important to interfere with the action of alcohol dehydrogenase (ADH) on ethylene glycol as soon after exposure as possible. Ideally, therapy with an ADH inhibitor should be started within 3 hours of ingestion in cats and within 8 hours of ingestion in dogs.

Supportive care and close monitoring are crucial. Fluid therapy is necessary to correct electrolyte and acid-base imbalance, restore hydration, increase tissue perfusion, and promote diuresis. Fluid rates should start at 3 times daily fluid maintenance and be adjusted as needed. Use the following formula to calculate daily fluid maintenance requirements:

$$\text{Daily fluid maintenance requirement (ml)} = (30 \times \text{kg body weight}) + 70$$

A conservative approach to bicarbonate supplementation is recommended, taking into account the positive effect of fluid therapy on acid-base disorders. The following formula may be used to determine sodium bicarbonate requirements:

$$\text{mEq of sodium bicarbonate needed} = (\text{body weight [kg]} \times 0.3 \times [12 - HCO_3])/3$$

Diazepam may be administered as needed for seizure control. In addition, 10% calcium gluconate (0.5–1.5 ml/kg slow bolus) may be necessary. Other considerations include protection of the airway, oxygen with or without ventilation, and use of pressor agents.

9. What methods can be used to inhibit ethylene glycol metabolism by alcohol dehydrogenase?

The classic method of preventing ethylene glycol metabolism is infusion of 20% ethanol. Ethanol has a higher affinity for ADH than ethylene glycol. In dogs, the suggested dose is 5.5 ml/kg given intravenously every 4 hours for 5 treatments, then every 6 hours for 4 treatments. In cats, the suggested dose is 5 ml/kg IV every 6 hours for 5 treatments, then every 8 hours for 4 treatments. Bolus injections are not recommended. The ethanol should be administered slowly over 1 hour or delivered by constant-rate infusion.

The disadvantages of ethanol infusion include increased severity of CNS depression, acidemia, hyperosmolarity, and hypothermia. An ideal ADH inhibitor in dogs, with no side effects, is 4-methylpyrazole (4-MP; Antizol-Vet, Orphan Medical, Minnetonka, MN). 4-MP is not currently recommended for use in cats. Due to the rapid metabolism of ethylene glycol in cats, 4-MP would have to be administered concurrently to be effective. The suggested protocol for 4-MP treatment is as follows:

INITIAL LOADING DOSE	12 AND 24 HOURS AFTER INITIAL DOSE	36 HOURS AFTER INITIAL DOSE
20 mg/kg	15 mg/kg	5 mg/kg

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104. LEAD POISONING

Colleen Murray, D.V.M.

1. What are the most common sources of lead exposure for companion animals?

The most common route of entry of lead is through the gastrointestinal tract. Lead sources include flaking paint from buildings painted prior to 1950, ashes from lumber painted prior to 1950, curtain weights, fishing sinkers, old lead toys, storage batteries, paint flakes and dust from bridges and water towers, artist's paints, solder, lead shot, lead glazed pottery, linoleum, putty, industrial pipe dope compounds, gasoline, motor oil, tar paper, golf balls, roofing materials, insulations, lead emissions that settle on soil or vegetation, and some inks and dyes.

2. What are the clinical signs of lead intoxication?

The primary signs are gastroenteritis and neurologic problems. As a rule, the neurologic signs predominate in acute, high level exposure to lead, whereas gastrointestinal signs result from lower, long-term exposures. The most common neurologic signs are convulsions, hysteria (barking, crying, running, indiscriminate biting), ataxia, tremors, blindness, clamping of jaws, grinding of teeth, and other behavioral changes. Such clinical signs may be mistaken for canine distemper and rabies. The most common gastrointestinal signs are vomiting, abdominal pain, tense abdomen, and anorexia.

3. What are the most common laboratory and radiographic findings?

Of prime importance is the finding of large numbers of nucleated erythrocytes (5–40+/100 white blood cells) without anemia. Other common findings include neutrophilic leukocytosis, basophilic stippling, and other abnormalities of red blood cell morphology.

The most helpful radiographic finding is the presence of radiopaque material in the gastrointestinal tract. However, it is impossible to differentiate these radiographic densities from

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The most helpful radiographic finding is the presence of radiopaque material in the gastrointestinal tract. However, it is impossible to differentiate these radiographic densities from

substances such as bone and gravel. Lead shot is a common radiographic finding in hunting dogs; it is typically not a problem in mammals but may be in birds. A small number of young, rapidly growing dogs may develop lead lines on the metaphyses of long bones. Lead lines are difficult to distinguish and are best seen proximal to the open epiphysis of the distal radius, ulna, and metacarpal bones.

4. What diagnostic tests are available?

Chemical detection of lead intoxication is best confirmed by abnormally high levels of lead using heparinized whole blood (check with the local laboratory for other blood-testing options). Blood levels > 0.4 ppm associated with clinical signs are diagnostic (normal = 0.05–0.25 ppm). Feces, liver, and kidney can also be tested. Lead levels greater than 35 ppm indicate exposure to lead in the feces. Lead levels greater than 5 ppm in the liver and 10 ppm in the kidney are significant.

5. What is the treatment?

Therapy for lead poisoning involves removal of lead from the gastrointestinal tract, blood, and body tissues; alleviation of neurologic signs; and prevention of reexposure. Lead should be removed from the gastrointestinal tract with enemas, emetics, and possibly surgery for large items in the stomach and intestines. Chelating agents have been used historically to bind to the absorbed lead, forming nontoxic, water-soluble complexes that can be excreted via the urine or bile. In the past, $CaNa_2EDTA$ has been the drug used for treatment. The dosage ranged from 75–110 mg/kg daily for 2–5 days. The daily dose is divided into 4 equal parts and given subcutaneously after dilution to a concentration of about 10 mg $CaNa_2EDTA$/ml in a 5% dextrose solution (high concentrations of $CaNa_2EDTA$ can be painful). $CaNa_2EDTA$ may be given by slow intravenous push in critically ill animals. Multiple treatments can be used in combinations of 5 days on, 5 days off. $CaNa_2EDTA$ is not without side effects. It may produce a reversible, acute necrotizing nephrosis, gastroenteritis, and depression. It should never be given to an animal in the absence of adequate hydration or urine flow. Rapid mobilization of lead from bone can aggravate signs of lead poisoning or even kill dogs with high body burdens of lead. $CaNa_2EDTA$ can also deplete other vital metals by nonspecific binding with zinc, copper, and iron.

The oral chelating agent D-penicillamine can be used in animals that are not acutely ill. It also may be used as a follow-up treatment to $CaNa_2EDTA$. Dosages range from 35–110 mg/kg divided into 3 or 4 daily doses for 1 week on, 1 week off. Multiple treatments may be needed for total recovery. D-penicillamine also may have adverse side effects. It is contraindicated in animals with penicillin allergies and may cause renal damage.

The drug of choice for lead intoxication is meso-2,3 dimercaptosuccinic acid (DMSA) (Chemet, McNeil Consumer Products Co., Fort Washington, PA). DMSA is a more specific chelator than $CaNa_2EDTA$, binding to the highest degree with lead, mercury, and arsenic. It does not deplete other body metals. Chelated metals are excreted in urine. Unlike $CaNa_2EDTA$, DMSA is not associated with chelation-induced absorption of lead from the gut or mobilization of lead into the body during therapy. In the original study by Ramsey, dogs treated with DMSA suffered no side effects except reports of halitosis and malodorous feces, characterized by an unpleasant sulphur smell. Dogs are treated with gelatin capsules at a dosage of 10 mg/kg every 8 hrs orally for 10 days.

6. What is the public health significance of lead intoxication?

The veterinarian should consider companion animals a sentinel for lead. The pet owner should be fully informed of the risk that lead presents for humans, especially children. If the situation indicates potential exposure, everyone in the home should be referred to the family physician for lead testing. Every effort should be made to identify the source of lead intoxication and to eliminate it from the environment. If identifying the source proves impossible, the pet should be tested for reexposure at selected intervals.

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105. ORGANOPHOSPHATE AND CARBAMATE TOXICITY

J. Michael Walters, D.V.M.

1. What are the two classes of cholinergic pesticides? Why do they cause toxicity?

The most common types of cholinergic pesticides formulated for use in cats and dogs are the organophosphates (OP) and carbamates. They are widely used in the control of fleas and ticks. Toxicoses can occur from accidental exposure, intentional misuse, and rarely, from idiosyncratic or allergic hypersensitivity reactions in cats and dogs. These two classes of pesticides differ in chemical structure and site of action on the acetylcholinesterase enzyme. Organophosphates are acetylcholinesterase inhibitors that disable the enzyme by an irreversible binding process known as "aging," whereas carbamates are reversible cholinesterase inhibitors. The signs of poisoning are similar.

2. What nervous pathways are affected by cholinergic pesticides?

Clinical signs are usually correlated with an overriding of the parasympathetic pathways but also may result from sympathetic stimulation. Acetylcholine stimulates nicotinic receptors of the somatic nervous system, parasympathetic preganglionic nicotinic and muscarinic postganglionic receptors, and sympathetic preganglionic nicotinic receptors. The effector organ of the somatic nervous system is skeletal muscle. Effector organs of the parasympathetic nervous system are the iris, cardiac muscle, blood vessels, smooth muscle of the lungs, smooth muscle of the gastrointestinal (GI) system, and exocrine glands. Effector organs of the sympathetic nervous system can be stimulated through preganglionic cholinergic neuron stimulation of the postganglionic adrenergic neurons in the adrenal gland, cardiac muscle, iris, blood vessels, smooth muscle of the lungs, smooth muscle of the GI system, and exocrine glands. The degree to which the parasympathetic or sympathetic nervous pathways is stimulated depends on many factors and explains the mix of clinical signs.

3. Where and how do cholinergic pesticides effect their toxicity?

Under normal conditions there is rapid hydrolysis of acetylcholine by acetylcholinesterase after neurochemical transmission at autonomic and neuromuscular synapses. In OP poisoning, phosphate radicals covalently bind to an active site on the enzyme, rendering it inactive. This process of producing an inactive enzyme is known as "aging," which is believed to fix an extra charge to the protein, altering the active site and thereby preventing regeneration. This inhibition of the acetylcholinesterase activity allows accumulation of acetylcholine at the synapses, resulting in overstimulation and later disruption of transmission in the CNS, parasympathetic nerve endings, some sympathetic nerve endings, somatic nerve, and autonomic ganglia. Carbamates lead to carbamylation of acetylcholinesterase; this bond is broken down within 48 hours with regeneration of acetylcholinesterase to the active form of the enzyme.

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4. Where are the compounds absorbed? How are they metabolized?

Most of the compounds are absorbed from the conjunctiva, skin, lungs, and GI tract. Once absorbed, they undergo extensive hepatic biotransformation, the route and rate are highly species-specific.

5. What are the clinical signs of toxicity due to cholinergic pesticides?

Clinical signs of OP or carbamate toxicoses most commonly result from parasympathetic stimulation. Clinical signs include vomiting, depression, hypersalivation, muscle tremors, diarrhea, ataxia, anorexia, hyperthermia, dyspnea, seizure, weakness, and death. Classic signs of toxicosis include miosis and bradycardia. Chronic signs of toxicosis include anorexia, muscle weakness, and twitching that may occur in cats with or without episodes of acute toxicoses. Occasionally signs of sympathetic nervous system stimulation can occur, such as tachycardia, and should not be considered inconsistent. Carbamate-containing pesticides, such as carbofuran, can produce rapid onset of seizure and respiratory failure and require aggressive therapy.

6. What OP and carbamate pesticides are commonly available?

Organophosphate compounds commonly available include chlorpyrifos, cythioate, diazinon, dichlorvos, fenthion, phosmet, tetrachlorvinphos, and safrotin. Carbamate insecticides include carbaryl, propoxur, methomyl, and bendiocarb. Individual toxicity varies and depends on the route of exposure.

7. How is the diagnosis made?

History of exposure associated with clinical signs of parasympathetic and skeletal muscle stimulation warrants a tentative diagnosis of poisoning. Chemical analyses are generally unrewarding because rapid metabolism results in low tissue levels. Recent evidence has shown that metabolites of these pesticides may be detected in the urine and may aid in the diagnosis. Finding insecticide in the stomach contents can be quite valuable in establishing the diagnosis. Assessing the degree of inhibition of acetylcholinesterase activity in whole blood, serum, or tissue of the affected animal may be of some benefit in confirming the diagnosis, but should not be relied on in the acute treatment phase. A reduction in whole blood/serum acetylcholinesterase activity to less than 25% of normal is indicative of excessive exposure. Depending on the insecticide used, the acetylcholinesterase activity in dogs may remain depressed for several days to several weeks after exposure. Some acetylcholinesterase activity depression is to be expected after routine use of insecticides. Therefore, whole blood/serum acetylcholinesterase activity should be viewed only as an indication of the status of the acetylcholinesterase enzymes in the body. Acetylcholinesterase activity can be measured in the brain and generally is less than 10% of normal activity in affected animals. For best laboratory results, whole blood/serum and brain tissue samples should be well chilled or frozen before submission. A sagittal half of the brain should be submitted, because laboratories vary in the portion of the brain used for determination of acetylcholinesterase activity. Samples of stomach contents as well as any suspected material should be frozen and submitted to the laboratory for chemical analysis. Other biochemical analysis can be performed such as complete blood count, serum chemistry panel, liver function tests, electrocardiogram, and chest radiographs.

8. What is the emergency management?

Effective supportive care is paramount, as is the use of specific antidotes. The ABCs of emergency case management should be followed. Establish an airway, and provide oxygen as necessary. Respiratory distress may be due to excessive secretions, bronchospasm, pulmonary edema, chemical pneumonitis, aspiration, adult respiratory distress syndrome, muscle weakness, or paralysis. Intravenous access should be established in severe cases, and specific therapy should be instituted. A detailed history of pesticide exposure and use, active ingredients, clinical signs, onset and duration of clinical signs, and exposure dose are important. If the patient has ingested an OP or carbamate product within the past 2 hours of presentation and is asymptomatic, an emetic such as 3% hydrogen peroxide (2 ml/kg orally; maximal dose: 45 ml) should be used after feeding a moistened meal. Emesis with hydrogen peroxide is reliable if adequate ingesta are in

the stomach. Alternatively, apomorphine may be used to induce emesis, 0.03mg/kg IV or 0.04mg/kg IM. Apomorphine may also be used topically in the conjunctival sac. In cats, xylazine is somewhat effective at inducing emesis. Dosing at 1.1 mg/kg IM or SQ. Care should be taken when using xylazine as it may aggravate respiratory depression and bradycarida. Xylazine can be reversed with yohimbine, 0.1 mg/kg IV. Induction of emesis after ingestion of a liquid OP should be avoided because of potential aspiration and pulmonary injury from petroleum distillate solvents. Induction of emesis after ingestion of carbamates should be avoided or attempted with caution because of the potential for rapid onset of seizures. Activated charcoal after oral ingestion (2.0 ml/kg orally or via stomach tube) mixed with a cathartic such as 70% sorbitol (3.0 ml/kg) diluted with water should be used to absorb any residual pesticide. Patients who are symptomatic after recently ingesting significant quantities of an insecticide product should be anesthetized and intubated with a cuffed endotracheal tube; gastric lavage should be performed using a large-bore orogastric tube. Gastric lavage should be performed until no more ingesta are evident, followed by a final wash of activated charcoal/sorbitol slurry. If some time has passed since the ingestion of the toxin, activated charcoal/sorbitol without emesis or lavage may have greater efficacy.

If the pet presents with seizures, phenobarbital (6 mg/kg, to effect) and atropine (0.2 mg/kg, 1/4 intravenously, the remainder subcutaneously or intramuscularly) should be used to control the seizure and combat the parasympathetic signs. Diazepam has been shown to potentiate OP toxicosis; the exact mechanism is unknown but is thought to result from activation of muscarinic signs by CNS sedation or by competitive release of bound insecticide. Because of the potential of worsening clinical signs, diazepam should not be used in cases of suspected OP toxicosis. Atropine is administered as needed to control life-threatening clinical signs such as respiratory depression, bronchoconstriction, and bradycardia. Atropine should not be used unless clinical signs are present and should be titrated to effect. Oxygen and ventilator support may be necessary until respiratory function returns to normal.

Clinical signs such as muscle fasciculation, resulting from the nicotinic receptor stimulation by OP, can be reduced by using pralidoxime chloride (2-PAM, Protopam) administered at 10–15 mg/kg intramuscularly or subcutaneously every 8–12 hours. Pralidoxime chloride is most effective when administered within the first 24 hours of exposure. Pralidoxime chloride should be continued for approximately 36 hours before cessation due to lack of improvement. Unused pralidoxime chloride may be refrigerated for up to 2 weeks if wrapped in foil.

Once the animal is stabilized, a mild detergent bath should be performed to remove adherent chemical in cases of dermal exposure and to help reduce further cutaneous absorption or ingestion while grooming. Activated charcoal may benefit even cases of dermal exposure because of biliary excretion and intestinal reabsorption of some OP compounds or metabolites. Dosages of 1 gm/kg every 6–8 hours should be repeated until improvement is evident.

Intravenous fluids, nutritional support, and maintenance of normal body temperature are important. The owner needs to be aware that nursing care and nutritional support may be needed for 1–4 weeks.

9. Are cats any more or less susceptible to OP or carbamates?

Cats can be extremely sensitive to OP and carbamates, especially chlorpyrifos. Chronic OP toxicosis may develop from the purposeful systemic or topical application of insecticidal agents or from a prolonged exposure to a contaminated environment. Cats appear to be more sensitive to chronic OP toxicosis than dogs.

10. What are the signs of chronic OP toxicosis in cats?

Chronic OP toxicosis in cats causes signs of CNS disturbance, including ataxia, lethargy, or anorexia and nicotinic signs of neuromuscular dysfunction, without the classic SLUD (salivation, lacrimation, urination, defecation) signs of the muscarinic syndrome of acute OP toxicosis. Chronic OP toxicosis is more difficult to diagnose because the signs have a much slower rate of onset (days to weeks), are less specific, and mimic signs caused by other systemic, infectious, nutritional, metabolic, and neuromuscular diseases.

11. What is considered a toxic amount of chlorpyrifos in cats?

The oral minimal lethal dose in cats is 10–40 mg/kg. The acute LD50 of chlorpyrifos is 118–245 mg/kg in rats, 504 mg/kg in guinea pigs, and approximately 2000 mg/kg in rabbits.

12. How is chronic chlorpyrifos toxicosis diagnosed in cats?

The diagnosis is similar to that of any other OP toxicosis. History of exposure to a sufficient amount coupled with clinical signs is adequate to make a tentative diagnosis of OP toxicosis. Additional supportive information from blood/serum or tissue acetylcholinesterase activity helps to confirm the diagnosis.

13. How is chronic chlorpyrifos toxicosis treated in cats?

Treatment in cats can be demanding and time-consuming. Most cats are not presented until 2–5 days after exposure. Redistribution of the compound to adipose tissue, particularly subcutaneous fat after dermal exposure, may create a depot effect that slowly releases the pesticide, resulting in continued exposure. Treatment, therefore, may have to be continued for weeks, even if it is initiated within a few hours of exposure.

Atropine (0.2 mg/kg, 1/4 intravenously, the remainder subcutaneously or intramuscularly) as needed and 2-PAM (10–15 mg/kg intramuscularly or subcutaneously, every 12 hr) should be started before bathing or feeding to help reduce the stress of treatments. Stress can trigger a respiratory crisis. Atropine and 2-PAM may be less than effective in cases of chronic OP exposure because of aging of the enzyme-insecticide complex. Diphenhydramine has been shown to help block the effects of nicotinic receptor overstimulation and to improve muscle strength in some animals with OP toxicosis. Other treatment methods, such as bathing, activated charcoal, and supportive care, are also important.

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106. ANTICOAGULANT RODENTICIDE TOXICITY

J. Michael Walters, D.V.M.

1. How were the anticoagulant rodenticides developed?

The anticoagulant rodenticides were developed after investigations of moldy sweetclover poisoning in cattle. A naturally occurring coumarin is converted to dicumarol, the toxic agent. Warfarin was synthesized from this toxic agent while its mode of action was under study. Warfarin has subsequently been widely used as a rodenticide. With continued use, warfarin-based anticoagulant rodenticides began to develop resistance in target animals. Subsequently, more potent rodenticides were developed, which had led to some difficulties in treating the nontarget host. Warfarin and other anticoagulant rodenticides (indandione derivatives) that are not effective against warfarin-resistant rodents are considered first-generation rodenticides whereas those effective against the more resistant rodents are second-generation rodenticides.

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2. Describe their mechanism of action.

The essential toxic mechanism is depletion of vitamin K1. Clotting factors II, VII, IX, and X must bind calcium to be active in clot formation. Dicarboxylic acid groups on the clotting factor form the active site that binds calcium. These factors require vitamin K1 to form the dicarboxylic acid groups. Vitamin K epoxide reductase is the enzymatic lesion of biologic importance; without this enzyme, vitamin K cannot be recycled. This leads to rapid depletion of vitamin K stores, and synthesis of new clotting factors is impaired. Clotting factors II, VII, IX, and X have the shortest half-lives (41, 6.2, 13.9, and 16.5 hours, respectively) in dogs; therefore, they can be rapidly depleted if not replenished. This leads to the "lag-time" that follows ingestion of the bait and onset of clinical signs.

3. How toxic are anticoagulant rodenticides?

Eight different anticoagulant rodenticides are sold over the counter and through exterminators in the United States. Generally, the pest must ingest a first-generation rodenticide for some time before it receives a lethal dose. This led to the development of second-generation rodenticides, which are more lethal with a single dose (one bite, one kill). Single-dose lethality was achieved by maximizing the potency, biologic duration of action, or both. Therefore, second-generation anticoagulant rodenticides are more potent, last longer, or both compared with first-generation anticoagulant rodenticides.

Toxicity of Rodenticides in Dogs and Cats

CHEMICAL	BAIT CONCENTRATION (PPM)	COMPOUND (MG/KG) DOG	COMPOUND (MG/KG) CAT	BAIT (OZ/LB) DOG
Warfarin	250	20–300	3–30	1.3
Fumarin	250	?	?	?
Pindone	250	5–75	?	?
Valone	250	?	?	?
Diphacinone	50	0.9–8	15	0.3
Chlorphacinone	50	?	?	?
Brodifacoum	50	0.2–4	~ 25	0.06
Bromadiolone	50	11–15	> 25	3.5

4. What are the common clinical signs?

Typically, the initial clinical signs include depression, weakness, muffled heart and lung sounds and dyspnea. External signs of hemorrhage include melena, epistaxis, hematemesis, hematuria, gingival bleeding, excessive hemorrhage from a wound, or bruising; these signs may or may not be immediately evident. Internal hemorrhage into the pleural and/or peritoneal cavities is also common.

5. How is the diagnosis made?

Differential considerations include disseminated intravascular coagulation, congenital factor deficiencies, von Willebrand's disease, hyperviscosity syndromes, platelet deficiencies, thrombocytopathies, hepatic failure, hemangiosarcoma and canine ehrlichiosis. Laboratory tests such as a clotting profile (one-stage prothrombin time [OSPT], activated partial thromboplastin time [APTT], fibrin degradation products, platelet count), factor testing, buccal mucosal bleeding times, activated clotting time (ACT), and serology should be considered whenever possible. A thorough history and exposure potential are by far the most important. A positive response to a 24-hour therapeutic trial of vitamin K_1 is also strongly suggestive. Prolongation of coagulation parameters—ACT (> 120–150 sec), OSPT, and APTT—are common. Platelet counts can be normal or decreased. Conclusive laboratory testing is analytical detection of the rodenticide.

6. Does the type of toxin have any influence on the length of the treatment course?

Yes. Once the diagnosis is made, the type of anticoagulant rodenticide has a major influence on the length of treatment. Because no tests distinguish between first- and second-generation anticoagulant rodenticides, proper identification may rely on recovering a package or portion of the agent to determine how long to treat. If the package is unavailable, the owner should be instructed to return to the store where it was purchased so that the active ingredients can be identified. Most first-generation anticoagulant rodenticides require a much shorter length of therapy (7–10 days), whereas second-generation anticoagulant rodenticides may require as long as 4–6 weeks. Below is a list of the common anticoagulant rodenticides and recommended length of treatment:

CHEMICAL NAME	LENGTH OF TREATMENT
Warfarin (first generation)	4–6 days
Diphacinone (second generation)	3–4 weeks
Chlorphacinone (second generation)	3–4 weeks
Brodifacoum (second generation)	3–4 weeks
Bromadiolone (second generation)	3–4 weeks

7. What therapeutic methods are used to treat anticoagulant rodenticides?

Vitamin K_1 is the preferred form of vitamin K. Both parenteral and oral forms are available. The intravenous route should not be used because of the high risk of anaphylaxis. The dosage of vitamin K_1 depends on the type (first- vs. second-generation anticoagulant rodenticide). Second-generation anticoagulant rodenticides require dosages 5–25 times higher than first-generation rodenticides. The most common routes of administration are oral and subcutaneous. Oral absorption of vitamin K may be improved by a fatty meal. A can of food with vitamin K improves absorption 4–5-fold compared with vitamin K administered alone. An initial intramuscular dose of vitamin K_1 may result in a life-threatening intramuscular hemorrhage; therefore, this route should be discouraged for initial therapy. Hypovolemic animals may have poor uptake of the drug from subcutaneous injection, although it is preferred to intravenous injection. With warfarin-based rodenticides, a loading dose of 0.25–2.5 mg/kg subcutaneously can be used, followed by oral medications for 4–6 days. Loading doses as high as the oral dose are often used. For second-generation rodenticides the dosage range is 2.5–5 mg/kg subcutaneously and then orally for 4–6 weeks. Higher dose ranges and longer treatment times are imperative. Most treatment failures with second-generation anticoagulant rodenticides are due to use of the lower warfarin-based treatment regimen for an inadequate time. Because vitamin K has no effect on the metabolism or elimination of the rodenticide, therapy must be maintained until toxic amounts of the material are no longer present within the animal.

When prompt control of hemorrhage is needed, an infusion of fresh or fresh frozen plasma provides concentrations of factors II, VII, IX, and X. This infusion can be repeated every 6 hours if needed. The amount of plasma should be approximately 5–10% of the patient's total blood volume, assuming a blood volume of 90 ml/kg for dogs and 70 ml/kg for cats. When anemia is coexistent, fresh whole blood or packed red blood cells and fresh frozen plasma can be used.

8. Can vitamin K_3 be used to treat anticoagulant rodenticide intoxications?

No. Although vitamin K_3 has been used as a feed additive, it is completely ineffective in the treatment of warfarin or dicumarol toxicity. The production and marketing of injectable vitamin K3 was suspended in 1985 by the Center for Veterinary Medicine of the Food and Drug Administration because it was found to induce Heinz-body anemia, methemoglobinuria, urobilinuria, and hepatic damage at dosages of 25 mg/kg.

9. How do you decide when to stop treatment?

Current recommendations are to measure prothrombin times 2–3 days after cessation of an adequate course of vitamin K1 for the type of anticoagulant rodenticide. Others feel that prothrombin

times are inadequate for mild-to-moderate reductions in factor VII activity (the factor with the shortest half-life) and that more sensitive tests should be used. Proteins induced by vitamin K absence or antagonism (PIVKA) are perhaps unfamiliar to most veterinarians, but once this test is understood, it is quite useful in the diagnosis and treatment of anticoagulant rodenticides. The PIVKA test (Thrombotest, Nycomed Pharma AS, Oslo, Norway) is a sensitive test for coagulation factors II, VII, and X as well as the PIVKA proteins and was developed for the specific control of anticoagulant therapy. If PIVKA remains normal 48 hours after suspected exposure to a rodenticide or 48 hours after cessation of vitamin K1 therapy, there is no need for continued treatment. In dogs with active hemorrhage due to intoxication with one of the long-acting rodenticides, it is safest to continue treatment for 4–6 weeks. The same may be said for animals exposed to an unknown quantity and type of rodenticide. It is advisable to treat them for an extended time rather than to stop treatment prematurely. Theoretically, there is a possibility of greater sensitivity upon reexposure; therefore, owners may want to change the type of rodenticide that they use.

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107. CHOLECALCIFEROL TOXICITY

J. Michael Walters, D.V.M.

1. Besides warfarin, what other rodenticides are in common use?

Rodenticides that contain vitamin D_3 (cholecalciferol) as the active components have recently been introduced, with the claim that they are less toxic to dogs and human beings than to rats. This claim has been challenged by a recent study concluding that these products pose a significant risk to dogs.

2. How long does it take for cholecalciferol rodenticides to work?

In the nontarget host a few days may be all that is required before clinical signs of toxicosis appear. Vitamin D was reported at one time to be a cumulative toxin, requiring 1–2 weeks before its maximal effects on the mineral metabolism occur, but the time probably depends on the amount of rodenticide ingested.

3. What are the typical clinical signs of cholecalciferol toxicosis?

Signs of toxicosis are relatively nonspecific, such as lethargy, anorexia, vomiting, weakness, ataxia, hematemesis, diarrhea and shock. A history of polyuria and polydipsia also may be noted. Most commonly the potential for exposure to a cholecalciferol rodenticide is reported.

4. What are the common biochemical findings?

Biochemical analysis typically indicates hypercalcemia (develops within 12 hours) with concurrent hyperphosphatemia (develops within 18 hours), although normophosphatemia and

times are inadequate for mild-to-moderate reductions in factor VII activity (the factor with the shortest half-life) and that more sensitive tests should be used. Proteins induced by vitamin K absence or antagonism (PIVKA) are perhaps unfamiliar to most veterinarians, but once this test is understood, it is quite useful in the diagnosis and treatment of anticoagulant rodenticides. The PIVKA test (Thrombotest, Nycomed Pharma AS, Oslo, Norway) is a sensitive test for coagulation factors II, VII, and X as well as the PIVKA proteins and was developed for the specific control of anticoagulant therapy. If PIVKA remains normal 48 hours after suspected exposure to a rodenticide or 48 hours after cessation of vitamin K1 therapy, there is no need for continued treatment. In dogs with active hemorrhage due to intoxication with one of the long-acting rodenticides, it is safest to continue treatment for 4–6 weeks. The same may be said for animals exposed to an unknown quantity and type of rodenticide. It is advisable to treat them for an extended time rather than to stop treatment prematurely. Theoretically, there is a possibility of greater sensitivity upon reexposure; therefore, owners may want to change the type of rodenticide that they use.

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107. CHOLECALCIFEROL TOXICITY

J. Michael Walters, D.V.M.

1. Besides warfarin, what other rodenticides are in common use?

Rodenticides that contain vitamin D_3 (cholecalciferol) as the active components have recently been introduced, with the claim that they are less toxic to dogs and human beings than to rats. This claim has been challenged by a recent study concluding that these products pose a significant risk to dogs.

2. How long does it take for cholecalciferol rodenticides to work?

In the nontarget host a few days may be all that is required before clinical signs of toxicosis appear. Vitamin D was reported at one time to be a cumulative toxin, requiring 1–2 weeks before its maximal effects on the mineral metabolism occur, but the time probably depends on the amount of rodenticide ingested.

3. What are the typical clinical signs of cholecalciferol toxicosis?

Signs of toxicosis are relatively nonspecific, such as lethargy, anorexia, vomiting, weakness, ataxia, hematemesis, diarrhea and shock. A history of polyuria and polydipsia also may be noted. Most commonly the potential for exposure to a cholecalciferol rodenticide is reported.

4. What are the common biochemical findings?

Biochemical analysis typically indicates hypercalcemia (develops within 12 hours) with concurrent hyperphosphatemia (develops within 18 hours), although normophosphatemia and

transient normocalcemia have been reported. Varying degrees of azotemia can be found, coupled with inadequately concentrated urine (isosthenuria). Glucosuria and proteinuria also may be present. Complete blood counts generally yield nonspecific findings; a normal or stress leukogram is common. Other findings that are variable include urine cytologic changes and metabolic acidosis.

5. Do any special laboratory or diagnostic analyses confirm the diagnosis?

High-performance liquid chromatography has been used to determine serum levels of 25-hydroxycholecalciferol. It may be difficult to locate a laboratory that performs this analysis, and normal values vary from laboratory to laboratory. If used, it probably is wise to submit samples from similar-aged animals, if possible, to provide a basis for normal. Abdominal ultrasonography of the kidneys can be performed as well. Increased echogenicity of the renal cortex that is indicative of glomerulonephritis, nephrocalcinosis, or tubular necrosis is a common finding in cholecalciferol rodenticide toxicosis and can be used as supportive data of metastatic calcification.

6. What does a differential list include?

Hypercalcemia of malignancy (paraneoplastic syndrome), primary hyperparathyroidism, hypoadrenocorticism, primary renal failure, nutritional oversupplementation, juvenile hypercalcemia and certain plants such as Cestrum sp. (day-blooming jessamine, day Cestrum, wild jasmine). Of interest, cod liver oil was at one time used as a source of vitamin A and D and was thought to be a source of toxicosis.

7. Describe the pathophysiologic changes.

Increased bone resorption coupled with increased gastrointestinal absorption of calcium and phosphorus is responsible for pathophysiologic abnormalities. The result is extensive soft tissue mineralization of the endocardium, blood vessels, tendons, kidneys, and lungs. A calcium and phosphorus product greater than 60 mg/dl (growing puppies may have a higher Ca × P product, perhaps in excess of 100 mg/dl) is considered an indication for metastatic calcification and is associated with microscopic mineralization of tissues.

8. What are the common pathologic and histologic findings in animals poisoned with cholecalciferol?

Severe gastric and intestinal mucosal hemorrhage has been reported, along with patchy mineralization of the cortical renal tubular basement membrane. Multifocal necrosis involves crypt cells in the small intestine as well as the pulmonary alveolar basement membrane.

9. How is it treated?

Treatment of cholecalciferol rodenticides should be aggressive, especially with the potential risk of metastatic calcification. Normal (0.9%) saline should be started to promote diuresis. Dehydration should first be corrected, then a minimum of 2–3 times maintenance provided. Furosemide (1.0–2.0 mg/kg, every 12 hours, subcutaneously or intramuscularly) helps in the diuresis once the animal is well hydrated; prednisolone (1–2 mg/kg, every 12 hours, subcutaneously or intramuscularly) helps to diminish calcium uptake in the gut; and salmon calitonin (Calicimar, USV Laboratories, Tarrytown, NY), (4.0–8.0 U/kg, every 6–8 hours subcutaneously) helps to diminish the resorption of calcium from bone. No well-defined dosage ranges have been established for salmon calitonin, although a wide range is reported. Its use for treating cholecalciferol rodenticide toxicosis has also not been well defined, but the principle is sound. The major biologic effect of calcitonin is inhibition of bone resorption by the suppression of osteoclastic activity and suppression of the recruitment of new osteoclasts from precursor cells. Frequent serum calcium determinations are important, and the dose and frequency of the drug may have to be titrated in order to achieve the desired effect. In humans, relatively mild, infrequent transitory side effects are reported. The signs include dermatologic reactions, urticaria, abdominal cramps, diarrhea, pruritus, and pollakiuria. In animals, anorexia and vomiting have been reported; these signs stopped soon after calcitonin was discontinued. Experimental use of the drug pamidronate

disodium (1.3 mg/kg in 150 mL 0.9% sodium chloride) has been shown beneficial if given within 1 to 8 days post ingestion. It currently is cost prohibitive for most clinical use.

10. What are the long-term treatment goals?

Once the animal is stable and no longer requires intravenous fluid support, it may be possible to discharge. Frequent rechecks of the serum calcium levels should be considered. Oral furosemide, calcitonin, and prednisolone may be continued at home. A calcium-free diet should be suggested. Long-term prognosis is good.

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108. TOXIN-INDUCED SEIZURES

J. *Michael* McFarland, D.V.M.

1. What are the common causes of seizures induced by toxic products?

- Organophosphates and carbamates
- Chlorinated hydrocarbons
- Pyrethrins
- Strychnine
- Metaldehyde
- Lead
- Caffeine
- Pseudoephedrine
- Ethylene glycol
- Drugs of abuse

2. How important is a good history in diagnosing toxin-induced seizures?

History is the most important part of the evaluation, especially when intoxication is suspected. In addition to routine questions about signalment, medical history, systems (e.g., cardiovascular, respiratory, gastrointestinal, renal), and diet, several points should be covered while interviewing the owner:

- Was exposure to a toxin actually observed?
- If so, how was the animal exposed (oral, dermal, inspired)?
- What was the amount and/or duration of exposure?
- Describe the pet's environment and level of confinement.
- When was the pet last seen normal?
- Describe the seizure itself (character, onset, duration).
- Was the seizure triggered by external stimuli (noise, touch, bright light)?
- Describe the pet's behavior and health before the seizure.
- Is anyone in the family taking medications of any kind?
- Is there any possibility for exposure to drugs of abuse? (A little discretion is in order here.)
- Have the neighbors made any threats toward you or your pets?
- Have any baits or insecticides been applied to your yard or your neighbor's yard?

Of course, time is of the essence, especially if the patient presents in status epilepticus. A preprepared questionnaire for the owner may help while you and your staff attend to the immediate medical crisis.

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Of course, time is of the essence, especially if the patient presents in status epilepticus. A preprepared questionnaire for the owner may help while you and your staff attend to the immediate medical crisis.

3. What is the minimal database required for toxin-induced seizures?

A complete blood count and chemistry panel with electrolytes should be run immediately. Urine is collected for urinalysis and toxicology screening. Stomach contents may be submitted for toxicology screening. Blood gas analysis is important, because prolonged seizures, apnea, tachypnea, or the toxin itself may have profound effects on acid-base balance. Cardiovascular monitoring (electrocardiogram and blood pressure) detects cardiac arrhythmias, hypotension, or hypertension. Thoracic and abdominal radiographs help to rule out aspiration, pulmonary edema, and foreign body ingestion.

4. What is the most common cause of toxin-induced seizures?

Insecticides. Organophosphates, carbamates and pyrethrins are found in various shampoos, sprays, and dips that are readily available to pet owners. Accidental exposure and overdose are extremely common. Insecticide toxicity is discussed in more detail in the next chapter.

5. How can metaldehyde intoxication be differentiated from strychnine intoxication?

History alone is usually sufficient; on presentation the two intoxications may look exactly alike. Both can lead to tetanic seizures and status epilepticus. Some metaldehyde baits include carbamate and may cause cholinergic signs (hypersalivating, vomiting) as well. Strychnine is a competitive inhibitor of the inhibitory neurotransmitter glycine. The seizures that result from strychnine intoxication are frequently triggered by external stimuli, such as loud noise or bright lights. Metaldehyde is hydrolyzed by stomach acid to acetaldehyde. The muscle tremors and seizures that result from metaldehyde ingestion are not triggered by external stimuli. In addition, acetaldehyde leads to profound metabolic acidosis, with little or no respiratory compensation in patients with seizures. Examination of stomach contents can be helpful. Most strychnine baits contain a green or pink die marker that may be visible in the ingesta. Metaldehyde may cause the odor of the stomach contents to resemble that of formaldehyde.

6. What are the specific treatment considerations in dealing with strychnine or metaldehyde intoxication?

It may take as long as 24–48 hours before strychnine is completely eliminated in the urine; thus, long-term sedation is needed. Repeated doses of pentobarbital (15–30 mg/kg) or inhalation anesthesia are used for seizure control. Higher doses than normal are often required to achieve complete relaxation. Methocarbamol (150 mg/kg intravenously or orally) may improve muscle relaxation. Diuretics and urinary acidifiers such as ammonium chloride enhance urinary excretion. Urinary acidification is contraindicated if the patient has acidosis or myoglobinuria. Close monitoring is extremely important, because respiratory depression and hypothermia are common sequelae of long-term barbiturate sedation. The patient should be kept in a warm, dry, dimly lit location.

Seizure control for metaldehyde intoxication is similar to that for strychnine intoxication. In addition, profound acidosis may require attention. Intravenous fluid administration with lactated Ringers' provides enough buffering to control acidosis in most cases. When possible, blood gases should be evaluated. If serum bicarbonate levels are less than 12 mmol/L, sodium bicarbonate supplementation is recommended. Continued supportive care and monitoring may be necessary for as long as 4 days. In some patients, death occurs 3–4 days later as a result of hepatic failure.

7. What common items found around the house can lead to seizures after ingestion?

Methylxanthines, such as chocolate and caffeine, are the most common. The approximate LD_{50} for methylxanthines is 100–500 mg/kg. Most caffeine-based stimulants contain 100 mg of caffeine. One ounce of milk chocolate contains approximately 5–10 mg of caffeine and 35–50 mg of theobromine. Dark or baker's chocolates are up to 10 times more toxic than milk chocolates. In addition, over-the-counter cold and sinus preparations that contain pseudoephedrine may be a problem.

Cigarettes and nicotine withdrawal products can occasionally cause seizures. The minimal lethal dose of nicotine in dogs and cats is approximately 20–100mg. Cigarettes may contain up to 2 mg of nicotine each. Nicotine withdrawal patches may contain 15 mg and nasal sprays as much as 100 mg of nicotine.

8. Is seizure prevention the only concern with methylxanthine and pseudoephedrine intoxication?

No. Methylxanthine and pseudoephedrine may lead to significant gastrointestinal (GI) and cardiovascular difficulties as well. After seizure control and detoxification procedures, attention should be focused on cardiovascular monitoring. Tachyarrhythmias and hypertension are significant problems and may lead to sudden death. Propranolol (0.04–0.06 mg/kg by slow intravenous push every 8 hours) is recommended to control most cardiovascular complications. Supraventricular tachycardia and ventricular premature contractions may require lidocaine (2 mg/kg by slow intravenous push or 50–75 mg/kg/min CRI) for control. Rarely, bradycardia develops and can be controlled with atropine (0.02–0.04 mg/kg intravenously, subcutaneously, intramuscularly).

GI irritation may be severe, and hemorrhagic gastroenteritis is common. Supportive care with intravenous fluids is important to maintain hydration and to promote diuresis. In addition, urinary catheterization keeps the bladder empty and prevents reabsorption of toxins. The long half-life of methylxanthines may require treatment for up to 72 hours.

9. Are there any special treatment considerations with nicotine toxicosis?

Initial signs of excitation are due to stimulation of sympathetic and parasympathetic ganglia. Atropine can be used to counteract severe parasympathetic signs. Very high doses of nicotine may lead to hypotension and respiratory depression requiring aggressive fluid therapy, supportive care, and monitoring.

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109. BITES AND STINGS

Terri E. Bo*nenberger*, D.V.M.

1. Where do most stings occur on cats and dogs?

Most stings occur on the head and paws, probably because of animals' natural nosy nature.

2. What groups of insects commonly cause the most severe reactions to pets?

The families within the order Hymenoptera that cause the most problems and side effects are *Apidae* (bees), *Vespidae* (wasps, hornets, and yellow jackets), and *Formicidae* (ants).

3. How do the stings of bees, wasps, and ants differ?

Apis (the honeybee) has a unique stinging apparatus. The stinger is eviscerated from the bee (killing the bee), and the stinger and venom sac are retained within the victim. The visual presence

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Apis (the honeybee) has a unique stinging apparatus. The stinger is eviscerated from the bee (killing the bee), and the stinger and venom sac are retained within the victim. The visual presence

of the venom sac allows positive identification of *Apis* as the source of the sting. *Vespa* (wasps and hornets) leave no stinger in the victim; therefore, they are free to attack and may sting a victim repeatedly. However, they generally only attack when they are hunting or provoked. The sting of fire ants is unique because it is a two-part process. First the ant bites its victim's skin with two powerful pinching jaws; the ant then stings the victim with its modified ovipositor apparatus. This process produces a circular pattern of stings with two centralized punctate holes. A sterile pustule forms after the bite.

4. What are the active components responsible for the toxic effects of the venom?

Bee and wasp/hornet venom are similar. They are composed primarily of protein, with phospholipase A1 and A2, hyaluronidase, acid phosphatase, antigen-5, melittin, and apamin. Wasp and hornet venom also contains wasp and hornet kinins, respectively. These specific kinins appear to act similarly to bradykinin and may be important in the pathogenesis of stings. Fire ant stings are again unique within Hymenoptera. Their venom is only approximately 5% protein and 95% alkaloid; however, the proteins are similar to those in other *Hymenoptera*.

5. How should a bee stinger be removed from the patient?

Because the stinger can pulsate venom into the animal for up to 2–3 minutes after being separated from the bee, it should be removed as soon as possible. The stinger should be scraped out (a scalpel blade can be used); it should not be squeezed out with fingers or tweezers because the venom sac may rupture, further exposing the animal to its contents.

6. How do the Africanized (killer) bees differ from honey bees?

Apis mellifera scutellata (Africanized or killer bees) resulted from breeding the docile European honeybee with the more aggressive African bee. The Africanized honeybees have retained the aggressive nature and are more militant in regard to colony defense. Although Africanized bees actually release less venom per sting, their aggressive stinging behavior makes them potentially more dangerous because of the possibility of multiple stings and, therefore, systemic toxic reactions.

7. What are the different classifications for insect stings?

Insect stings can be grouped according to the type of reaction that they cause:

Group 1: Small, local (toxic in origin)	Group 3: Systemic, allergic (anaphylaxis)
Group 2: Large, local (allergic in origin)	Group 4: Systemic, toxic (massive envenomation)

8. What is the recommended medical treatment for mild reactions?

Group 1 reactions rarely require veterinary attention. The lesions result from local irritation by the venom, which can cause redness, pain, and swelling. Ice compresses and topical lidocaine help to ease the symptoms. Group 2 reactions are allergic in origin and may cause facial or limb edema. Management should include treatment recommended for group 1, as well as, antihistamines (diphenhydramine 2–4 mg/kg every 2 hours) and cortisone if swelling is severe (prednisone, 1 mg/kg every 12 hours, tapered over 5 days). The patient should be monitored for the next 2–3 hours to assess for a positive response to therapy. Unfortunately, antihistamine and corticosteroids have not been shown to be beneficial in preventing or resolving the pustules associated with fire ant bites.

9. What are the clinical signs of anaphylaxis (group 3)?

Anaphylaxis is a rarely reported complication of insect stings. Affected animals generally begin to show symptoms within 15 minutes of the bite. Clinical signs include swelling, vomiting, urination, defecation, muscle weakness, and seizures. Symptoms in cats include pruritus, dyspnea, salivation, ataxia, and collapse.

10. What is the recommended medical treatment for anaphylaxis?

Treatment should be directed at impending vascular collapse. Crystalloid and colloidal fluids are imperative and should be administered at shock volumes. Antihistamine (diphenhydramine hydrochloride, 2 mg/kg by slow intravenous push and intravenous glucocorticoids (prednisolone

sodium succinate, 10 mg/kg) may be helpful if given early. The use of epinephrine is questionable and may be helpful only early in the onset of shock.

11. What clinical signs are associated with massive envenomation (group 4)?

Large numbers of stings can cause a toxic reaction due to the large amount of venom. This reaction is toxic and not allergic; therefore, patients may not present with edema or urticaria. Neurotoxic, hepatotoxic, nephrorotoxic, and cytotoxic signs have been seen in cats and dogs. These clinical signs may not be present initially but may develop several days after the attack. The patient is generally febrile and depressed. Neurologic signs include ataxia, facial paralysis, and seizures. Vomiting, red-to-brown urine, brown vomitus, and bloody stool also may be seen.

12. What laboratory abnormalities are associated with massive envenomation?

Laboratory results include elevations in total bilirubin, alanine aminotransferase, blood urea nitrogen, and creatinine. The hemogram often reflects leukocytosis with a degenerative or regenerative left shift. Anemia can be present secondary to intravascular hemolysis. More serious cases show increases in clotting times (increased activated partial thromboplastin time, OSPT, fibrin degradation products) and thrombocytopenia. A high index of suspicion for the development of disseminated intravascular coagulation (DIC) is required (treatment is more successful when started before the animal develops the classic signs of DIC). Evidence of renal tubular damage (granular casts in urinalysis) and acute renal failure are possible.

13. What is the recommended treatment for systemic toxicosis from insect stings?

Patients suffering from multiple hymenopteran stings should be hospitalized and observed for immediate or delayed toxic reactions. Systemic inflammatory response syndrome (SIRS) may be a complication; thus, the most important goal of treatment is correction of hypovolemia and vascular stasis. Fluid therapy, supportive care, prophylactic antibiotics, and monitoring of hemodynamic function are the cornerstones of treatment. Intravenous glucocorticoids may be helpful if neurologic or intravascular hemolysis is seen. Antihistamines are helpful only early in the disease process and only if there is an allergic component.

14. Do fire ants pose a serious threat to cats and dogs?

Not usually. Severe and fatal attacks by fire ants are extremely rare. Patients that suffer a massive attack from fire ants are usually debilitated in some way and are unable to move out of the swarm's path. The stings can result in scars or secondary infection.

15. What are the clinical signs of *Lactrodectus* envenomation (black widow spider bite)?

The initial bite is usually not painful, and local tissue changes are generally absent. The bite appears as two small puncture wounds with a blanched area surrounded by erythema. The bite is often difficult to visualize because of the dense hair coat and pigmented skin. The local reaction may develop into granulomatous nodules within days. Severe cramping of large muscle masses is common; abdominal cramping sometimes interferes with respiration. Abdominal rigidity without pain is considered a hallmark sign. The severe muscle cramping may cause anxiety, spasms, and seizures. The cat is extremely sensitive to the bite; clinical signs include severe pain, restlessness, excessive salivation, and paralysis.

16. What is the treatment for the muscle cramping and other signs caused by *Lactrodectus* envenomation?

The slow intravenous injection of 10% calcium gluconate, 10–30 ml (dogs) and 5–15 ml (cats). The patient's cardiac rate and rhythm should be monitored during administration. Repeated dosing in 4–6 hours may be necessary. If seizures occur, diazepam is recommended. The prognosis may be guarded (especially in cats); therefore, close monitoring over the next 2–3 days is recommended.

17. What are the characteristic signs of *Loxosceles* bite (brown recluse or fiddleback spider)?

The bite is not painful initially, but within 2–6 hours an area of pain and erythema develops, followed by a blister (12 hours) and then classic bulls-eye lesion (a necrotic center surrounded by a white ring of ischemia against an area of erythema). The lesion then progresses to focal ulceration and necrosis. Other symptoms include fever, arthralgia, lethargy, vomiting, and seizures. The wound is slow to heal, and aggressive open wound management with debridement is often necessary.

18. What are the signs of scorpion envenomation?

The sting of a scorpion is acutely painful and generally only pain management of the sting is required (ice compresses and aspirin), however, systemic signs may develop. Some species of scorpions possess neurotoxins which can cause an excitatory neurotoxicity. Clinical signs include salivation, urination, defecation, lacrimation and mydriasis which can easily be confused with organophosphate or carbamate toxicity. Death can result from respiratory collapse, hypertension and cardiac arrhythmias. Treatment is supportive; antihistamines, corticosteroids and atropine are not helpful. Intravenous fluids should be administered with caution due to the possibility of pulmonary edema.

CONTROVERSY

19. Can hyposensitization therapy help animals who have suffered serious allergic attacks from the stings of *Hymenoptera*?

In humans, immunotherapy is extremely effective at decreasing the severity of the systemic response to hymenopteran stings. Therapy is more effective if directed at the specific insect. However, cross-sensitivities to various venoms are common, and multivalent venom is available for hyposensitization therapy. Patient selection for immunotherapy is based on clinical history and results of intradermal skin testing. Patients are candidates for immunotherapy if they have a history of systemic reactions to previous stings (groups 2 and 3) and demonstrate positive skin reactivity to 1 mg/ml of dilute venom. Veterinary dermatologists report successful cases of venom hyposensitization in which the patient (while receiving maintenance immunotherapy) did not develop allergic reactions when owners reported known stings. The option of venom immunotherapy should be discussed with the owner and a veterinary dermatologist for selected patients.

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110. NONSTEROIDAL ANTIINFLAMMATORY DRUG TOXICITIES

Wayne E. *Wingfield*, M.S., D.V.M.

1. How do nonsteroidal antiinflammatory drugs (NSAIDS) work?

NSAIDS inhibit prostaglandin production and thereby decrease the low level of peripheral inflammation in osteoarthritis. NSAIDS also provide analgesia by inhibiting prostaglandin production in the central nervous system.

2. List the NSAIDs currently approved for use in dogs.

- Carprofen
- Etodolac
- Meclofenamic acid
- Phenylbutazone
- Aspirin

3. What dosage of NSAIDs can cause toxic symptoms in dogs and cats?

Aspirin in dogs can be toxic at 15 mg/kg every 8 hours (1 regular strength tablet/50 lb 3 times/day). Because of the much longer half-life in cats, 25 mg/kg/day of aspirin ½ regular strength tablet daily) may be toxic.

Acetaminophen toxicosis in dogs occurs at a dose of 150 mg/kg (2 regular strength tablets per 10 lbs). Cats are extraordinarily poor conjugators of the active metabolite of acetaminophen and become intoxicated at a dose of 50 mg/kg (as little as ½ tablet).

Ibuprofen has been reported to produce toxicity at a dose of 50 mg/kg (1 regular strength tablet per 10 lb).

4. Describe the pathophysiology of NSAID intoxication.

Gastric irritation with mucosal erosions and ulceration is the hallmark of aspirin toxicosis. Aspirin inhibits prostaglandin production and alters prostaglandin's protective abilities. This combination of events results in damaged gastric mucosa. In addition, aspirin can gain direct entry into mucosal cells by virtue of its lipid solubility and cause cellular damage. An acid-base disturbance develops—respiratory alkalosis followed by metabolic acidosis. Cats are prone to develop Heinz-body anemia and bone marrow hypoplasia. Toxic hepatitis also may develop, especially with chronic administration.

Acetaminophen overdosage results in toxic levels of an active metabolite that is normally conjugated by glutathione. A limited glutathione supply, coupled with a diminished ability to biotransform and eliminate the drug, may rapidly lead to toxicosis, especially in cats. The cat's hemoglobin molecule is particularly prone to methemoglobinemia in such circumstances. Hemolysis and Heinz-body anemia also may occur. As with aspirin, hepatic necrosis may develop, particularly with chronic administration.

5. What are the symptoms of NSAID toxicity?

The major side effect is gastrointestinal bleeding. With aspirin, watch for vomiting (with or without blood) and abdominal pain. Early respiratory alkalosis results in tachypnea. Elevated body temperature and depression are common. Untreated, signs may progress to coma and death. Icterus may develop over time.

In acetaminophen toxicosis, the major symptoms in dogs are usually related to hepatotoxicosis, whereas in cats the greatest clinical symptoms are related to methemoglobinemia. The development of methemoglobinemia causes tachypnea and cyanosis. Cats particularly may void dark brown urine (from hematuria and hemoglobinuria). Edema may develop in the face and distal extremities. As with aspirin toxicosis, vomiting and abdominal pain may be seen, especially early

after ingestion. Depression develops progressively. Icterus from toxic hepatitis also may be seen, especially in dogs. Cats show more severe signs and more rapid progression in NSAID overdosage.

6. What laboratory findings are useful in over-the-counter NSAID toxicities?

ASPIRIN	ACETAMINOPHIN
Heinz-body anemia (especially in cats)	Methemoglobinemia
Elevated bilirubin, alanine aminotransferaes (especially in chronic dosing)	Elevated bilirubin, alanine aminotransferase alkaline phosphatase (dogs)
Acid–base disturbances Repiratory alkalosis followed by metabolic acidosis	Heinz-body anemia (cats)
Hypokalemia	Hematuria/hemoglobinuria
Hyponatremia	

7. What is the treatment for aspirin toxicosis?

Induce vomiting and/or perform gastric lavage, even as long as 12 hours after ingestion, because aspirin tends to remain in the stomach as an insoluble mass. Vomiting and lavage should be followed by 2 gm/kg of activated charcoal. Fluids and electrolytes should be replaced, particularly in depressed patients. Consider using sodium bicarbonate at 1 mEq/kg intravenously to alkalinize urine. This treatment increases excretion of salicylate.

Gastric ulceration may be addressed in various ways; the most common is administration of cimetidine, 5 mg/kg subcutaneously, intravenously, or orally 4 times/day. Ranitidine (Zantac) is an H_2 blocker that is reportedly more potent than cimetidine and has the advantage of twice daily dosing at 2 mg/kg intravenously, subcutaneously, or orally. Also consider using sucralfate (Carafate) if you are fairly certain that ulceration exists; this drug binds to the ulcer site and has sustained local protective effects. Sucralfate is dosed at 0.5–1.0 gm orally 4 times/day. Another drug to consider if ulceration exists or is strongly suspected is misoprostol (Cytotec). Misoprostol is both antisecretory and cytoprotective and has been shown to be quite effective in ulcer management in dogs and humans. Misoprostol is dosed at 2–4 mg/kg orally 3 times/day.

8. Is treatment for acetaminophen toxicosis different from that described for aspirin?

Yes. Methemoglobinemia must be aggressively treated. N-acetylcysteine (Mucomyst) is given at 140 mg/kg initially, followed by 70 mg/kg every 6 hours for 5–7 treatments. N-acetylcysteine is generally administered orally in a 5% dextrose solution but may be given intravenously to patients unable to receive oral therapy. Vitamin C can also be given in addition to N-acetylcysteine to reverse methemoglobinemia, especially in cats. Vitamin C is dosed at 200 mg/cat 3 times a day, intravenously, subcutaneously, or orally. In cats, a single dose of methylene blue at 1.5 mg/kg intravenously has been used to reverse methemoglobinemia successfully and rapidly. Repeated doses are not recommended, however, because they may actually cause methemoglobinemia.

Fluids and electrolytes should be given as needed to replace losses. While blood transfusions may be necessary in patients with severe methemoglobinemia, massive red blood cell destruction, or hepatic necrosis from hepatocyte destruction.

Gastric irritation or ulceration should be treated as described for aspirin toxicosis.

9. What kind of follow-up care is important?

For aspirin, monitor electrolytes, liver enzymes, and renal function. Anemia from bone marrow suppression is a poor prognostic indicator.

In acetaminophen toxicosis, continual monitoring of methemoglobinemia is vital for effective management, especially in cats. Also, monitor liver enzymes, especially in dogs.

10. How should toxicities from other over-the-counter NSAIDs be treated?

Ibuprofen essentially causes the same symptoms as aspirin and should be treated as such. Acetophenetidin (phenacetin) is contained in some over-the-counter analgesics and sinus remedies. Acetophenetidin is metabolized into acetaminophen and should be treated and managed like acetaminophen toxicosis.

11. Is hepatotoxicity associated with NSAID administration?

Yes. Carprofen is reported to cause hepatotoxicity in a small percentage of dogs. Clinically Laborador retrievers appear to present most commonly with this complication. Hepatocellular necrosis is often seen on biopsy. This toxicity appears to be an idiosyncratic reaction and may be due to unusual metabolism of the drug in certain patients.

12. What is the mechanism of hepatotoxicity with carprofen administration?

There are currently two theories promoted for the development of hepatoxicity following carprofen administration:

1. Immune-mediated phenomenon
2. Hepatic metabolism of carprofen results in the formation of toxic metabolites

13. What is the treatment for carprofen toxicity?

Supportive care using intravenous fluids, GI protectants, and vitamins E and K.

14. Do NSAIDs have nephrotoxic effects?

Yes—if the animal is dehydrated. NSAIDs work by inhibiting prostaglandins and these substances are important for vasodilation in the kidney. As long as the patient is normovolemic, effects on the kidney are minimal. If the animal has evidence of preexisting renal disease, NSAIDs should be used with caution.

15. Why do animals with NSAID toxicity often show increased tendencies towards bleeding?

The two theories about the bleeding with NSAIDs are as follows:

1. Inhibition of platelet function
2. Hepatodysfunction resulting in inadequate production of clotting factors

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XIV. Emergency Procedures

Section Editor: Robert J. Murtaugh, D.V.M.

111. TEMPORARY TRACHEOSTOMY

Steven Mensack, V.M.D.

1. What are the indications for performing a temporary tracheostomy?

An emergent tracheostomy is indicated in animals with upper airway compromise secondary to laryngeal or tracheal foreign body, laryngeal paralysis, laryngeal crushing injuries, and proximal tracheal tears or avulsions. Additional indications include:

- Long-term (> 12 hours) mechanical ventilation.
- Surgical intervention to the larynx or proximal trachea that renders endotracheal intubation impossible and postoperative maintenance of a patent airway is necessary.
- Conditions requiring facilitated removal of lower airway secretions when the cough reflex is abolished, as in comatose patients and cases of smoke inhalation.
- Conditions in which large amounts of secretions are produced, as in patients that have undergone lung lobe resection.

2. What types of tracheostomy tube are available?

Tracheostomy tubes are available as single-cannula tubes, with or without an inflatable cuff, in sizes ranging from internal diameters of 2.5–10 mm. For tracheostomy tubes with internal diameters of 7–9 mm, a disposable inner cannula is also manufactured. The inner cannula decreases the internal diameter of the tube by 2 mm. One such unit is the Blue Line tracheostomy tube manufactured by Smith Industries Medical System, Keene, NH.

3. What are the indications for the different types of tubes?

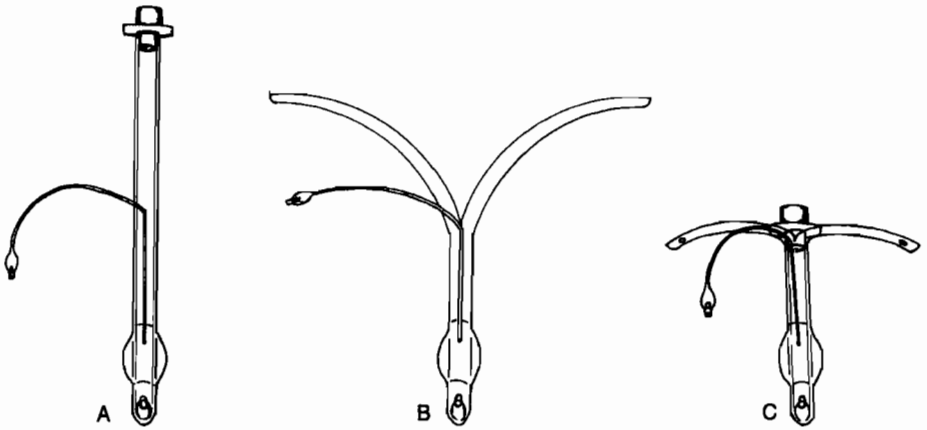
Cuffed tracheostomy tubes are indicated when the patient is scheduled for anesthesia, is comatose and thus at increased risk of aspiration pneumonia, or will be placed on ventilatory support. The cuff should be a high-volume, low-pressure cuff. An uncuffed tracheostomy tube should be used for most other situations in which a tracheostomy is indicated. Alternatively, the cuffed tracheostomy tube may be placed without inflating the cuff. The uncuffed tracheostomy tube allows air to move around the tube, making tube obstruction less of a life-threatening situation.

A double-cannula tracheostomy tube is preferred when the diameter of the patient's trachea is large enough. The double-cannula tube allows removal of the inner cannula for cleaning while the outer cannula maintains airway patency. Unfortunately, the sizes required for use in small-breed dogs and cats are available only in single-cannula tubes.

4. If a commercial tracheostomy tube is not available, what are the alternatives?

A modified tracheostomy tube can be made from an endotracheal tube. The breathing circuit adapter is removed from the end of the endotracheal tube. The body of the tube is split longitudinally, preserving the cuff-inflation mechanism. The tube should be split so that approximately 4-7 cm of endotracheal tube remain intact at the distal end. Thus 2 cm of intact tube lie within the trachea, and 2 cm of intact tube lie outside the skin incision in small dogs and cats. In larger-breed dogs, a longer segment of endotracheal tube is left intact so that 4 cm of the tube are inserted into the trachea. The adapter is replaced in the endotracheal tube, and holes are made in

both flanges to facilitate securing the tube to the patient. Once in place, the tube is secured with gauze or umbilical tape passed through these holes. Red-rubber endotracheal tubes should be avoided in making a modified tracheostomy tube because they may be more irritating to the tracheal mucosa than other materials.



Procedure for modifying an endotracheal tube for use as a tracheostomy tube. *A*, The adapter is removed from a standard endotracheal tube. *B*, The tube is split longitudinally, preserving the inflation mechanism. *C*, The adapter is replaced and holes put in the flanges.

5. Is special equipment required to perform a temporary tracheostomy?

No. An ideal tracheostomy pack includes the following:

- 4 towels/drapes
- 4 towel clamps
- 1 scalpel handle
- 1 no. 10 Bard-Parker scalpel blade
- 1 no. 11 or no. 15 Bard-Parker scalpel blade
- 2 mosquito forceps
- 1 pair of Metzenbaum scissors
- 1 rat-tooth tissue forceps
- Allis tissue forceps
- small Weitlander retractor
- 1 large Weitlander retractor
- 1 needle holder
- Gauze sponges

6. How is a surgical tracheostomy performed?

1. The patient is placed in dorsal recumbency after induction of general anesthesia, when possible. The neck is extended, and the thoracic limbs are pulled caudally and secured lateral to the thorax. The ventral cervical region is clipped of hair and prepared in a sterile fashion (time permitting). In an immediate life-threatening situation, the ventral cervical region is clipped and infiltrated with lidocaine.

2. A longitudinal midline incision is made from the larynx to about the eighth tracheal ring. The paired strap muscles (sternohyoideus and sternothyroideus) are bluntly separated at the midline to expose the trachea. Retracting these muscles with a Weitlander retractor helps to protect neurovascular structures and provides better tracheal exposure.

3. A stab incision is made in the annular ligament between the fourth and fifth tracheal rings. The incision is extended laterally in both directions to encompass approximately 50% of the tracheal circumference. The recurrent laryngeal nerve lies in close proximity to the trachea and should be identified before the tracheal incision is extended laterally.

4. Long stay sutures of silk or nylon are placed around 1-2 tracheal rings immediately cranial and caudal to the tracheal incision to facilitate isolation of the stoma for tube placement and replacement.

5. A tracheostomy tube of the appropriate size is inserted into the stoma. The tube is secured by tying pieces of gauze or umbilical tape from the phalanges of the tube around the dorsal aspect

of the neck. The most rostral and caudal ends of the skin incision are closed with sutures. The skin incision around the tracheostomy tube is left open to allow air to pass.

7. What is a percutaneous tracheostomy? How is it performed?

A percutaneous tracheostomy is a rapid, minimally invasive method of placing a tracheostomy tube. The tracheostomy tube is placed using a modified Seldinger technique. The area over the cricoid cartilage is identified, quickly clipped, and infiltrated with lidocaine. A saline-filled syringe with a large-bore needle is inserted in the annular ligament between the second and third tracheal rings. Air is aspirated when the tracheal lumen is penetrated. A stab incision is made along the needle on ventral midline. A closed curved hemostat is inserted into the tracheal lumen through the incision. The jaws of the hemostat are opened, creating a stoma for insertion of the tracheostomy tube.

8. What is the proper size of the tracheostomy tube?

A tracheostomy tube should be between ⅔ and ¾ of the tracheal diameter. This size aids in the prevention of respiratory arrest by allowing inspired air to move continuously around an uncuffed or uninflated cuffed tube if it becomes occluded. This tube size also minimizes the occurrence of iatrogenic tracheal trauma and decreases the incidence of postintubation stenosis.

9. What complications may occur during placement of a tracheostomy tube? How can they be avoided?

Complications encountered in placing a tracheostomy tube include damage to neurovascular structures around the trachea, airway obstruction, and subcutaneous emphysema. Damage to peritracheal neurovascular structures can be avoided by familiarity with regional anatomy before surgery, good surgical technique, and maximal tracheal exposure. The incidence of airway obstruction can be decreased by choosing a tracheostomy tube of the proper size. Even with appropriately sized tubes, kinking or occlusion of the distal end of the tube may occur during insertion. It is important to recognize such occurrences rapidly and to adjust or replace the tube as needed. A small degree of subcutaneous emphysema usually occurs but can be minimized by leaving the skin and soft tissue around the tube open so that air leaking from the tracheal incision can escape the tissues.

10. Once the tracheostomy tube is placed, what steps are necessary to maintain it?

Proper care of the patient and tracheostomy tube includes humidification of inspired gas, suctioning of respiratory secretions, periodic replacement of the tracheostomy tube, and proper wound management.

1. **Humidification.** Humidification helps to maintain the normal tracheal defense mechanisms and facilitates the removal of respiratory secretions. Humidification of inspired gas is best accomplished by the use of a commercial humidifier or nebulizer (PulmoAide, DeVilbiss Co., Somerset, PA). If the patient is receiving supplemental oxygen, the gas can be run through the humidifier before reaching the patient. If the patient is breathing room air, placement in a chamber with a humidifier or nebulizer for 15 minutes every 4–6 hours helps to keep the airways moist. If neither of these devices is available, instilling 0.1 ml/kg sterile saline (1 ml minimum, 5 ml maximum) into the tracheostomy tube every 1–2 hours helps to maintain upper airway hydration.

2. **Suctioning.** Routine suctioning of respiratory secretions from the trachea and tracheostomy tube helps to prevent airway obstruction while the tube is in place. Suctioning should be performed with sterile technique. The patient is preoxygenated with 100% oxygen for several minutes before suctioning. A sterile suction catheter is inserted without vacuum down the tracheostomy tube into the trachea. A light intermittent vacuum is applied as the catheter is rotated and removed. The vacuum should not be applied for longer than 10–15 seconds; longer applications have been associated with severe hypoxemia. 100% oxygen should be supplied for several minutes following tracheal suctioning. Suctioning should be done as needed, depending on the amount of respiratory secretions produced. It may be required as often as every 15 minutes initially and should be done at least 4 times daily. Complications of suctioning include hypoxemia, vomiting, retching, gagging, cardiac arrhythmias, and tracheal mucosal damage. Tracheal suctioning should not be repeated on patients showing extensive discomfort, respiratory distress, or cardiac arrhythmias.

3. **Tube replacement.** The tracheostomy tube should be replaced at least once every 24 hours or more frequently if occlusion from respiratory secretions occurs. In tubes with a double cannula, the inner cannula may be removed while the outer cannula is suctioned, as described above. A sterile inner cannula can then be inserted. In the single-cannula tracheostomy tube, the patient is preoxygenated with 100% oxygen, the stay sutures are grasped, and the old tube is removed. A sterile tracheostomy tube can then be placed.

4. **Wound management.** The wound should be cleaned daily with sterile saline and gauze or cotton-tipped applicators. Antiseptic solutions may irritate the exposed tracheal mucosa and should be avoided.

11. Should the tracheostomy tube cuff be periodically deflated?

If the tracheostomy tube cuff has been inflated for ventilatory support or the patient is comatose, the cuff should remain inflated throughout the time that the tube is in place. Periodically deflating the cuff has not been proved to reduce cuff-induced tracheal damage. At the same time, periodically deflating the cuff may lead to complications. Patients that have a tracheostomy tube in place because of inability to protect the airway may develop aspiration pneumonia while the cuff is deflated. Patients on ventilatory support cannot maintain proper airway pressure while the cuff is deflated, leading to ineffective ventilation.

12. What complications may occur while the tracheostomy tube is in place? How can they be avoided?

Obstruction, nosocomial infections, and dislodgment of the tracheostomy tube are the most commonly reported complications. Obstruction can be avoided by carefully monitoring the patient for signs of dyspnea, stridor, or anxiety, which may indicate that the lumen of the tube is becoming obstructed. Proper humidification, frequent suctioning of respiratory secretions, and appropriate tube changes help to minimize this risk. The incidence of nosocomial infection can be lessened by following proper tube care guidelines, including use of sterile technique whenever the tracheostomy tube is handled, daily wound care, removal of respiratory secretions by suctioning, and appropriate tube placement. Prophylactic antibiotics are not indicated; their use may increase the risk of infection by selecting for antibiotic-resistant bacteria. Tracheostomy tube dislodgment can be avoided by carefully securing the proper-length tube with gauze or umbilical tape and checking frequently to ensure that it is secure.

13. When should the tracheostomy tube be removed?

The tracheostomy tube may be removed once a patent proximal upper airway is reestablished or ventilatory support is no longer needed. The tube should be removed in a stepwise fashion to evaluate airway patency. Tracheostomy tubes of sequentially smaller diameter are inserted, and the patient is observed for respiratory distress or stridorous breathing. When a tube of less than one-half the tracheal diameter is in place, the lumen of the tube may be occluded; again, the patient is observed for distress or stridor. If the patient is breathing comfortably while the lumen is occluded, the tube may be removed and the patient monitored. If at any time during the tube removal process signs of respiratory compromise are observed, a tube large enough for comfortable breathing is inserted. Tube removal may be reattempted in 12–24 hours.

14. Should the tracheostomy incision be surgically closed?

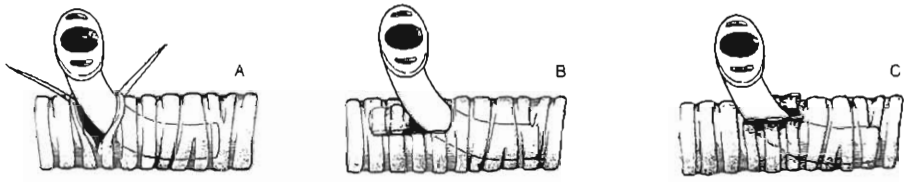
No. The tracheostomy incision should be allowed to heal by second intention. Surgical closure may lead to subcutaneous emphysema and infection. The healing wound should be cleaned at least once daily with sterile saline until a bed of granulation tissue forms.

CONTROVERSY

15. What is the best method for incision of the trachea?

Four methods are available for making an incision in the trachea: transverse, longitudinal/vertical, transverse flap, and longitudinal flap. Few studies describe the complications encountered with

each of these methods in animals. The parameters compared in limited studies include ease of changing the tracheostomy tube, necrosis of tracheal mucosa around the stoma, and degree of postextubation tracheal stenosis. The studies found that the flap techniques facilitate replacement of tracheostomy tubes. The flap techniques require only a single stay suture to open the stoma, leaving one hand free to insert the tube. Some degree of necrosis of the tracheal mucosa adjacent to the tracheal opening has been reported with all techniques. With the longitudinal and transverse techniques, mucosal necrosis is due to the semirigid nature of the trachea, which causes pressure against the tube. The flap techniques were designed to decrease this problem. However, the longitudinal flap technique has the disadvantage of destruction or deformation of the created tracheal flap due to repeated traction on the flap during tube changes. No studies of the degree of tracheal mucosal necrosis with the transverse flap technique have been undertaken.



Three methods of creating a temporary tracheostomy. A, Transverse tracheotomy. B, Longitudinal tracheal flap. C, Vertical/longitudinal tracheotomy. (From Slatter D: Textbook of Small Animal Surgery, 2nd ed. Philadelphia, W.B. Saunders, 1993, with permission.)

16. Is postextubation tracheal stenosis a complication I should worry about?

Multiple studies have shown no significant differences in the degree of tracheal stenosis after the tracheostomy tube is removed and the incision is allowed to heal by second intention. The degree of stenosis after temporary tracheostomy has been reported to be 18–25% of the tracheal diameter. This degree of stenosis has not been associated with clinically apparent compromise of respiratory ability. The amount of tracheal stenosis can be minimized by using good surgical technique with gentle handling of the tracheal mucosa.

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112. THORACIC DRAINAGE

Nancy S. Taylor, D.V.M.

1. What is the purpose for thoracocentesis and chest tube drainage?

These techniques can be used as a diagnostic tool and/or as a therapeutic intervention.

2. What are the main indications for thoracic drainage?

- To alleviate signs caused by free air or fluid in the chest cavity
- To obtain fluid for cytologic and microbiologic evaluations

3. How does air accumulate in the thoracic cavity?

A pneumothorax, or accumulation of free air between the chest wall and lung, may be caused by numerous factors. Pneumothorax may be partial, or the entire lung may collapse. When a lung is ruptured or torn, a one-way valve mechanism leads to progressive lung collapse. During inspiration, negative intrapleural pressure causes the edges of the laceration on the surfaces of the lungs to pull apart, pulling air into the pleural space. During expiration, positive intrapleural pressure closes the hole and compresses the leaking surface.

4. What are the different types of pneumothorax?

1. **Closed pneumothorax** results from a tear in the visceral pleura.
2. **Open pneumothorax** results from a tear in the chest wall.
3. **Spontaneous pneumothorax** is a closed pneumothorax that occurs unexpectedly after rupture of a pulmonary bulla or bleb.
4. **Traumatic pneumothorax** results from direct trauma to the lung or from a broken rib that lacerates the lung.
5. **Tension pneumothorax**, which causes severe compromise of respiratory function, occurs when air continues to leak through the one-way valve mechanism after complete lung collapse. The result is a progressive increase in intrapleural pressure that exceeds atmospheric pressure. This effect causes the mediastinum to shift toward the opposite side of the chest with resultant compression of the opposite lung. In addition, the vena cava becomes compressed, decreasing venous return and cardiac output. If the mediastinum is not intact, both lungs collapse because of the increased intrathoracic pressure. Although any pneumothorax compromises respiratory function, a tension pneumothorax is especially life-threatening. It must be relieved immediately, or the animal will die.

5. How does the character of a pleural effusion affect the approach to chest drainage?

Transudates are caused when fluid is passively transferred into the pleural space because of an imbalance among intravascular, intrapleural, and oncotic fluid pressures. This type of effusion is seen in congestive heart failure, pericardial disease, hepatic failure, and nephrotic syndrome. The protein levels are low in transudates. If the underlying problem is corrected the effusion dissipates. If the fluid is drained but the underlying problem is not corrected, the effusion recurs. It makes sense to drain large amounts of fluid in patients with congestive heart failure to relieve respiratory distress, but the benefits of chest drainage must be weighed against the risk of stress from the procedure.

Exudates are fluids with high protein content that are actively secreted into the pleural space in association with tumors, inflammation, viral or bacterial infections, and disrupted lymphatic drainage (chylous effusions). Exudates are treated by drainage procedures. Recurrence of the effusion is common unless the cause is addressed.

Hemorrhagic effusions also may be drained. However, draining blood due to trauma or coagulopathy is still a controversial procedure. The accumulation of blood may increase intrapleural pressure

enough to provide tamponade for cessation of bleeding, but a substantial hemorrhagic pleural effusion may cause a significant decrease in pulmonary function. It is generally recommended that blood be removed if it is causing a significant decrease in pulmonary function and respiratory compromise. The quantity of blood removed should be only the amount needed to relieve respiratory distress.

Purulent effusions should be drained with a chest tube because the viscosity of the fluid limits removal via needle thoracocentesis. Chest tube drainage also promotes resolution of the inflammatory response and removes bacterial toxins.

6. What do you need for a needle-based thoracocentesis?

- Clippers
- Materials for a sterile scrub
- 19–22 gauge butterfly needle with extension tubing coupled to it
- Three-way stopcock
- 12-cc or larger syringe
- Assistant

7. How is thoracocentesis performed?

1. Minimal restraint of the animal is usually required. Placing the animal in lateral recumbency is best for removal of a pneumothorax. Standing, sitting, or sternal position is best for tapping fluid.

2. An area of the chest wall at intercostal space 7–8 should be clipped and aseptically prepared. The spot for the needle insertion is dorsal on the chest wall for a pneumothorax and lower on the chest for removal of pleural effusions, depending on the positioning of the animal.

3. The butterfly apparatus is attached to the stopcock, which is attached to the syringe. The butterfly needle is introduced into the thoracic cavity at the cranial edge of rib 7 or 8 to avoid laceration of intercostal vessels. The fluid or air accumulation is then aspirated into the syringe. Sometimes it is best to have the assistant manage the syringe and stopcock while you maneuver the needle. When the needle is in the pleural space, it is best to orient it parallel with the chest wall (wrapped around the rib) with the bevel facing the pleural surface of the chest wall to minimize potential laceration of the lung as it reexpands. The use of a 3-way stopcock allows evacuation of the syringe without having to withdraw the needle.

4. Fluid should be saved in an EDTA tube for cytologic evaluation. Aerobic and anaerobic samples for bacterial culture and isolation also should be obtained. Sometimes redirection of the needle, repositioning of the animal, or multiple insertions are necessary to ensure complete evacuation of any nonconfluent pockets of air or fluid.

8. What are the complications of thoracocentesis?

Iatrogenic lung laceration and pneumothorax may result from needle thoracocentesis. If excessive restraint is used, dyspnea and respiratory compromise may worsen. It may be prudent to sedate the animal with butorphanol (0.2–0.4 mg/kg IV) to decrease anxiety and the need for excessive restraint. Infection is usually a rare complication.

9. When is a chest tube inserted?

A chest tube is indicated when a pyothorax is present or when the patient requires frequent chest taps to alleviate reaccumulation of air or fluid in the chest. In addition, chest tubes are frequently placed after thoracic surgery to ensure complete evacuation of intraoperative air or postoperative fluid accumulation.

10. What items are needed to place a chest tube?

Clippers and materials for preparing the skin for a sterile procedure are required. In addition, a sterile commercial chest tube (Argyle Trocar Catheter, Sherwood Medical, St. Louis) or a red-rubber catheter is needed. The size of the chest drain depends on the size of the animal: 14–16 French can be used in cats and very small dogs, 18–22 French in small dogs, 22–28 French for medium-to-large dogs, and 28–36 French for large dogs. It is best to cut additional holes near the end of the chest tube before insertion. This should be done in a sterile manner. Ensure that none of the holes will be outside the thoracic cavity after insertion. If you are using a commercial chest tube, place the last hole on the radiopaque line to facilitate radiographic determination of chest tube placement.

General anesthesia is preferred for placement of a sterile chest tube; however, if the patient's condition is critical, necessitating rapid intervention, local infiltration with 2% lidocaine may be used in the chest wall.

A full surgical kit is necessary, including cap, mask, sterile drape and gloves, scalpel blade and handle, needle driver, curved and straight hemostats, and gauze sponges. A stopcock, bubble tubing (Argyle, Sherwood Medical, St. Louis), nonabsorbable suture material, large catheter tip syringe, 22-gauge wire, bandage scissors, and bandage material are also required.

11. What is the procedure for placing a chest tube?

If the patient's condition permits, induce anesthesia with the animal in lateral recumbency. Then clip and surgically prepare the skin over the lateral thorax from the fifth to the ninth intercostal spaces. With 2% lidocaine, locally infiltrate the skin, subcutaneous tissue, intercostal muscles, and pleura at mid-thorax over the sixth or seventh intercostal space. Don cap, mask, sterile gown, and gloves, and place sterile drapes.

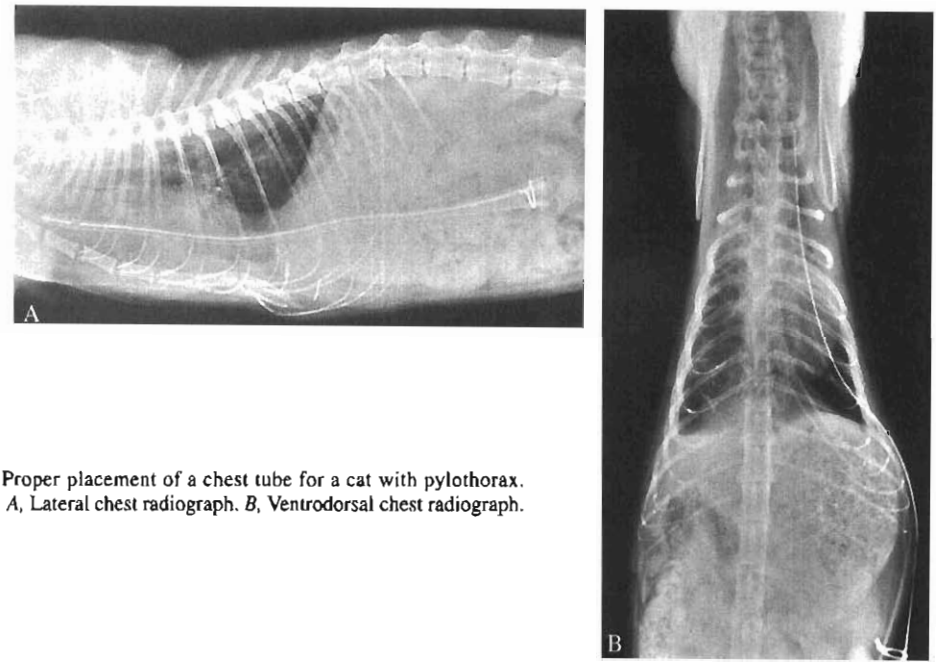
Commercial chest tube. An assistant should grasp the skin along the entire lateral chest wall just caudal to the elbow and pull it forward. A small skin incision should be made at the mid-thorax over the sixth or seventh intercostal space. Preplace a pursestring suture around this incision, and estimate the length of the tube to be inserted. Next, with the chest tube tip resting on the chest wall in the incision, maintain a good hold of the chest tube and trocar a few centimeters above the surface of the chest wall, and pop the commercial chest tube through the pleura by delivering a firm blow to the top of the trocar with the heel of your hand. The trocar should not extend beyond the tip of the chest tube once you have entered the pleural space to avoid damage to the lung, heart, or vessels. After you have advanced the partially retracted trocar and tube unit a few centimeters into the chest cavity, advance the chest tube the premeasured distance from the trocar at a 45° angle into the chest cavity. Angle the tube in a cranial ventral direction for pleural effusions or in a cranial dorsal direction for a pneumothorax.

Next, remove the trocar and clamp the chest tube before the trocar is fully withdrawn from the tube to minimize the amount of air entering the pleural cavity. A 60-cc syringe or 3-way stopcock with bubble tubing attachment is placed into the exposed end of the chest tube, and the skin is allowed to fall back into its normal position. The skin fold forms a tunnel around the tube and acts as an occlusive dressing to prevent air from entering the pleural space. The preplaced pursestring suture through the skin edges is tied around the exit point of the chest tube through the skin. A butterfly bandage around the tube is sutured to the skin, or a Chinese finger trap (see Smeak reference in bibliography) is placed to secure the tube to the body wall.

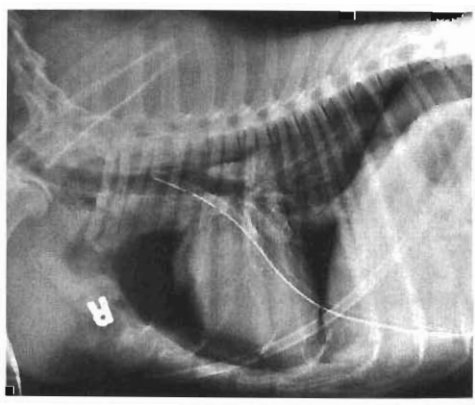
Red-rubber chest tube. If a commercial chest tube is not available, a red-rubber tube may be used. Prepare and hold the skin as described previously, and make your incision. Using a closed curved hemostat, force a hole into the thoracic cavity, keeping close to the cranial edge of the seventh or eighth rib. Spread the jaws of the hemostat, and leave the spread hemostat in place. Take the tip of the red-rubber tube in the jaws of a second hemostat, and advance it so that the tip of the hemostat enters the thoracic cavity. Open the second hemostat, and advance the tube into the thoracic cavity as described. Remove both hemostats, and let the skin return to its former position. The skin opening and tube are secured as described above.

The external end of the chest tube is connected to the suction apparatus or a Heimlich valve (Heimlich Chest Drain Valve, Bard-Parker, Rutherford, NJ). A triple antibiotic dressing is placed over the skin incision, and a bandage is placed securely but nonconstrictingly around the thorax, incorporating the chest tube. Make a small loose coil in the excess drainage tubing, and secure it to the outside of the chest bandage with tape. This procedure helps to prevent dislodgment of the chest tube. It is important to avoid kinks in the chest tube, connection tubing, and drainage tubing because the kinks will impede drainage and possibly allow pressure to build up in the pleural cavity.

All connections should be wired securely to prevent accidental disconnection. If continuous suction or the Heimlich valve is not used and only intermittent aspiration is required, a 3-way stopcock with the bubble tube connector is placed at the end of the chest tube and secured in place by cerclage wire.



Proper placement of a chest tube for a cat with pylothorax. *A*, Lateral chest radiograph. *B*, Ventrodorsal chest radiograph.



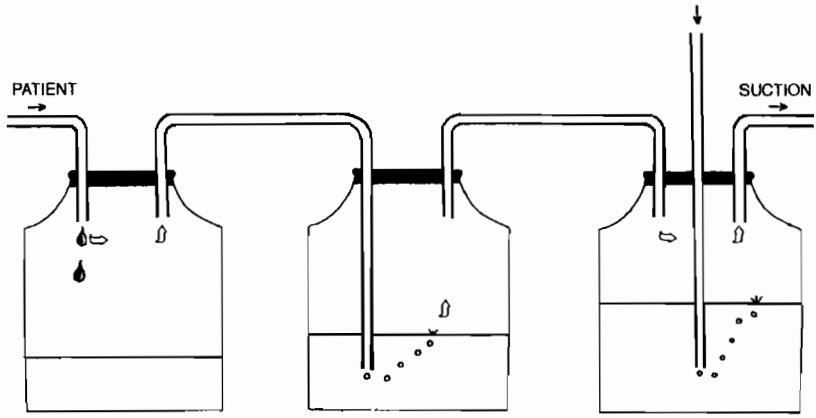
Lateral chest radiograph showing proper placement of a chest tube in a dog with pneumothorax.

12. How does a chest tube drainage system work?

Most drainage systems work on the principle of gravity and positive expiratory pressure. A three-way bottle system consists of two bottles for collection of drainage in the presence of a water seal and a third bottle that controls suction applied from an external source and serves as an air vent. The level of fluid in the suction control bottle determines the amount of suction provided to facilitate drainage from the pleural space.

Commercial chest tube drainage systems (Hemovac, Snyder Labs, Dover, OH) are based on the three-bottle system. The first chamber is the collection chamber. Any air aspirated from the patient moves into the second chamber, which is the water seal. The water seal usually contains about 2 cm of water. The incoming air bubbles upward through the water, which acts as a one-way valve to prevent backflow of air through the system. The air then exits the water seal chamber and enters the third, or suction control, chamber. The suction chamber allows regulation of the amount of negative pressure that can be applied to the pleural space. Normally the chamber is

filled with 20 cm of sterile water. When the negative pressure generated by the suction applied to the third chamber exceeds 20 cm of water, air from the atmosphere enters through a vent and begins to bubble through the water, relieving excessive pressure. The drainage unit should remain below the patient to promote gravity drainage and to prevent fluid and air from reentering the chest cavity by backflow.



Three-bottle chest tube drainage system.

12. Should I use a collection system or perform intermittent aspiration from the tube?

A continuous-suction drainage collection system is used to facilitate constant drainage of a pyothorax. This approach is often beneficial because of the thickness of the material and aids in minimizing fluid accumulation in the chest, thereby decreasing the onus for ongoing local and systemic inflammatory responses. Unrelenting pneumothorax and any conditions in which large amounts of fluid reaccumulate will benefit from continuous-suction drainage. Usually these systems are used only with dogs because of the amounts of fluid or air being drained, apparatus size, and amount of required tubing. Such factors make use in cats cumbersome.

13. What is a Heimlich valve?

A Heimlich valve is a small, plastic one-way valve that is connected to the chest tube (Heimlich Chest Drain Valve, Bard-Parker, Rutherford, NJ). It has a collapsible rubber tube inside a chamber that acts as a one-way valve. Air escapes from the pleural space during expiration when intrathoracic pressure exceeds atmospheric pressure. Heimlich valves do not work well for drainage of pleural fluid. Fluid passing through the tube may not allow the valve to close completely because of accumulation of proteinaceous fluid, which clots or adheres to the sides of the valve, preventing drainage or allowing air to enter the pleural cavity.

14. What should I watch for in patients with a chest tube and continuous suction?

Check for air leaks by monitoring bubbling in the water seal bottle. The absence of bubbling indicates that the evacuation of air is complete and that the pressure of the expanded lung has sealed the chest tube openings. Intermittent bubbling during inspiration indicates normal function and continuing pneumothorax. Continuous bubbling on inspiration and expiration indicates an air leak in the system. In this case, if you clamp the tube near the patient and the bubbling stops, the leak most likely is in the tube. The tube may have become dislodged, or there may be a leak around the tube at the site of insertion. If bubbling continues after the initial check, the leak is somewhere between the clamp and chamber. Continue to move the clamp down the tubing toward the drainage unit, checking the water with each move. If you find a point at which the continuous bubbling stops, the clamp is between the leak and the drainage unit, and the defective tubing needs to be changed.

If the leak persists when you clamp the end of the tubing, the drainage systems are leaking and need to be replaced. Observe the patient for subcutaneous emphysema. If it develops, reassessment of the insertion site for dislodgment of the tube is necessary.

15. Should I regularly milk the tubes?

Milking or stripping the chest tube or drainage tubing to maintain patency is not necessary. Recent studies suggest that stripping a chest tube may harm the patient by producing negative pressures as high as 400 cmH_2O in the pleural space.

16. Should I clamp the chest tubes when I move the patient?

No. Clamping a chest tube may cause air from a pneumothorax to accumulate in the thoracic cavity and create enough pressure to cause a tension pneumothorax, which may be life-threatening. In general, clamping for more than a moment is indicated only for assessing how a patient will tolerate removal of the tube. If an animal must be moved, disconnect the drainage system from suction and move the entire system with the patient. If the chest tube or connection tubing becomes disconnected between the patient and drainage system, submerge the end of the chest tube connection in a container with 2 cm of sterile saline until it can be reconnected. The saline acts as a water seal without building up excessive pressure in the thoracic cavity.

17. What happens if the chest tube is pulled out by mistake?

Quickly apply a dry sterile dressing. If the lung still has a leak that causes ongoing pneumothorax, be careful not to apply an occlusive dressing, which may result in development of a tension pneumothorax. If there is no ongoing air leak, apply an occlusive dressing. An emergency thoracocentesis may be performed to evacuate ingress of air as a result of an open chest wound in the latter cases or before replacement of the chest tube in the former case.

18. When is the chest tube removed? How?

Chest tube removal is indicated when the patient's respiratory condition improves, radiographs demonstrate reexpansion of the lungs, fluid drainage is less than 10 ml/kg day, and no air leak is noted in the drainage system.

Before removing the chest tube, continuous suction should be turned off for a trial period of a few hours to ensure that the lung will remain inflated and no respiratory distress is noted. Before pulling the chest tube, administration of an analgesic agent is recommended (butorphanol, 0.2–0.4 mg/kg IV). If chest tube withdrawal is indicated, remove the bandage, cut the suture(s), and pull the chest tube out in one swift, continuous motion. The insertion site may be closed with sutures if necessary, and an occlusive dressing should be placed. The patient is monitored closely for the next 24 hours for signs of recurrent pleural disease.

19. What complications are associated with chest tubes?

Improper positioning, bleeding of an inadvertently lacerated intercostal vessel, intercostal nerve damage, injury to the diaphragm and thoracic or abdominal organs, infection, and pain may be complications after insertion of chest tubes.

20. How can I control pain due to the chest tube?

In medium- to large-breed dogs, 0.5% bupivacaine (1.5 mg/kg diluted in 20–25 cc of sterile saline) may be introduced into the chest tube, followed by 10–15 cc sterile saline flush to deliver local anesthetic to the parietal pleura. This procedure may be repeated every 6 hours if needed. For cats and small dogs, 1.1 mg/kg of bupivacaine diluted in 10–15 cc of sterile saline every 6 hours may be used. Placing the animal in dorsal recumbency for 5–10 minutes after infusing the analgesia may aid improve the effect by blocking the intercostal nerves as they exit the spinal cord. Butorphanol, 0.2–0.4 mg/kg given intravenously every 6 hours, may be administered in cats and dogs to provide analgesia and to reduce anxiety associated with placement and maintenance of a chest tube.

21. Should I irrigate the chest tube?

In general, no. Irrigation of the chest tube involves risk of introducing nosocomial bacteria into the thoracic cavity. An exception is to provide pain relief, as described above. If a chest tube becomes clogged with blood or purulent material, it is best to change the chest tube.

22. Is antibiotic administration required for patients with chest tubes?

In general, no. However, a decrease in complications such as pneumonia or pyothorax has been observed when prophylactic antibiotics were administered for chest tube placement in human patients with traumatic hemothorax.

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113. PERICARDIOCENTESIS

Jean M. *Betkowski*, V.M.D.

1. When is pericardiocentesis indicated?

Animals with pericardial effusion or pericardial effusion with cardiac tamponade are in need of pericardiocentesis for diagnostic and therapeutic purposes. Cardiac tamponade, a state of cardiogenic shock caused by pericardial effusion, occurs when intrapericardial pressure exceeds pressure in the right atrium, and at times the right ventricle, during diastole. With elevated intrapericardial pressure, the central venous pressure (CVP) must increase to maintain adequate cardiac output. Clinical manifestations of CVP elevation are distended jugular veins, jugular pulses, ascites, and pulsus paradoxus. Pulsus paradoxus is manifested by femoral pulses that are palpably weaker during inspiration than during expiration. This variation in pulse pressures is caused by increased venous return to the right heart coupled with decreased venous return to the left heart with inspiration. Cardiac tamponade may occur with either a large or small amount of fluid accumulation. If fluid accumulates rapidly, a small amount of intrapericardial fluid may cause a substantial increase in intrapericardial pressure. If intrapericardial fluid accumulates slowly, the pericardial sac stretches, and large volumes of fluid may need to be present before cardiac tamponade occurs. In the latter case, animals may present for other manifestations of pericardial effusion such as right heart failure with ascites, before reaching the stage of cardiac tamponade. The presence of ascites at initial presentation is a positive prognostic indicator, most likely due to a longer standing pericardial effusion.

2. What diagnostic studies should be considered to confirm the need for pericardiocentesis?

If the animal has stable cardiopulmonary function and suspected or confirmed pericardial effusion, full cardiac evaluation is recommended before pericardiocentesis. A **complete physical examination** of the cardiovascular system, including examination of the jugular veins, palpation of the femoral pulses, and careful auscultation of the thorax, provides useful clues. The jugular veins may be distended, or jugular pulses may reach past the thoracic inlet when the

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neck is extended. The femoral pulses may be weak or vary in intensity with respiration. The heart sounds may be muffled in conjunction with a tachycardic heart rhythm. If anticoagulant rodenticide toxicity is suspected, an activated clotting time or coagulation profile is recommended prior to pericardiocentesis, and the tap should be performed only in life-threatening situations.

An **electrocardiogram** (ECG) may show characteristic features of sinus tachycardia, electrical alternans, and low-voltage complexes. Electrical alternans is defined by beat-to-beat variations in the height of the R wave and is caused by the rocking back and forth of the heart within the pericardial sac. The low-voltage complexes are caused by the attenuation of electric current through the intrapericardial fluid (and pleural fluid, if present). CVP also may be measured; elevations above 10 cmH_2O are supportive of significant pericardial effusion.

Thoracic radiographs are strongly suggestive of pericardial effusion if a large globoid cardiac silhouette with preservation of cranial and caudal waist is observed. The caudal vena cava also is distended. If the caudal vena cava at its widest point is 1.1–1.5 times the width of the aorta at the same rib space, the caudal vena cava is most likely distended.

Echocardiograms provide direct evidence of pericardial effusion and cardiac tamponade. Ideally, echocardiographic examination is performed before pericardiocentesis to maximize sensitivity in demonstrating an underlying cause, such as neoplasm or ruptured left atrium. Such findings may be less obvious on echocardiograms after the fluid has been removed.

CT or MRI scan may be used after the patient is stabilized with pericardiocentesis to examine for intrapericardial neoplasia or foreign body and to evaluate the thickness of the pericardial sac.

3. What are the proper approaches to treatment before or in conjunction with pericardiocentesis?

Fluid administration before pericardiocentesis may not be necessary if the patient is hemodynamically stable. If the patient is in shock, the increased preload provided by intravenous fluid administration at 1–3 times maintenance rate may be helpful for stabilization. ECG may reveal arrhythmias or electrical alternans. Significant ventricular arrhythmias (> 25–30% of beats) may require specific therapy, such as intravenous lidocaine (2 mg/kg IV bolus, repeated up to 3 times). Oxygen administration also may be useful. Diuretics generally are not indicated because they reduce preload to the right heart, which compromises right heart filling and further depresses cardiac output.

4. What type of sedation and analgesia may be used?

Most animals with pericardial effusion that warrants pericardiocentesis do not require sedation. If the animal is fractious or active and alert, small doses of sedation may be prudent to prevent iatrogenic injury to the heart or lungs during the procedure. The combinations of intravenously administered sedatives that may be used include ketamine (11 mg/kg) and diazepam (0.02 mg/kg), acepromazine (0.025 mg/kg) and butorphanol (0.02 mg/kg) or buprenorphine (0.0075 mg/kg), or diazepam and butorphanol. Drugs should be titrated to effect because compromised animals may not require full doses. Local infiltration with 1–2 ml of 2% lidocaine from skin surface to pleura should be used in the area of the puncture to prevent discomfort in all patients.

5. What equipment is necessary to perform pericardiocentesis?

A large-bore catheter is used for the pericardiocentesis, and continuous ECG monitoring is maintained throughout the procedure. In dogs, a 14- or 16-gauge, 5 1/4-inch over-the-needle catheter (Abbocath Laboratories, North Chicago, IL) is used most frequently. Full evacuation of the pericardial sac may be enhanced by adding 1–3 side holes at the distal end of the catheter with a scalpel blade (be careful not to leave burrs on the cut edges). In cats, an 18- or 19-gauge butterfly catheter may be used for pericardiocentesis.

A 3–6-ml syringe is attached to the catheter after insertion through the chest wall, and negative pressure is applied as puncture of the pericardial sac is attempted. The initial sample drawn with the syringe is placed in a red top or activated clotting time tube to observe for evidence of clot formation. Clot formation most likely indicates that a cardiac chamber or an intrapericardial tumor has been punctured. After this initial assessment to ensure proper placement of the catheter, the catheter is fully advanced off of the needle and then the needle stylet is removed.

Intravenous extension tubing with a three-way stopcock is connected to the catheter. The three-way stopcock is connected at its other end to a larger syringe (12 cc for cats, 60 cc for dogs) for ease in evacuation of the pericardial effusion. In large-breed dogs, an adequate container for fluid collection should be at hand; pericardiocentesis may yield from 500 ml to over 1 liter of fluid. Both red top and EDTA collection tubes should be available for sample collection for possible cytologic and microbiologic analysis.

6. How is pericardiocentesis performed?

1. The animal is placed in left lateral recumbency. An area of the right chest wall is clipped from the sternum to the mid-thorax and from the ninth to third intercostal spaces. The area is aseptically prepared with an antiseptic solution. The area of insertion of the catheter is infiltrated with 1–2 ml of 2% lidocaine to the level of the pleura.

2. A small stab incision is made in the skin to facilitate insertion of a large-bore catheter. The exact point of catheter insertion may be based on palpation of the apex beat or use of the echocardiogram and thoracic radiographs to judge proximity of the pericardium to the chest wall and the best trajectory for needle insertion. In general, the catheter is inserted in the fifth or sixth intercostal space at the level of the costochondral junction.

3. The catheter is inserted through the chest wall and angled dorsocranially toward the opposite shoulder. After penetration of the chest wall, the catheter is gently advanced while negative pressure is applied to the attached syringe. If hemorrhagic fluid is obtained, the possibility of cardiac puncture should be considered (see question 5).

4. After this determination is made, the catheter is advanced well into the pericardial sac and as much fluid as possible is removed. Withdrawal of fluid may be facilitated by changing the position of the animal and by slowly withdrawing or advancing the catheter to tap isolated pockets of effusion. Echocardiographic guidance to identify pockets also may be useful at this point.

Complete removal of fluid is recommended so that reaccumulation can be monitored accurately by ultrasound. Complete removal of pericardial effusion is unnecessary to return the heart to normal function. Partial removal of effusion, even small amounts in some instances, usually causes the intrapericardial pressure to drop sharply and relieves cardiac tamponade. Puncture of the pericardial sac sometimes results in drainage of pericardial fluid into the pleural space rather than through the catheter. This effect still decreases intrapericardial pressure, although complete drainage of the pericardial sac is generally not achieved.

7. What parameters should be monitored during and after pericardiocentesis?

The most important monitoring tool is continuous ECG. ECG detects premature ventricular contractions (PVCs), which may occur during the procedure as the catheter contacts the heart or after the procedure as a result of primary disease or reperfusion injury to the myocardium. When PVCs occur during the procedure, the catheter should be repositioned to avoid potential ongoing mechanical irritation to the myocardium. As the fluid is removed and pressure decreases in the pericardial sac, ECG manifestations of pericardial effusion should resolve. Heart rate decreases, R waves may increase in size, and electrical alternans, if present, disappears. CVP values also return to normal once the intrapericardial pressure decreases. Return to normal may be delayed if right heart failure and large-volume ascites or pleural effusion are present. Continuous EKG monitoring for 24 hours after pericardiocentesis is ideal because of the potential life-threatening cardiac arrhythmias. Appropriate antiarrhythmic therapy, such as intravenous lidocaine (2 mg/kg, repeated up to 3 times and followed by constant-rate infusion at 40–80 mcg/kg/min if necessary), is indicated if ventricular tachycardia is observed. Monitoring CVP values or jugular pulses in the hours after the procedure can be a useful way of assessing reaccumulation of pericardial fluid. A repeat echocardiogram the following day is a more sensitive test for the presence of smaller fluid volumes in the pericardial sac. A two-week recheck echocardiogram is also recommended to assess the long-term success of pericardiocentesis. The recheck allows the examiner to identify underlying causes, such as a neoplasm that may have grown in the intervening period.

8. What tests should be performed on the pericardial fluid?

Although cytologic evaluation of pericardial fluid is often unrewarding, it is recommended, especially if the fluid does not have the typical nonclotting, hemorrhagic appearance. Samples should be collected and handled for potential bacterial and fungal culture. The need for submission of samples for microbiologic culture, aerobic and anaerobic, should be based on the results of rapid cytologic examination. Recently, pH analysis of pericardial fluid in dogs has been shown to be of some diagnostic value. A pH < 7.0 is consistent with an inflammatory process, whereas a pH > 7.0 suggests neoplastic disease. The pH of the fluid may be determined with a blood gas analyzer or the supernatant from a fluid sample can be placed on a urine dipstick reagent strip. Unfortunately, this test is not always accurate in predicting the underlying condition.

9. What are the most common complications of pericardiocentesis?

Complications of pericardiocentesis requiring intervention are relatively uncommon. Ventricular arrhythmias are common but often require no specific treatment. Postpericardiocentesis hemorrhage occurs occasionally, especially if a right atrial hemangiosarcoma is present and punctured during the procedure. A coronary artery may be lacerated inadvertently, but the approach from the right side makes this less likely because the descending coronary artery lies on the left side of the heart. Recurrence of pericardial effusion is common and may take place within hours to weeks.

10. What treatment is required after pericardiocentesis?

If the animal remains hypovolemic after pericardiocentesis, appropriate replacement and maintenance fluids should be administered intravenously. Most often fluid administration is not indicated because of natural diuresis due to restored cardiac output and mobilization of ascitic fluid. Diuretics should not be administered unless a large volume of ascites or pleural effusion compromises respiratory function.

Antiinflammatory agents have been used to prevent recurrence of idiopathic pericarditis. Prednisone, 1 mg/kg orally every 12 hours, tapered over 2–3 weeks, has been advocated after initial pericardiocentesis. Dexamethasone, 1 mg/kg subcutaneously every 24 hours, also may be used. No studies have confirmed the efficacy of corticosteroid therapy for idiopathic pericarditis. Azathioprine, 1 mg/kg orally once daily for 3 months, has demonstrated promise in preventing recurrence of idiopathic pericardial effusion but again there are no long term controlled studies for this therapy. Pericardectomy may prove curative and provide a definitive diagnosis if fluid reaccumulates. Recently, a thoroscopic approach for pericardectomy has been improved which should lessen the pain and time of hospitalization for the procedure. If a hemangiosarcoma is present on the right atrial appendage, surgical removal is possible, although micrometastases have most likely occurred and long-term survival is poor. Pericardectomy, along with surgical debulking of a chemodectoma, may prevent recurrence of clinical signs for months. Intrapericardial or intrathoracic infusion of chemotherapeutic agents, such as cisplatin (70 mg/m^2) or adriamycin (30 mg/m^2), or antiinflammatory agents, such as dexamethasone (0.2 mg/kg), has been attempted on an experimental basis. Anecdotally, the response to intracavitary cisplatin has been favorable, but no controlled studies have been performed. Antiinflammatory agents have been less promising.

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114. EMERGENCY VENOUS ACCESS

Lisa L. *Powell*, D.V.M.

1. List two common emergency situations in which immediate venous access is necessary.
- Shock
- Cardiopulmonary arrest

2. Is it difficult to obtain vascular access to a peripheral vein in hypovolemic states?

It may be difficult to place intravenous catheters in hypovolemic and hypotensive patients. Peripheral veins are often constricted because of the adrenergic response after an event that stimulates the hypovolemic or hypotensive state. Venous access also may be complicated in small patients, pediatric patients, small exotic veterinary patients, edematous patients, and obese patients. In most situations, an intravenous catheter can be placed with conventional methods.

3. If conventional methods fail, what other ways are available to obtain venous access?

Alternate methods of obtaining venous access include facilitation incisions, venous cutdown procedures, and intraosseous catheterization.

4. Is chemical sedation necessary for placement of an intraosseous catheter or venous cutdown?

Because most patients are critically ill, chemical restraint usually is not necessary for placement of an intraosseous catheter or venous cutdown. Local infusion of 2% lidocaine is usually sufficient.

5. What is a facilitation incision?

A facilitation incision is a full-thickness skin incision over the vein into which catheterization is attempted. Time permitting, the area is aseptically prepared, and lidocaine is infused. A no.-11 blade or the bevel of an 18-gauge needle is used to make a small, full-thickness skin incision in the area of catheterization. The catheter can then be advanced through the incision and into the more easily visualized vein. This method decreases skin tension and friction against the catheter and allows better catheter control.

6. How is venous cutdown performed?

Two different types of venous cutdown procedures can be performed: minicutdown and full cutdown. The **minicutdown** is similar to facilitation incision, but the incision is extended so that the superficial surface of the vein is visualized. The vessel is incised with the bevel of a 20-gauge needle, and the catheter is advanced into the vein.

The **full cutdown** must be performed under sterile conditions. After infusion of lidocaine into the area, a 2.5–5-cm incision is made through the skin parallel and to one side of the vessel. The vessel is dissected free of the surrounding tissues and clamped proximally and distally with either vascular clamps or sutures. A venotomy is made between the clamps, and a catheter is advanced through the venotomy site toward the proximal clamp. The clamps are removed, sutures are placed around the catheter and vein proximal and distal to the insertion site to secure the catheter into the vein, the area is flushed with sterile saline, and the skin is closed with sutures

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around the catheter. The full cutdown is used when a long-term intravenous catheter is needed or in emergency settings when other venous access methods have failed.

7. What are the major contraindications for doing a cutdown?

Relative contraindications for performing venous cutdown include significant coagulopathy, such as disseminated intravascular coagulation (DIC); systemic infection; metabolic disease; immune-mediated thrombocytopenia and thrombocytopenia secondary to DIC, hemorrhage, or infectious disease (e.g., Rocky Mountain spotted fever, ehrlichiosis, Lyme disease); factor deficiencies such as von Willebrand's disease; and toxicities such as warfarin ingestion. If a catheter must be placed via cutdown in such situations, efforts must be made to control hemorrhage at the placement site (i.e., use of direct pressure). The facilitation incision, minicutdown, or intraosseous methods are preferred if conventional methods have failed.

8. What complications are associated with venous cutdown?

Possible complications associated with the cutdown procedure include hemorrhage at the catheter placement site, which can be avoided if hemorrhage is controlled during the placement procedure, and infection, which can be avoided if sterile methods are used when the catheter is initially placed. Sterile bandage material should be used to cover the catheter site for further protection against contamination and infection.

9. What sites are most commonly used for placement of an intraosseous catheter?

The most common sites for placement of an intraosseous catheter include the intertrochanteric fossa of the femur, wing of the ilium, tibial tuberosity, medial surface of the proximal tibia just distal to the tibial tuberosity, and greater tubercule of the humerus.

10. How do you place an intraosseous catheter?

In placing an intraosseous catheter, the following materials are needed:

- 1% lidocaine for local anesthesia
- No. 11 scalpel blade
- Needles: 16–20-gauge bone marrow needle (dogs, cats)
  18–22-gauge spinal needle (cats, young dogs)
  18–25-gauge hypodermic needle (neonates)
  12- and 15-gauge commercial intraosseous catheter
- 12-ml syringe
- Heparinized saline (3 ml)
- Antiseptic ointment

The site must be clipped and aseptically prepared. The skin and periosteum are infused with 2% lidocaine solution. The scalpel blade is used to make a stab incision down to the periosteum. The needle is then passed through the stab incision and into the cortex of the bone. The needle is seated in the cortex by applying light pressure and turning the needle back and forth at about 30° turns. A sudden decrease in resistance usually occurs once the marrow has been entered. The needle is advanced to the hub if possible. Placement is checked by moving the limb and noting that the needle moves solidly with the limb when it is flexed and extended; the needle will wobble if it is not seated in the bone. The 12-cc syringe is used to aspirate marrow, further verifying placement within the marrow cavity. The needle is flushed with heparinized saline. Little resistance should be encountered in flushing the needle. If resistance is felt, turning the needle 90–120° may help to move the bevel away from the inner cortex. A tape strip should be placed at the junction of the needle and skin. Sutures are placed through the tape strip and then through the periosteum or surrounding skin. Antiseptic ointment on gauze is applied over the entrance site, and the whole needle apparatus is covered with bandage to prevent movement and breakage of the needle and to protect against contamination of the site. A common bandage method consists of figure-eight placement of cast padding around the catheter, then coverage with a small amount of stretch gauze and Vetwrap or elasticon for the outer layer.

11. What are the indications for use of intraosseous catheters?

Intraosseous catheterization is an excellent method for gaining venous access in small patients, pediatric patients, and severely hypotensive and hypovolemic patients. Intraosseous administration of fluids and medications achieves the same blood levels as administration into peripheral veins. Patients in cardiopulmonary arrest often benefit from intraosseous catheterization for two reasons: (1) most peripheral veins are collapsed, and (2) gaining venous access is often impossible.

12. What are the major contraindications to placing an intraosseous catheter?

Contraindications to placement of an intraosseous catheter include bone disease at the insertion site (e.g., fractures, neoplasia, osteomyelitis), abscesses over the placement area, skin and wound infections, and sepsis. In treating septic patients, the potential for causing osteomyelitis (i.e., providing a nidus for hematogenous spread of bloodborne pathogens) must be weighed against increased mortality due to inadequate fluid resuscitation.

13. What complications are associated with placing an intraosseous catheter?

The most common complication associated with intraosseous catheterization is infection. Other complications include extravasation of fluids into surrounding tissues if the catheter pierces both bone cortices and, rarely, bone fractures. The risk of infection increases with the amount of time the catheter remains in the bone.

14. Which medications can be delivered through an intraosseous catheter?

Many drugs have been shown to be effective when administered through the intraosseous catheter, including:

Aminophylline	Dexamethasone	Epinephrine
Atropine	Diazepam	Insulin
Calcium gluconate	Digitalis	Morphine
Sodium bicarbonate	Diphenhydramine	Thiopental
Cefoxitin	Dobutamine	Dextrose

15. What about administration of plasma, blood products, hypertonic saline, hetastarch, and dextrans through an intraosseous catheter?

Plasma, blood products, hypertonic saline, and synthetic colloids can be administered safely through an intraosseous catheter. The maximal rate of infusion is slower than that achievable with a large-bore venous catheter, but resuscitation may be successful when the intraosseous route is used.

16. Do you need to change the doses of medications, colloids, blood products, or crystalloids when they are administered through an intraosseous catheter?

Using an intraosseous catheter is comparable to using an intravenous line. Therefore, the dose of medications, colloids, blood products, and crystalloids administered through an intraosseous catheter is the same as the intravenous dose.

17. How long can intraosseous catheters remain safely in a patient?

An intraosseous catheter can remain in place safely for 72 hours as long as aseptic technique is used for placement and bandaging is adequate.

18. Overall, what is the safest and most effective method of catheter placement if conventional methods fail in the emergency setting?

In an emergency situation, venous access may be the one procedure necessary to save the patient's life; it also may the most difficult and, in some instances, a seemingly impossible procedure to perform. With alternative methods for catheter placement such as venous cutdowns and intraosseous catheterizations, aseptic technique should be used. If there is no time for aseptic preparation of the catheter site, a conventional venous catheter should replace the emergent catheter when resuscitation and stabilization are achieved.

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115. URETHRAL CATHETERIZATION

Steven Mensack, V.M.D.

1. What are the indications for urethral catheterization?

Single or intermittent catheterization is most frequently used to relieve urethral obstruction or to obtain urine directly from the bladder for diagnostic purposes when cystocentesis is not possible or practical. Other indications include instillation of contrast media for radiographic study of the bladder or urethra, retrieval of urocystoliths for analysis, prostatic washes, and removal of urine in animals that are unable to void normally because of recumbency, neurologic dysfunction of the bladder, and pain.

An **indwelling urinary catheter** is indicated for measuring urine output, maintaining urethral patency after relief of urethral obstruction (especially when the obstruction is associated with significant inflammation and persistence of debris in the urinary tract), continued emptying of a hypotonic bladder, and collection of urine in recumbent animals. It also is used in selected cases after surgery involving the urinary bladder, urethra, and prostate.

2. What are the relative contraindications for urethral catheterization?

Urethral catheters should be avoided in patients that are immunocompromised (e.g., viral infections such as parvovirus, pancytopenia, chemotherapy) or septic, when urinary catheterization is not easily achieved without significant risk of urethral or bladder trauma (urethral or bladder neoplasia), and when the presence of a urethral catheter may adversely affect the outcome of a surgical intervention (prepubic urethrostomy).

3. Which catheter types are most commonly used?

Urinary catheters vary in size, composition, and design. They are sized according to outer diameter, using the French (Fr) system. One French unit equals ⅓ mm. The inner diameter of the catheter is affected by design and material. Catheters may be either self-retaining or non-self-retaining.

The **Foley catheter** is the most commonly used self-retaining catheter. It has a balloon at the tip that can be inflated with sterile saline through an inflation channel incorporated into the catheter wall. Inflation of the balloon when the tip of the catheter is in the bladder prevents removal of the catheter from the bladder lumen. Foley catheters are composed of Latex with a Teflon coating or silicone; this composition makes the catheter flexible and inert. Foley catheters are highly flexible and less traumatic than many stiff, non-self-retaining catheters. The Foley catheter is used mainly as an indwelling catheter in larger female dogs; the narrow and long urethra of male dogs requires a stiffer, longer catheter. The 8-Fr or larger size of the Foley catheter precludes its use in cats and small dogs.

The most commonly used non-self-retaining catheters are straight urethral catheters with a single lumen and one or more openings at the distal end. Materials used in these catheters include metal, polypropylene, polyvinyl chloride (red rubber), and polyurethane. Non-self-retaining catheters may be secured by use of tape and/or sutures. **Metal catheters** for female dogs are available in a single size. They are sometimes used for a single catheterization because their

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The most commonly used non-self-retaining catheters are straight urethral catheters with a single lumen and one or more openings at the distal end. Materials used in these catheters include metal, polypropylene, polyvinyl chloride (red rubber), and polyurethane. Non-self-retaining catheters may be secured by use of tape and/or sutures. **Metal catheters** for female dogs are available in a single size. They are sometimes used for a single catheterization because their

rigidity facilitates catheterization. However, metal catheters are more traumatic to the urinary tract and therefore not highly recommended. **Polypropylene catheters** are relatively stiff, have a closed end, and are available with various internal diameters but only a single length (22 inches). They are commonly used in male and female dogs. **Tomcat catheters**, also made of polypropylene, are available only in one diameter (3.5 Fr) with either a closed or open end. Their main use is for the relief of urethral obstruction in male cats. Polypropylene catheters are not ideal for use as indwelling catheters because the stiffness may cause urethral and bladder trauma. **Polyvinyl chloride (red-rubber) catheters** are available in multiple diameters and two lengths. Most of these catheters are 16 inches in length. The 8-Fr size is also available in a 22-inch length. Red-rubber catheters are more flexible and less traumatic than polypropylene catheters. Studies also have shown that they are less irritating to the urethral mucosa than the polypropylene type. These properties make the red-rubber catheter more suitable for use as an indwelling catheter in both genders of dogs and cats. **Polyurethane tubes** are used most commonly for enteral feeding but also have shown utility as urethral catheters. Polyurethane is less irritating than polyvinyl chloride on mucosal surfaces. These tubes are available in sizes of 5 Fr or greater and lengths of 22 cm or longer.

4. How do you decide the proper size of urethral catheter to use?

Urethral catheters are available in sizes ranging from 3.5–14 Fr. In dogs, the proper size is based on body weight. A 3.5–5 Fr catheter should be used for male dogs weighing less than 12 kg, an 8-Fr catheter for male dogs weighing 12–35 kg, and a 10- or 12-Fr catheter for male dogs weighing more than 35 kg. A 5-Fr catheter should be used for female dogs weighing less than 5 kg, an 8-Fr catheter for female dogs weighing 5–25 kg, and a 10–14-Fr catheter for female dogs weighing more than 25 kg. A 3.5-Fr catheter should be used for most cats. Occasionally, a 5-Fr catheter may be used for urethral catheterization in larger cats.

Recommended Sizes and Types of Urethral Catheters for Use in Dogs and Cats

ANIMAL	CATHETER TYPE	CATHETER SIZE (FRENCH)
Cat	Tomcat (polypropylene) or polyvinyl chloride	3.5
Male dog		
Weight ≤ 12 kg	Polypropylene or polyvinyl chloride	3.5–5
Weight 12–35 kg	Polypropylene or polyvinyl chloride	8
Weight ≥ 35 kg	Polypropylene or polyvinyl chloride	10–12
Female dog		
Weight ≤ 5 kg	Polypropylene or polyvinyl chloride	5
Weight 5–25 kg	Polypropylene, polyvinyl chloride, or Foley	8
Weight ≥ 35 kg	Polypropylene, polyvinyl chloride, or Foley	10–14

5. How is urethral catheterization performed in male dogs?

In general, two people are required to catheterize a male dog. The dog is placed in lateral recumbency.

1. The first person retracts the prepucial sheath to expose the glans penis, which is gently cleansed with a 1% povidone-iodine solution.

2. The second person dons sterile gloves and obtains a catheter of appropriate length and diameter. The distance to which the catheter is to be inserted is estimated by measuring the length from the tip of the prepuce to the perineum and half the distance back to the prepuce. The distal 3–5 cm of the catheter is lubricated with a sterile lubricant (K-Y Jelly, Johnson & Johnson). As an alternative to wearing sterile gloves, two slits can be cut into the packaging of the catheter about 3–5 cm apart near the distal end of the catheter. The end of the packaging is removed, and the 3–5-cm section is broken away from the rest of the packaging. This segment acts as a sterile handle for introducing the catheter.

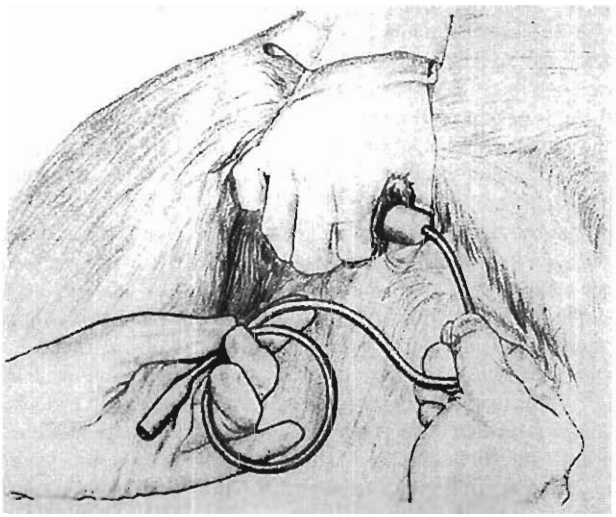
3. The tip of the catheter is introduced into the distal urethral orifice and passed slowly into the bladder. Resistance may be encountered as the catheter passes over the ischial arch. Passing

over the ischial arch may be facilitated by rotating the catheter and pushing on the perineum below the anus. Excessive force should be avoided because it may lead to urethral mucosa damage and potential rupture of the urethra.

4. If no urine is obtained after passing the catheter a sufficient distance to be within the bladder, an attempt should be made to aspirate urine with a sterile syringe. Compression of the urinary bladder at this point should not be attempted because it may damage the bladder. If no urine is obtained, the catheter should be withdrawn and/or advanced a short distance; aspiration for urine should be repeated before gentle removal and a second attempt at catheterization.

5. If catheterization is used to obtain a urine specimen or to decompress the bladder, the catheter is gently removed after completion of the procedure.

6. If the catheter is to remain in place as part of a closed collection system, it should be made of either polyvinyl chloride (red rubber) or polyurethane. To secure the catheter to the patient, phalanges made of 1-inch waterproof adhesive should be placed in a butterfly fashion on the catheter as it exits the prepuce. The phalanges are secured to the paraprepucial area with nonabsorbable sutures. Alternatively, the catheter may be secured to the paraprepucial area with nonansorbable sutures in a Chinese fingerknot technique. The collection system is then attached to the urinary catheter. A piece of tape or bandage may be placed circumferentially around the catheter and cranial abdomen of the patient to help prevent the catheter from kinking and to prevent the patient from removing the catheter. An Elizabethan collar should be used if the patient is able to reach the catheter.



Placement of urethral catheter in male dogs. (From Crow SE, Walshaw SO: Urethral catheterization. In Manual of Clinical Procedures in the Dog and Cat. Philadelphia, J.B. Lippincott, 1987, pp 110–127, with permission.)

6. How is urethral catheterization performed in female dogs?

Urethral catheterization in female dogs requires two people.

1. The first person restrains the dog in a standing position. If this is not possible, lateral or sternal recumbency with the hind limbs hanging over the edge of a table is an acceptable alternative. A towel or other padding should be placed under the dog at the edge of the table if the sternal recumbency position is used. The dog's tail is pulled to the side to expose the vulva. The vulva and perivulvar region are gently cleansed with 1% povidone-iodine solution.

2. The second person dons sterile surgical gloves in preparation for urethral catheterization. A topical anesthetic, such as ophthalmic anesthetic drops (Ophthaine 0.5%, Solvay), 2% lidocaine liquid, or 2% viscous lidocaine, may be instilled into the vagina to decrease discomfort associated with catheter placement.

3. A sterile vaginal speculum or sterile otoscopic speculum is lubricated with sterile lubricant (K-Y Jelly, Johnson & Johnson) and inserted into the vagina. The speculum is directed dorsally to avoid the clitoral fossa and then ventrally to visualize the urethral papilla. The urethral papilla appears as a slit or dimple, usually located at the caudal pelvic brim.

4. A catheter of appropriate type and diameter is chosen, and the end is lubricated with sterile lubricant. The catheter is inserted into the urethra under direct visualization and advanced into the bladder. This distance is normally 8–14 cm (the length of the female dog's urethra). Excessive force should not be used because it may lead to urethral mucosa damage and rupture of the urethra.

5. If no urine is obtained after the catheter is passed a sufficient distance to be within the bladder, aspiration of urine may be attempted with a sterile syringe. If urine still is not obtained, the catheter is advanced and/or withdrawn a short distance, and aspiration is repeated. Compression of the urinary bladder should not be attempted at this point because it may damage the bladder. If urine is not obtained, the catheter is gently removed and catheterization is reattempted.

6. Once the urine sample is taken or the bladder decompressed, the catheter is gently removed. If the catheter is to remain in place for continuous drainage it is secured to the dog, as described below, and a closed urine collection system is attached.

Alternatively, a urinary catheter can be placed in female dogs using a tactile technique:

1. The dog is positioned and prepared as with the visual technique. Topical anesthetic may be introduced as previously described.

2. The person placing the catheter dons sterile gloves and chooses a catheter of appropriate diameter and type. The catheter is lubricated.

3. The index finger of the nondominant hand (left hand for the right-handed person) is lubricated and inserted into the vagina. The urethral papilla is palpated.

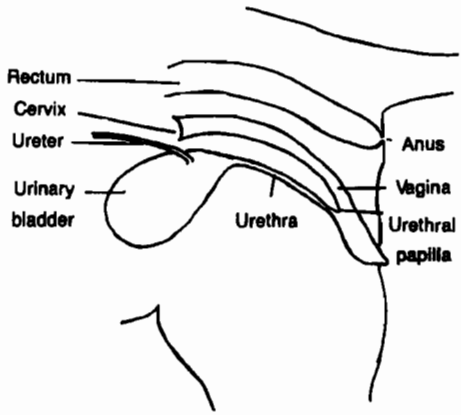
4. The catheter is passed ventral to the finger, which is used to guide the catheter gently into the urethra. If the catheter can be palpated beyond the tip of the index finger, it is not in the urethra. In this case, the catheter should be withdrawn a short distance and redirected ventrally (beneath the finger) into the urethral orifice.

5. Once the catheter tip is in the urethra, the catheter is advanced as described previously.

In female dogs, an indwelling catheter may be secured by several methods:

1. If a Foley catheter is used, the balloon is inflated with sterile saline. If resistance is met during inflation, the balloon may be within the urethra. The balloon should be deflated, and the catheter is advanced a short distance before reinflating the balloon. The amount of saline necessary for inflation is usually listed on the balloon inflation mechanism as well as on the packaging.

2. If the dog is too small for a Foley catheter, a red-rubber or polyurethane catheter is recommended. The catheter is secured to the dog by waterproof adhesive tape phalanges placed around the urinary catheter in a butterfly fashion as it exits the vulva. The catheter is sutured through the tape phalanges to the perivulvar area with nonabsorbable suture. An Elizabethan collar is placed on the dog if it is able to reach the catheter.



Lower urinary tract of female dogs. (From Phillip S: Urine collection in cats and dogs. Part II: Urinary catheterization. Vet Tech 11:1, 1990, with permission.)

7. How is urethral catheterization performed in male cats?

Two people are required to place a urethral catheter in a male cat. Sedation or short-term anesthesia is usually necessary.

1. The first person holds the patient in lateral recumbency while pulling the hind limbs cranially and the tail laterally or dorsally. The area around the prepuce is clipped and cleansed with 1% povidone-iodine solution.

2. The second person dons sterile gloves. The end of a 3.5-Fr polypropylene tomcat catheter or 3.5-Fr (5-Fr in larger cats) red-rubber catheter is lubricated with sterile lubricant (K-Y Jelly, Johnson & Johnson). Closed-end tomcat catheters are preferred because the tip is less traumatic to the urethral mucosa.

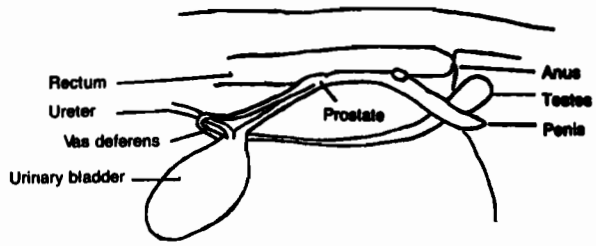
3. The penis is extruded from the prepucial sheath by placing the thumb and index finger of the nondominant hand on either side of the prepuce, with the palm resting on the cat's spine at the tail base. Pressure is exerted in a cranial direction to extrude the penis.

4. The tip of the catheter is introduced into the urethral orifice, and the catheter is gently advanced into the bladder. Gentle traction with the thumb and forefinger on the prepuce in a caudoventral direction helps to straighten the urethra and allows the catheter to pass smoothly over the ischial arch into the bladder.

5. If difficulty is encountered in advancing the catheter (secondary to urethral obstruction or deviation), the catheter may be flushed gently with sterile saline to straighten the urethra, to dislodge an obstruction, and to allow advancement into the bladder. Excessive force should not be used because it may lead to urethral mucosa damage and potential rupture of the urethra.

6. If the catheter is to remain in place as part of a closed urine collection system, the indwelling catheter, which should be made of polyvinyl chloride or polyurethane, is secured to the cat. If a polypropylene catheter was initially used to remove an obstruction, it should be replaced. Flushing the polypropylene catheter with sterile saline during removal helps to flush grit in the urethra back into the bladder and distends the urethra for reinsertion of a polyvinyl chloride catheter. Freezing the polyvinyl chloride catheter before lubrication and insertion into the urethra stiffens the catheter and facilitates passage.

7. To secure the catheter, phalanges made of 1-inch waterproof adhesive tape are placed on the catheter in a butterfly fashion as it exits the prepuce. The phalanges are secured to the perineal region of the cat with nonabsorbable sutures. The collection system is attached to the catheter, which is then taped to the tail to relieve tension on the catheter and sutures and to prevent premature removal of the catheter by the patient. An Elizabethan collar should be used if the cat is able to reach the catheter.



Lower urinary tract of male cats. (From Phillip S: Urine collection in cats and dogs. Part II: Urinary catheterization. Vet Tech 11:1, 1990, with permission.)

8. How is urethral catheterization performed in female cats?

Urethral catheterization in female cats requires two people. Sedation or short-term anesthesia is usually necessary.

1. The first person restrains the cat in lateral recumbency and pulls the tail laterally or dorsally. The perivulvar region is gently cleansed with 1% povidone-iodine solution. Topical anesthetics, such as ophthalmic anesthetic drops (Ophthaine, Solvay), 2% lidocaine liquid, or 2%

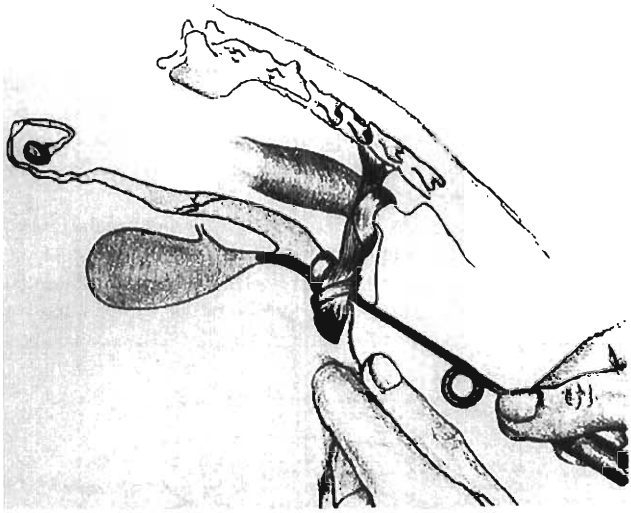
viscous lidocaine, may be instilled into the vagina to lessen discomfort associated with catheter placement.

2. The second person dons sterile gloves. The end of a 3.5-Fr polypropylene tomcat catheter or 3.5-Fr red-rubber catheter is lubricated with sterile lubricant (K-Y Jelly, Johnson & Johnson).

3. The vulvar lips are pulled caudally with one hand while the catheter is advanced along the ventral vaginal wall until it slides into the urethral orifice. A thin wire stylet inserted into the lumen of the catheter may facilitate passage. Excessive force should not be used because it may lead to urethral mucosa damage and rupture of the urethra.

4. If urine is not obtained once the catheter has been advanced a sufficient distance to be within the bladder, aspiration of urine with a sterile syringe may be attempted. Compression of the bladder is not recommended because it may damage the bladder. If no urine is obtained, the catheter should be withdrawn and/or advanced a short distance, and aspiration of urine should be reattempted before gentle removal and a second attempt at catheterization.

5. Once a urine sample is obtained or the bladder is decompressed, the catheter is gently removed. If the catheter is to remain in place as part of a closed urine collection system, it should be made of polyvinyl chloride and secured to the patient. The catheter is secured by placing 1-inch waterproof adhesive tape phalanges around the catheter in a butterfly fashion as it exits the vulva. The catheter is sutured to the perivulvar region through the tape phalanges with nonabsorbable sutures. The collection system is attached to the catheter. An Elizabethan collar should be placed if the patient can reach the catheter.



Placement of urethral catheter in a female cat. (From Crow SE, Walshaw SO: Urethral catheterization. In Manual of Clinical Procedures in the Dog and Cat. Philadelphia, J.B. Lippincott, 1987, pp 110–127, with permission.)

9. If the catheter is left in place for continuous urine collection, what are the guidelines for catheter and collection system care?

When a urinary catheter is left in place, certain guidelines should be followed to lessen the incidence of trauma and infection. Once the catheter is secured to the patient, a closed urine collection system is attached. The closed system usually consists of sterile intravenous tubing attached to an empty sterile intravenous fluid bag. Alternatively, commercial urine collection systems (Dover Urinary Drainage Bag, Sherwood Medical) are available. They allow drainage of urine from the collection bag without disconnection. Many commercial systems are adapted to fit the Foley catheter.

The closed urine collection system should be handled in an aseptic manner. Once the catheter is connected to the sterile tubing, the connection should not be disrupted unless the catheter becomes obstructed. If it does, the tubing should be disconnected aseptically, and the catheter should be flushed with sterile saline. The catheter should be removed if it becomes nonfunctional or if bladder catheterization is no longer needed. The urine collection bag should be kept below the level of the patient to prevent urine reflux into the bladder; urine reflux increases the chance of bacterial colonization of the bladder. The urine collection bag also should be kept off the floor to reduce the chance of contamination of the system and colonization of the bladder with hospital pathogens. Addition of povidone-iodine or hydrogen peroxide to the urine collection bag has not been shown to prevent bacterial contamination of the system or subsequent bacterial colonization of the bladder. Any patient with an indwelling urinary catheter and the ability to reach the catheter should be fitted with an Elizabethan collar.

10. When should an indwelling urinary catheter be removed?

An indwelling urinary catheter should remain in place for the shortest time necessary. Urinary catheters should be removed under the following three circumstances:

1. **If it becomes nonfunctional.** Before removal the catheter and system should be checked for kinks. If no kinks are noted, the catheter should be flushed gently with sterile saline. If urine flow cannot be reestablished after these procedures, the catheter should be removed and examined for an explanation of malfunction. A new sterile urinary catheter may be inserted and connected to a new sterile collection system, if indicated.

2. **If bladder or urethral trauma or systemic signs of infection are observed.** If systemic signs of infection (pyuria, fever, and leukocytosis) are present, catheter removal and microbiologic cultures of both urine and catheter are recommended. Recatheterization of the urethra should be avoided unless absolutely necessary.

3. **If the condition that prompted catheterization resolves.** After removal of an indwelling catheter, the patient should be monitored carefully to ensure adequate passage of urine (volume and stream) when voiding.

11. Should antibiotics be administered during indwelling urethral catheterization?

No. Multiple studies in dogs of both sexes and male cats have shown that antibiotic administration while an indwelling urinary catheter is in place provides no protection against urethral and urinary bladder bacterial colonization. Bacterial colonization of the bladder occurred within 4 days of catheter placement despite antibiotic administration. Several studies also showed that if antibiotics were given while the animal was catheterized, the bacteria developed resistance. Antibiotics administered after catheter removal should be based on results of microbiologic culture and antibiotic sensitivity testing of urine samples.

CONTROVERSIES

12. What are the effects of urethral catheterization on urinalysis and microbiologic testing of urine specimens?

Several studies have addressed this issue in male and female dogs and male cats. Urinalysis results may be altered by obtaining samples via urethral catheter rather than cystocentesis. Reported differences include the presence of blood and increased protein concentration on urinalysis of catheterized samples from the bladder. Examination of comparative urine sediments revealed an increased presence of red blood cells (caused by urethral and/or bladder trauma), white blood cells, and bacteria (from urine contamination in the urethra and/or vagina) in samples obtained by catheterization. Results in dogs have shown that contamination of specimens is more likely in females than males. The results of urinalyses taken by urethral catheterization should be interpreted with caution.

Results of microbiologic culture should be reviewed critically if the specimen was obtained by urethral catheterization. Several studies have shown that cultures may be negative even though bacteria are present in the urine sediment of catheterized samples. This may be attributed to low bacterial colony counts (a minimum of 1.0×10^5 bacteria/ml is necessary to differentiate infection from contamination); large amounts of amorphous debris, which may mimic the presence of bacteria; or presence of anaerobic bacteria. Other studies have shown that microbiologic cultures obtained by catheterization are falsely positive compared with results of urine samples obtained by cystocentesis in the same animal.

13. What ancillary methods may be used to dislodge urethral obstructions?

Hydropulsion, the most commonly used method to remove obstructions of the urethra, involves injecting sterile saline through the catheter into the urethra in an attempt to flush the obstructing object back into the bladder. Gentle pressure is applied to the syringe to create a steady stream of saline. Alternatively, short pulsatile jets of saline may be used in an attempt to dislodge the obstruction. In male dogs and cats, digital occlusion of the urethra distal to the obstruction during hydropulsion may increase retrograde pressure and distend the urethra sufficiently to dislodge the obstruction. If tremendous resistance is met during injection of saline, hydropulsion should be discontinued because it may cause urethral mucosal damage and potentially rupture the urethra.

In male cats, several other types of catheters and adjuncts to catheterization have been used successfully to relieve urethral obstructions. Open-end tomcat polypropylene catheters, small over-the-needle intravenous catheters with the stylet removed, and metal lacrimal or olive-tip catheters have been used with hydropulsion to dislodge urethral obstructions. These types of catheters may cause significant urethral trauma and should be used with caution and only when attempts with a closed-end polypropylene tomcat catheter have failed.

Walpole's solution is a highly acidic flush that aids in the dissolution of mucocrystalline plugs. If an obstruction cannot be relieved by the above methods, a small amount of Walpole's solution may be instilled through the catheter, followed several minutes later by additional attempts at hydropulsion. This solution is highly irritating to the tissues and should not be instilled directly into the bladder. If all attempts at relief of urethral obstruction are unsuccessful, surgical intervention (urethrostomy, cystostomy, or temporary tube cystostomy) is indicated.

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116. ABDOMINAL PARACENTESIS

Orna Kristal, D.V.M.

1. What is abdominal paracentesis?

Needle or catheter puncture of the abdominal cavity to remove variable amounts of fluid for diagnostic and/or therapeutic purposes.

2. What are the indications for abdominal paracentesis?

- Peritonitis
- Obvious or suspected blunt abdominal trauma
- Penetrating abdominal wall trauma (especially if peritoneal penetration is unknown)
- Acute abdomen
- Suspected postoperative gastrointestinal dehiscence
- Peritoneal fluid accumulation
- Evaluation of trauma patients with multiple injuries
- Evaluation of patients with hypovolemic or hemorrhagic shock and unsatisfactory response to shock therapy
- Removal of excessive quantity of ascitic fluid

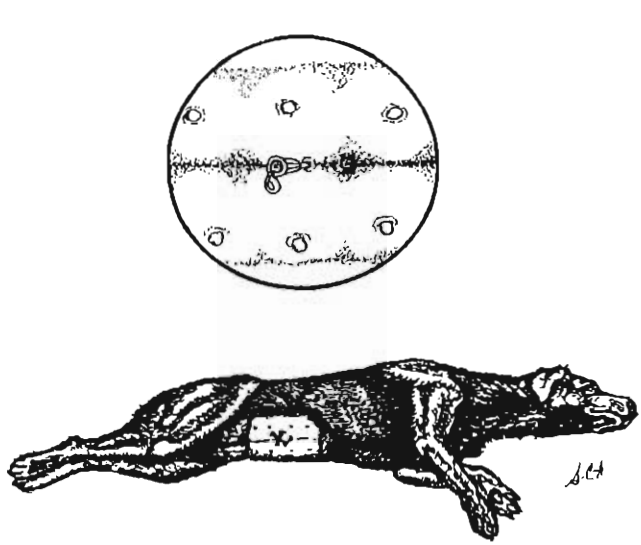
3. How is abdominal paracentesis performed?

Abdominal paracentesis in dogs and cats may be performed with a simple needle, over-the-needle intravenous catheter, or peritoneal dialysis catheter. Preparation of the patient and site for paracentesis is essentially the same with all methods. The urinary bladder should be emptied by allowing the animal to void, manual expression, or catheterization to avoid accidental cystocentesis. The animal is restrained in left lateral recumbency to minimize risk of puncturing the spleen. A standing position in large dogs is also acceptable for needle paracentesis. The ventral midline area is clipped and aseptically prepared for needle or catheter insertion 1–2 cm caudal to the umbilicus. Use of this site avoids the falciform fat, which readily blocks the needle barrel.

Needle paracentesis. The use of local anesthesia is usually not necessary. A 1-inch, 18–20 gauge needle is inserted in the ventral midline or slightly lateral to it (see figure at top of next page). Insertion through obvious scars should be avoided because of the possibility of adhesion of underlying abdominal viscera. After needle insertion, the fluid is collected from the hub of the needle into an EDTA tube and a serum (red-top) tube for analysis, and the needle is removed. This technique of open-needle abdominocentesis is reportedly more sensitive than aspiration with a syringe. If a syringe is attached, only mild negative pressure should be applied; otherwise the needle may be occluded with omentum or other abdominal contents.

Over-the-needle intravenous catheter paracentesis. The paracentesis site is infiltrated with 1% lidocaine down to and including the linea alba. A 2.5-inch, 14-gauge, styleted intravenous catheter is used. Once the peritoneum is penetrated, the catheter is advanced into the abdominal cavity, and the stylet is removed. The addition of side holes to the catheter and application of abdominal compression may enhance fluid collection.

Peritoneal dialysis catheter paracentesis. The dialysis catheter (Diacath, Travenol Laboratories, Deerfield, IL) may be introduced into the abdominal cavity by using the trocar supplied with the catheter. The patient is placed in left lateral recumbency and prepared as described above. A small skin incision is made, and the catheter-trocar unit is inserted through the linea alba with a controlled rotational movement. Once the peritoneum is penetrated, the point of the trocar is pulled back into the catheter, and the whole unit is advanced a short distance into the abdomen. The catheter is then threaded caudally over the trocar until all of the catheter holes are within the abdominal cavity. Then the trocar is removed, allowing fluid collection.



Needle paracentesis.The needle is inserted in the ventral midline 1–2 cm caudal to the umbilicus. The fluid sample is collected from the hub of the needle into the appropriate tubes.

4. What is a "minilap" procedure?

The minilaparotomy procedure is an alternative method of peritoneal dialysis catheter paracentesis. It has a lower risk for laceration or puncture of abdominal viscera and is more suitable for small patients. The patient is placed in dorsal recumbency, and a small incision is made through the skin, subcutaneous tissue, and linea alba. Strict hemostasis is necessary to avoid bleeding into the peritoneal cavity, which may create false-positive results. The catheter, without use of the trocar, is then inserted caudally, and a fluid sample is aspirated with a syringe. After a sample is obtained, the catheter is removed and the skin incision is sutured. If a sample cannot be obtained with either technique of peritoneal dialysis catheter paracentesis, the animal is rolled gently from side to side, and reaspiration is attempted. The catheter may be sutured in place if repeated sampling, drainage, or peritoneal lavage is indicated.

5. What are the advantages and disadvantages of the three techniques for paracentesis?

Needle paracentesis is rapid, inexpensive, and easy to perform; it requires minimal equipment and restraint. The risk of puncturing bowel is low because the mobile loops of gut simply move away from the needle. Patient restraint is important while the needle is in the abdomen because movement increases the risk of lacerating abdominal viscera. The main disadvantage of needle paracentesis is that it is not sensitive to small amounts of intraperitoneal fluid. A single-hole needle is also easily occluded by the omentum. Kolata has shown that at least 5.2–6.6 ml/kg body weight (BW) of fluid must be present in the abdominal cavity of dogs to obtain positive results in 78% of cases. Other investigators report 47–52% accuracy with needle paracentesis.

A 14-gauge **over-the-needle intravenous catheter** with added side holes has the same advantages as needle paracentesis. In addition, there is less chance of lacerating abdominal organs. This technique is more sensitive because of additional length and presence of side holes. The plastic catheter, however, may easily kink and occlude.

Paracentesis with a dialysis catheter is the most sensitive method of the three and can detect the presence of 1–4.4 ml/kg BW of abdominal fluid. Other investigators found that this technique accurately detects presence of abdominal fluid in 41–83% of cases. The great reliability of this method can be attributed to the large internal diameter (11 French), length of the catheter, and multiple fenestrations. The fenestrations make complete occlusion of the catheter by the omentum and bowel unlikely and provide a large surface area for fluid contact. These qualities make the dialysis

catheter more efficient in recovering large volumes of abdominal fluid and most suitable for use in abdominal lavage techniques. Disadvantages include expense, time, and effort requirements, increased discomfort to the patient, and use of a surgical approach with sedation and local anesthetic. In addition, if the trocar is used, accidental puncture of abdominal organs is possible.

6. Is it possible to get false-positive results with abdominocentesis?

Yes. False-positive results may be obtained with iatrogenic hemorrhage or penetration of an abdominal organ (e.g., spleen, bowel, bladder). Collection of blood that clots usually indicates that the needle has entered a blood vessel or organ. This finding can be confirmed microscopically by identifying the presence of platelets and the absence of erythrophagocytosis. When the reliability of the results is in doubt, paracentesis at a different site is indicated. Truly positive findings are repeatable.

7. How should one proceed if the results of needle paracentesis are negative?

A tap should be considered positive when a minimal amount of nonclotting fluid is obtained, sometimes filling only the hub of the needle. False-negative results are significantly more common than false-positive results, particularly with simple needle paracentesis. The main causes for false-negative results are a small amount of peritoneal fluid, occlusion of the needle by the omentum, and retroperitoneal injuries. In cases of a suspected false-negative result, all or some of the following steps may be taken to enhance the chance of obtaining a positive result:

1. **Repositioning** of the needle should be attempted (i.e., rotating the needle and/or changing the angle of insertion).
2. **Gentle aspiration** with a syringe and, if unsuccessful, injection of a small quantity of sterile saline to alleviate positional occlusion of the needle hole by the omentum.
3. Paracentesis may be attempted at several sites. In **four-quadrant abdominocentesis**, four separate needle paracenteses are performed. Paracentesis is undertaken in the center of each anatomic quadrant of the abdomen (cranial right, cranial left, caudal right, and caudal left).
4. Paracentesis with a 14-gauge intravenous catheter and **added side holes** or with a peritoneal dialysis catheter.
5. **Diagnostic peritoneal lavage** (DPL) is the most reliable method for early detection of intraabdominal injury or disease. It accurately detects abdominal fluid in 94–100% of cases, regardless of the amount present. A 14-gauge intravenous catheter or, preferably, a peritoneal dialysis catheter is placed as previously described. The catheter insertion is followed by instillation of 22 ml/kg BW of warm lactated Ringer's solution or 0.9% saline, rapidly infused via an intravenous administration set into the abdominal cavity. The animal is gently rolled from side to side to distribute and mix the fluid; then a representative sample of 10–20 ml is collected for analysis. It is not necessary to collect all of the infused lavage fluid. If no fluid is collected after the lavage, another 22 ml/kg BW may be infused and the collection attempt repeated.

8. How should the fluid sample be handled?

When possible, a sample of 2–3 ml should be collected into an EDTA tube for analysis of total cell counts, total protein concentration, and cytologic examination. Another sample of 3–10 ml should be collected into one or two serum (red-top) tubes, which can be used for biochemical analysis and bacteriologic culture. The fluid should be examined as soon as possible, especially if the sample was obtained by DPL because the salt solution in the lavage results in cell lysis within 30 minutes. If immediate analysis is not possible, air-dried smears should be made soon after fluid collection, and the remainder of the fluid should be refrigerated (maximum of 24–36 hours) until further examination is possible. A culture sample should be transferred to a transport medium or culture broth and handled appropriately. Fluid specimens with low turbidity warrant centrifugation and examination of sediment smears.

9. What tests should be performed on the fluid sample?

Fluid analysis should include assessment of color and turbidity, specific gravity, hematocrit, and white cell count, along with cytologic examination of air-dried smears. Biochemical tests for total

protein, creatinine, and bilirubin concentrations or amylase, alanine aminotransferase, and alkaline phosphatase activities may be selected, depending on the suspected abdominal disease. Aerobic and anaerobic cultures should be submitted if fluid cytology and clinical signs suggest bacterial infection. In many cases, the definitive cause of fluid accumulation can be discovered. Even when the specific cause cannot be determined, this analysis may indicate the direction of further investigation. A point to remember is that long-standing effusions nearly always incite some degree of peritoneal reaction, resulting in secondary sterile inflammation that may modify fluid characteristics.

Interpretation of Abominal Paracentesis Fluid Data

CHARACTERISTIC	TRANSUDATE	MODIFIED TRANSUDATE	EXUDATE	HEMORRHAGIC EXUDATE
Physical appearance	Clear to straw	Serous to serosanguinous	Amber to red	Pink to red
Specific gravity	< 1.018	1.018–1.025	> 1.025	> 1.025
Total protein	< 2.5 gm/dl	2.5–7.5 gm/dl	> 3 gm/dl	> 3 gm/dl
Nucleated cells	< 1000/µl	1000–7000/µl	> 7000/µl	> 7000/µl
Cell composition	Macrophages Mesothelial cells Neutrophils	Macrophages Mesothelial cells Neutrophils Small lymphocytes (occasionally) Red blood cells with or without neoplastic cells	Neutrophils predominate with inflammation Macrophages Mesothelial cells Small lymphocytes Red blood cells with or without neoplastic cells	Red blood cells and white blood cells with or without mesothelial cells or neoplastic cells
Cause	Hypoproteinemia Neoplasia Obstructed intestinal lymph drainage Prehepatic and hepatic portal hypertension Uroperitoneum	Neoplasia Congestive heart failure Posthepatic and hepatic portal hypertension Feline infectious peritonitis Chyle/pseudochyle (ruptured lymph vessel, lymphosarcoma, lymphangiectasia	Infectious peritonitis Pancreatic peritonitis Bile peritonitis Urine peritonitis Neoplasia Feline infectious peritonitis Chyle/pseudochyle with or without secondary inflammation	Bleeding disorders Neoplasia Trauma Torsion of spleen or stomach

Interpretation of Chemical Analysis of Abdominal Paracentesis Fluid

TEST	INTERPRETATION
Bilirubin	Values greater than serum concentration indicate leakage of bile from the hepatobiliary tree or proximal GI tract. Not valid in jaundiced animals.
Amylase	Values greater than serum concentration indicate pancreatitis or intestinal ischemia.
Creatinine	Values greater than serum concentration indicate leakage of urine into abdominal cavity.
Alanine aminotransferase (ALT)	Values greater than serum concentration indicate direct liver trauma or inflammation.
Akaline phosphatase (SAP)	Values greater than serum concentration indicate small bowel ischemia or perforation.

10. Which abdominal paracentesis findings indicate the need for exploratory laparotomy?

1. Hemoperitoneum that is not responsive to volume replacement.

2. If DPL is performed, a packed cell volume (PCV) of lavage fluid greater than 5% indicates that significant intraabdominal bleeding has occurred. This warrants repeat lavage sampling at 20–30-minute intervals. If the PCV progressively increases, surgical intervention is indicated.

3. A high white cell count with a high number of degenerative neutrophils indicates suppurative peritonitis. Exploration should be performed.

4. Intracellular bacteria in neutrophils from the fluid sample indicate infectious peritonitis (the finding of extracellular bacteria exclusively needs to be interpreted with caution because the bacterial origin may be from the stain).

5. Vegetable fibers in the fluid sample indicate bowel perforation.

6. Creatinine concentration in the fluid sample greater than serum concentration indicates urinary tract injury and uroperitoneum.

7. Concentrations of bilirubin in the fluid sample greater than concentrations in serum indicate hepatobiliary or proximal gastrointestinal tract injury and leakage of bile.

8. The results of peritoneal fluid analysis should be evaluated in conjunction with clinical manifestations. Overzealous interpretation of findings may result in unnecessary surgery.

11. When is drainage of large quantities of abdominal fluid indicated?

Therapeutic abdominal fluid drainage by paracentesis is not routinely done for several reasons:

1. Visible ascites is a secondary sign of disease. Consequently, the correct approach to ascites is to determine the nature of the primary disease (e.g., heart disease, renal disease, neoplasia) and to attempt treatment. The removal of abdominal fluid without addressing the primary problem results in rapid reaccumulation of fluid.

2. In some cases, depending on the primary disease, gradual and controlled removal of abdominal fluid may be achieved medically with the use of sodium-restricted diets, diuretics, aldosterone-inhibiting drugs, and angiotensin-converting enzyme inhibitors.

3. The risks of rapid removal of large quantities of abdominal fluid include development of hypovolemic shock from rapid reaccumulation of ascites, protein depletion, and iatrogenic infections.

Therapeutic removal of ascitic fluid is recommended only when the volume is large enough to result in respiratory distress due to compression of the diaphragm or abdominal discomfort. Although no documented evidence indicates that rapid withdrawal of peritoneal fluid results in the development of circulatory shock, it is recommended that fluid be withdrawn slowly with provision of intravenous fluid support. The removal of large volumes of peritoneal fluid also may be indicated for enhancement of the ability to perform percutaneous abdominal organ biopsy, laparoscopy, or abdominal radiography.

12. What are the possible complications of abdominocentesis?

The prevalence of complications of abdominocentesis is low if the exact procedural protocol is followed. The main complication of needle paracentesis is laceration of abdominal organs. This risk is increased if the animal is struggling. The complications of catheter paracentesis are visceral perforation, iatrogenic or spreading infection from a localized lesion, and iatrogenic hemorrhage. With DPL, subcutaneous hematoma and subcutaneous leakage of lavage fluid have been reported.

13. What are the contraindications to abdominal paracentesis?

The only conditions in which abdominal paracentesis is generally not recommended unless absolutely necessary are coagulopathy and thrombocytopenia, both of which may increase bleeding tendency. Needle or catheter puncture of the abdominal wall (with the risk of lacerating a visceral organ or blood vessel) may induce or exacerbate serious bleeding. In such cases, the decision whether to perform abdominocentesis should be made on a case-by-case basis after weighing the risk against the benefit. In addition, paracentesis with or without lavage must be used cautiously in patients with dyspnea, organomegaly, suspected body wall adhesions, or suspected diaphragmatic hernia.

14. What are the general recommendations for use of the different techniques of abdominal paracentesis?

Needle paracentesis should be attempted first because it is rapid, inexpensive, and relatively safe. It usually is sufficient in patients with obvious abdominal effusion. Catheter paracentesis with or without lavage is recommended in cases with a high index of suspicion of intraperitoneal injury or disease requiring surgery, but in which other methods of diagnosis (including needle paracentesis) provide inconclusive results.

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117. CEREBROSPINAL FLUID COLLECTION AND ASSESSMENT

John J. McDonnell, D.V.M., M.S.

1. Why perform a cerebrospinal fluid (CSF) tap?

A CSF or spinal tap is an easy procedure to perform that can yield valuable diagnostic information. CSF bathes the ventricular system and subarachnoid space. Certain central nervous system (CNS) conditions, particularly infectious and inflammatory brain diseases, may alter the CSF. Analysis of CSF can often determine the general category and occasionally the specific cause of CNS disease.

2. What sites can be used to obtain CSF?

- The cisterna magna (CM) at the atlanto-occipital junction is the site of choice for collecting CSF in dogs and cats.
- The lumbar cistern (LC) at the L5–L6 or L6–L7 vertebral level is a less satisfactory site.

3. What requirements do I need to perform a CSF tap?

1. For most dogs and cats, a $1\frac{1}{2} \times 22$-gauge spinal needle with stylet is adequate. For large and giant breeds, a $2\frac{1}{2} \times 22$-gauge spinal needle with stylet is recommended. Collection of CSF

14. What are the general recommendations for use of the different techniques of abdominal paracentesis?

Needle paracentesis should be attempted first because it is rapid, inexpensive, and relatively safe. It usually is sufficient in patients with obvious abdominal effusion. Catheter paracentesis with or without lavage is recommended in cases with a high index of suspicion of intraperitoneal injury or disease requiring surgery, but in which other methods of diagnosis (including needle paracentesis) provide inconclusive results.

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from the LC typically requires a slightly longer spinal needle in comparison with collection from the CM. The distance between the skin and the subarachnoid space of the CM in cats and various sized dogs is specified in the table below.

2. An EDTA, clot (red-top), or plastic test tube is needed for sample collection and transportation. The submission of samples for cell count and cytologic evaluation in EDTA, clot, or plastic tubes is often at the discretion of the laboratory analyzing the sample.

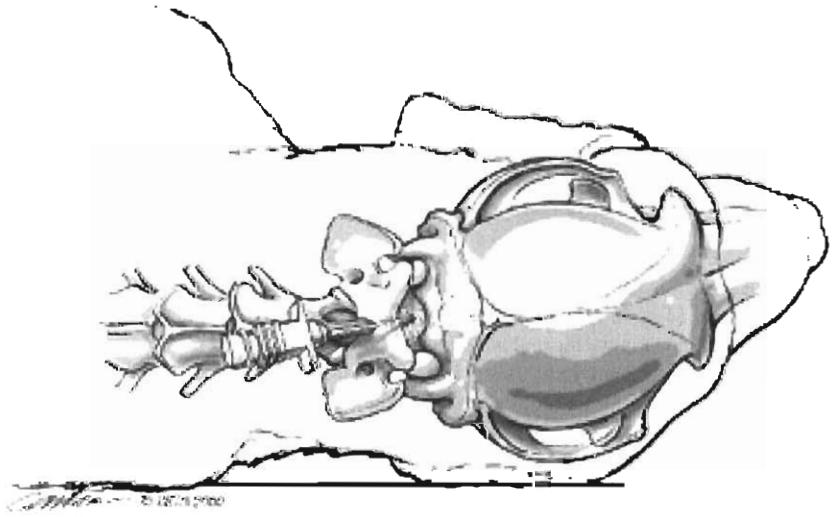
3. Access to an in-house or commercial clinical pathology laboratory that can rapidly analyze the sample (within 60 minutes of collection) is an important requirement.

Distance between the Skin and Subarachnoid Space at the Cisterna Magna as a Function of Weight

WEIGHT (KG)	DISTANCE (CM)
Cats or dogs < 4.5	0.5–1.25
Dogs 4.5–9.1	1.8
Dogs 9.2–22.7	2.8
Dogs 22.8–50.9	3.8
Dogs > 51	5.0

4. What are the landmarks for collection of CSF from the cisterna magna?

A right-handed person should use the left hand to locate the landmarks. Use the thumb and middle finger to palpate the cranial aspects of the wings of the atlas (C1). The index finger palpates and locates the occipital protuberance of the skull and axis (C2). The site for entry of the spinal needle is the intersection of a line joining the cranial borders of the wings of the atlas with a line from the occipital protuberance to the spinous process of the axis.



Landmarks for cerebrospinal fluid collection from the cerebellomedullary junction are the occipital protuberance and the transverse processes of the axis (C2).

5. How is CSF collected from the cisterna magna?

1. The animal is placed under general inhalant anesthesia. Dissociative agents such as ketamine or teletimine (Telazol) should be avoided because they increase intracranial pressure as well as the risk of seizures.

2. An endotracheal tube should be used to ensure a patent airway during the procedure. The endotracheal tube may become occluded if neck flexion is excessive during sample collection.

3. The skin over the cisterna magna is clipped and aseptically prepared from the ears caudally to the dorsal spinous process of the axis.

4. For a right-handed person, the animal is placed in right lateral recumbency. An assistant holds the patient's head with the neck flexed at a 90° angle to the upper cervical vertebrae. Ensure that the spine, head, and nose are aligned and parallel to the table surface.

5. The collector should kneel such that the atlanto-occipital area is at eye level. After determination of the proper entry site, visualize an imaginary line from the point of entry to the patient's chin or nose; follow this imaginary line during puncture.

6. The spinal needle should be handled with sterile surgical gloves. The skin is pierced in a controlled manner to prevent the needle from being driven too deeply once the initial skin resistance is overcome. In particularly thick- or tough-skinned dogs and cats, an 18-gauge needle is used initially to puncture the skin and to facilitate advancement of the spinal needle.

7. The spinal needle (with stylet in place) is advanced very slowly. A "pop" is typically felt as the needle penetrates the subarachnoid space into the cisterna magna.

8. At this point, remove the stylet and check for the flow of CSF from the hub of the needle. Use the left hand to stabilize the needle and hub while removing the stylet with the right hand to prevent iatrogenic injury to the spinal cord or brainstem.

9. If no CSF is observed after 5–10 seconds, replace the stylet, advance the needle a few millimeters at a time, and repeat the procedure of observation for flow of CSF after each advancement (see table in question 3 for typical distances between skin and cisterna magna).

10. Once CSF is flowing, collect the samples by dripping the CSF into the collection tubes held 3–5 mm below the hub of the spinal needle.

6. If the CSF is flowing slowly, may I aspirate with a syringe?

No. Aspirating CSF with a syringe increases the risk of contaminating the sample with blood. This approach also increases the risk of iatrogenic injury to the spinal cord and caudal brainstem. Be patient. In many animals with inflammatory brain disease it may take 3–5 minutes to collect 1 ml of CSF. If the flow of CSF is slow, the assistant may occlude the jugular veins to increase the intracranial pressure, which in turn increases CSF flow.

7. No CSF was visible as I advanced the spinal needle. What should I do now?

If you have advanced past the usual depth of the cisterna magna, withdraw the needle slowly and check for CSF flow every millimeter. Also check to be sure that the needle is not occluded.

8. The CSF sample looks like fresh blood. What should I do?

If the sample clots in a red-top tube, it is probably blood from the vertebral venous plexus. You should withdraw the needle and begin again with a clean spinal needle. If you are unsuccessful in obtaining a CSF sample in three attempts, abandon the procedure. Trauma to the spinal cord from needle penetration or iatrogenically induced bleeding into the subarachonid space is a potentially serious complication of repeated attempts to collect CSF.

9. This procedure sound risky and dangerous. How can I practice the technique?

Use a fresh cadaver to gain competence and confidence in the collection of CSF. A fresh cadaver is necessary because cerebrospinal pressure and consequent ability to collect CSF are greatly diminished within 10–20 minutes after death.

10. Can I collect CSF from the lumbar area?

Yes, but the lumbar cistern is more difficult to enter and yields smaller volumes of CSF. In obese animals it is difficult to palpate the point of entry. In many middle-aged and older animals, it is extremely difficult to enter the lumbar cistern because of mineralization of the interarcuate ligament and subsequent narrowing of the intervertebral canal. The preferred volume for CSF analysis (1 ml) is rarely collected from the lumbar cistern. In addition, this approach commonly yields a higher rate of blood contamination of CSF samples.

11. What are the landmarks for collection of CSF from the lumbar cistern?

The dorsal processes of L6 and L5 and the wings of the ilium. The dorsal process of L6 is palpated and identified; this structure lies between the wings of the ilium.

12. What is the procedure for lumbar cistern collection?

1. Palpate the point of entry by locating the dorsal spinous process of L6.
2. Site preparation and other general approaches described in question 5 hold true for CSF collection from the lumbar cistern.
3. As an assistant flexes the lumbar spine of the patient, direct a spinal needle (typically 1½–3 inches × 22 gauge) perpendicular to the spine and slightly to one side of the spinous process of L6 to penetrate the interarcuate ligament between L5–L6.
4. After insertion through the skin, the needle contacts bone. At this point, direct the needle cranially or caudally to locate the interarcuate depression of L5–L6.
5. The needle is forced through the interarcuate ligament of L5–L6 and into the dorsal or ventral subarachnoid space.
6. This approach often results in piercing of the spinal cord and needle stoppage on the ventral floor of the vertebral canal. In this case, withdraw the needle slowly to enter the ventral subarachnoid space. Needle penetration of the spinal cord at the L5–L6 level is not usually associated with residual neurologic signs.
7. If hemorrhage is evident when the stylet is removed, wait for a few drops to flow and/or pull the needle back slightly to determine whether the CSF will clear. If the fluid does not clear within 8–10 drops, withdraw the needle and begin the procedure with a clean needle.

13. How much CSF can be safely obtained from dogs and cats?

One to two milliliters is the volume required to perform most tests. One ml can be obtained safely from dogs and cats that weigh at least 4 kg. If the animal weighs more than 9 kg, 2 ml of CSF can be withdrawn safely. In collecting for culture and/or titers, remember to collect the sample in either transport media or a sterile clot (red-top) tube.

14. What if I am able to collect only 0.5 ml of CSF?

The collection of less than 0.5 ml of CSF limits the number of tests that can be performed. The most useful diagnostic tests, in order of decreasing importance, are white blood cell (WBC) and red blood cell (RBC) counts, determination of protein concentration, and cytologic examination.

15. What are the normal values for various CSF parameters in dogs and cats?

As with all reference values, those determined for CSF parameters vary from laboratory to laboratory. Representative normal values are listed in the table below.

Normal Values of Canine CSF Obtained from the Cisterna Magna and Lumbar Cistern

CELL COUNTS	CISTERNA MAGNA	LUMBAR CISTERN
White blood cells	0–5 cells/μl	0–8 cells/μl
Differential cell counts		
Neutrophils	0–9%	NA
Lymphocytes	0–27%	NA
Monocytes	69–100%	NA
Macrophages	0–3%	NA
Eosinophils	< 1%	NA
Total protein	5–25 mg/dl	25–45 mg/dl

16. Why do I have to analyze the sample within 60 minutes of collection?

CSF is low in protein and nucleated cell count. This combination may cause the cells to degenerate or lyse after 30–60 minutes. A delay in analysis alters the cytologic evaluation and may affect

the total nucleated cell count. If access to a laboratory is not readily available, the following concentrating techniques may be used: cytospin; centrifuging and slide preparation of CSF sediment; millipore filtration; well-slide sedimentation preparation (see references at the end of this chapter). Alternatively, you can preserve CSF for up to 48 hours at refrigeration temperatures by adding the patient's serum to a final concentration of 10%. Clinicians should talk with laboratory personnel before CSF collection to determine preferences in sample handling and slide preparation.

17. How are concentrated cells analyzed?

Slide preparations of cells should be air-dried rapidly by waving the slides vigorously for 2 minutes, followed by alcohol fixation for 1 minute. The prepared slides should be sent for analysis by an experienced cytopathologist. For in-house analysis, stain the slides with Diff-Quick Differential Stain Set (American Scientific Products), Wright's stain, or Giemsa stain. Because it is difficult to differentiate between monocytoid and lymphoid cells in CSF, results must be interpreted with care.

18. Can I do the other CSF analysis in the clinic?

Red blood cell and white blood cell counts in CSF can be determined with a hemocytometer. One chamber of the hemocytometer is filled with unstained CSF. The white and red blood cells in all nine squares of the chamber are counted. The total numbers of white and red blood cells are multiplied by 1.1 to obtain the number of cells per microliter. Red and white blood cells can be differentiated with a little experience (WBCs are larger, more granular, and more refractile than RBCs).

19. How can I measure the protein concentration of the CSF sample?

The protein concentration is much lower in CSF than in plasma; it is measured in mg/dl vs. gm/dl. Because CSF protein concentration is similar to urine protein concentration, a urine dipstick may be used to estimate the CSF protein concentration. Dogs and cats normally have less than 30 mg/dl protein in CSF; most animals test negative or have trace amounts (< 30 mg/dl) with a urine dipstick (e.g., Multistix, Bayer, Miles, Diagnostic Division, Elkhart, IN). CSF protein concentration should be confirmed by submitting the sample to a reference laboratory. Protein is determined spectrophotometrically after Coomassie blue staining.

20. Is there a way to store CSF so that analysis is not flawed?

Refrigeration of CSF in a plastic vial may slow cellular degradation. Because normal values for refrigerated samples are not published, results must be interpreted cautiously. Protein concentration in CSF is not altered by refrigeration. CSF that is to be submitted for infectious disease titers should be refrigerated until analysis is performed. Samples submitted for microbiologic culture should be inoculated into appropriate culture media.

21. Can I still use the sample if it is contaminated with RBCs?

Yes. CSF contaminated with a moderate number of RBCs (5000–13,000 cells/μl) does not significantly alter CSF nucleated cell counts or protein concentration. If more than 13,000 RBC/μl are in the sample, the collection procedure should be repeated in 24–48 hours.

22. What diseases can be diagnosed with a CSF sample?

CSF collection and analysis are most useful in diagnosing infectious and inflammatory brain or spinal cord diseases. The general nature of the disease process can be determined in most cases, and the specific cause is evident in some diseases. Fungal and bacterial organisms occasionally are observed on analysis of a CSF sample. Feline infectious peritonitis (FIP) causes a tremendous protein and cellular response. FIP meningitis or encephalomeningitis is typically seen in young cats less than 3 years old. Bacterial, viral, rickettsial, and fungal diseases can be diagnosed by appropriate serologic, microbiologic, or ultrastructural test procedures. Many infectious diseases demonstrate multisystemic clinical signs and can be diagnosed via cytologic or histopathologic analysis of specimens obtained from other sites or from serologic tests of blood,

negating the need for a CSF tap. The table below lists selected diseases with a typical pattern of CSF abnormalities. However, because these parameters demonstrate substantial overlap with various diseases, be conservative in interpreting results. Except for infectious diseases, CSF analysis rarely gives a definitive diagnosis. Although CSF bathes the central nervous system, a disease process must involve the subarachnoid space or ventricular system to alter values in CSF. For instance, most CNS tumors do not exfoliate cells into the CSF and do not cause an increase in CSF cell count. CNS tumors may alter the blood-brain barrier and increase the CSF protein concentration; the term for this phenomenon is albuminocytologic dissociation. Meningiomas are often in close contact with the subarachnoid space; an increase in WBCs (predominantly neutrophils) in the CSF can be seen with necrosis of these tumors.

Selected Diseases with Typical Patterns of CSF Abnormalities

DISEASE	WBC COUNT	PROTEIN (MG/DL)	CYTOLOGIC FEATURES
Neoplasia (except meningioma)	N or ↑	↑, ↑↑	N, M, Ma, L
Meningioma	↑, ↑↑, ↑↑↑	↑, ↑↑	N, Ma, L
Bacterial meningitis	↑↑, ↑↑↑	↑↑, ↑↑↑	N, (org)
Fungal meningitis	↑, ↑↑	↑↑, ↑↑↑	N, L, E, M, Ma, (org)
Protozoan meningitis	↑, ↑↑	↑↑, ↑↑↑	L, E, M, Ma
Aseptic meningitis (young dogs)	↑↑, ↑↑↑	↑↑, ↑↑↑	N, L
Viral encephalitis	N or ↑↑	N or ↑↑	M, L, Ma
FIP encephalitis	↑↑, ↑↑↑	↑↑, ↑↑↑	M, L, Ma
Rickettsial diseases	↑, ↑↑	↑, ↑↑	M, L, N
Granulomatous meningoencephalitis	↑↑, ↑↑↑	↑↑, ↑↑↑	M, L, Ma

FIP = feline infectious peritonitis. For WBC count: N = normal value, ↑ = mild pleocytosis (10–15 cells/μl), ↑↑ = moderate pleocytosis (50–100 cells/μl), ↑↑↑ = marked pleocytosis (> 100 cells/μl). For protein concentration: ↑ = mild increase (10–50 mg/dl), ↑↑ = moderate increase (50–200 mg/dl), ↑↑↑ = marked increase (> 200 mg/dl). Cytologic findings: N = neutrophils, L = lymphocytes, M = monocytes, Ma = macrophages, E = eosinophils, org = organisms (occasionally the causative organism can be identified on cytologic evaluation).

23. Can the CSF analysis be normal when brain disease is present?

Absolutely. Depending on the location of the disease process and the course of the illness CSF results may be completely normal. The influence of the disease process location is discussed in question 22. In addition, if a CSF tap is performed early in the course of a disease, a normal result is possible.

24. What factors should be considered before doing a spinal tap?

A spinal tap is an invasive diagnostic procedure that is not without risks. A spinal tap requires general anesthesia, and animals should be stable (airway, breathing, and circulation) before the procedure is done. Less invasive ancillary tests for the differential diagnosis should be performed and interpreted before a spinal tap is done. The potential consequences of a spinal tap include subarachnoid bleeding, spinal cord trauma, and respiratory arrest or death from brain herniation. These consequences are obviously quite serious, and the potential benefits of the diagnostic information should be weighed against the risks.

25. When should I definitely *not* do a spinal tap?

1. If anesthesia is contraindicated, CSF should not be obtained.
2. Myelography causes an inflammatory reaction in the subarachnoid space for at least 48 hours after the procedure. Analysis of CSF will be abnormal in this time frame, making interpretation of the sample difficult or impossible. CSF collection should precede myelography in animals with spinal cord disease.

3. A CSF tap should not be performed on an animal with a recent history of head trauma or with suspected or confirmed cervical vertebral fractures or luxations.

4. Any animal with signs of increased intracranial pressure, such as altered consciousness (stupor, coma), propulsive walking, head pressing, or papilledema on fundic examination, should be treated for increased intracranial pressure before consideration of a CSF tap. Brain imaging (computed tomography or magnetic resonance imaging) also should be performed.

5. CSF should not be collected in animals with suspected or confirmed brain herniation. Brain herniation may be recognized by a rapidly deteriorating state of consciousness, change in pupils from small and reactive to fixed and dilated, loss or slowing of the oculocephalic reflex, development of decerebrate or decorticate rigidity, and pathologic breathing (Cheyne-Stokes or apneustic breathing).

26. Can I give corticosteroids or mannitol to lower intracranial pressure before collecting CSF?

If you are concerned enough about intracranial pressure to intervene with drugs, the animal is unlikely to be stable enough for a CSF tap. Administration of corticosteroids and mannitol may alter the results obtained from a CSF tap.

CSF TRIVIA

- Approximately 25% of CSF is produced in the fourth ventricle.
- Dogs produce approximately 3 ml of CSF per hour; humans produce 20 ml/hour.
- The total amount of CSF turns over every 5–6 hours.
- Harvey Cushing described the flow of CSF as the "third circulation."

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118. INVASIVE BLOOD PRESSURE MONITORING

Carolyn M. Selavka, M.S., V.M.D., and Elizabeth Rozanski, D.V.M.

SYSTEMIC ARTERIAL BLOOD PRESSURE

1. What is systemic arterial blood pressure?

The term **systemic arterial blood pressure (SABP)** refers to the amount of force exerted on the walls of the large arteries by the action of the contracting heart. SABP is the product of cardiac output and systemic vascular resistance. The description of SABP is generally divided into three components:

1. **Systolic arterial pressure (SAP)**, which is the pressure generated by cardiac contraction (or systole);
2. **Mean arterial pressure (MAP)**, which is the average pressure across the vessel during the cardiac cycle and is the main determinant of adequate organ perfusion; and
3. **Diastolic arterial pressure (DAP)**, which represents the lowest pressure in the arteries during the period of cardiac filling (diastole).

2. Why is measurement of SABP important?

Abnormalities in SABP are common in animals with acute conditions (e.g., trauma, sepsis, anesthesia) or chronic diseases (renal failure). In critically ill animals, SABP is maintained within a normal range by compensatory mechanisms until severe compromise occurs. Serial determination of SABP, coupled with other routine monitoring, helps to detect patients at risk for decompensation at a point when resuscitation is possible. In addition, SABP monitoring is indicated during anesthesia and administration of medications known to affect blood pressure (e.g, dopamine, vasodilators).

3. What is normal SABP?

	SYSTOLIC	DIASTOLIC	MEAN
Dogs	100–160 mmHg	80–120 mmHg	90–120 mmHg
Cats	120–150 mmHg	70–130 mmHg	100–150 mmHg

Mean SABP can be approximated by the formula:

$$MAP = \frac{SAP - DAP}{3} + DAP$$

4. Define hypotension.

A mean SABP < 60 mmHg represents hypotension and results in inadequate perfusion of renal, coronary, and cerebral vascular beds. The causes of hypotension include hypovolemia, sepsis, and cardiogenic shock. The clinical signs of hypotension are nonspecific and include cerebral depression, weak pulses, and tachycardia. Rapid identification and appropriate corrective measures are required to prevent irreversible organ damage or death.

5. Define hypertension.

Hypertension is defined as a repeatable SABP > 200/110 mmHg (systolic/diastolic) or a mean SABP > 130 mmHg (mean: 133 mmHg) in animals at rest. Because "white-coat " hypertension has been shown to occur in small animal patients, readings must be reproducible and ideally coupled with appropriate clinical signs. Hypertension results from increased cardiac output or increased systemic vascular resistance and may occur as a primary disease or be related to various

conditions, including cardiac disease, hyperthyroidism, renal failure, hyperadrenocorticism, pheochromocytoma, and pain. Untreated hypertension may result in retinal detachment, encephalopathy, vascular accidents, and organ failures.

6. How is SABP measured?

SABP may be measured directly or indirectly. Direct SABP measurement involves placement of a catheter or needle into an artery and connecting the catheter to a pressure transducer. It is considered the gold standard in determination of SABP. Indirect SABP measurements are made with oscillometric or Doppler ultrasound techniques over a peripheral artery (see chapter 119).

7. How do you monitor direct SABP measurement?

SABP may be continuously measured by placing a catheter in the dorsal metatarsal artery. Catheters are generally easily placed in any animal with palpable pulses that weighs more than 5 kg. The arterial catheter is placed either percutaneously or via surgical cutdown. Percutaneous catheter placement is done by clipping the hair and sterile preparation of the insertion site over the dorsal metatarsal artery. The artery runs in the groove between the second and third metatarsal bones. The pulse should be palpable before an attempt to place the catheter is made. Typically, a 22-gauge, 1½-inch over-the-needle catheter is placed, although in small dogs a 24-gauge catheter may be placed instead. The catheter is inserted at a 30–45° angle directly over the pulse until arterial blood is observed freely flowing through the catheter. The catheter is then advanced, the stylet removed, and the catheter secured with standard intravenous catheter techniques.

The differences in placement of an arterial catheter compared with a venous catheter include higher risk of catheter "burring" during placement, increased difficulty in feeding the catheter despite proper insertion, and increased problems with maintaining catheter patency. Arterial catheters should be flushed with a heparinized solution every 4 hours and require an occasional resecuring of catheter placement.

The measurement of the SABP after placement of an arterial catheter involves use of a pressure transducer and monitor. Many commercially available EKG machines also have adaptation for pressure measurements. In general, the pressure transducer is connected to the monitor, and the transducer should be at the approximate level of the patient's heart. Sterile plastic tubing filled with heparinized saline is connected via stopcocks to the pressure transducer at one end and to the patient at the other. An attempt must be made to ensure that no air bubbles are present in the tubing; otherwise, the trace may be dampened. Use of stiffer tubing provides less alteration in pressure waves.

Before measurement, the system is zeroed first by making sure that there is no pressure across the transducer (i.e., close the stopcock to the patient) and then by zeroing the transducer as directed by the manufacturer. Typically this procedure involves holding the zero button until zero is displayed on the screen. The stopcock to the patient is then reopened, and the generated pressure trace is observed.

Pressure waves appearing as a steep upstroke with a dicrotic notch indicate reliable measurement. If the pressure wave appears dampened, flush the arterial catheter. If the patient moves during measurement, zero the transducer again. Overall, the first few arterial catheters that a clinician places can be frustrating, but soon the benefits far outweigh the occasional inconveniences.

8. What are the advantages and disadvantages of direct SABP measurement?

Direct SABP monitoring is the gold standard to which indirect methods are compared. The readings are considered more accurate, and the technique enables constant monitoring. The continuous access to arterial blood sampling is also of benefit when serial blood gas samples are required to monitor the patient's status.

Disadvantages include the advanced technical skills required to place and maintain arterial catheters. The invasive nature of arterial catheter placement predisposes the patient to infections or vessel thrombosis, and bleeding from the cannulation site is a concern if the line becomes dislodged or damaged.

CENTRAL VENOUS PRESSURE

9. What is central venous pressure?

Central venous pressure (CVP) is the pressure exerted on the cranial vena cava or right atrium; CVP reflects intravascular volume, cardiac function, and venous compliance. Following the patient's CVP trends may give a close approximation of circulation efficiency. The CVP is not wholly a measure of circulating blood volume; it is a measure of the ability of the heart to accept and pump blood brought to it.

10. How is CVP measured?

CVP can be measured accurately only by direct methods. An intravenous catheter is introduced into an external jugular vein and advanced so that the tip of the catheter rests in the cranial vena cava near the right atrium. A three-way stopcock is connected via intravenous extension tubing to the catheter, fluid administration set, and manometer. The manometer must be vertically positioned on the wall of the patient's cage, with the zero level aligned to approximate the position of the catheter tip and right atrium. This level can be approximated with the patient in sternal recumbency at a point 2–3 inches above the sternum at the fourth intercostal space. If the patient is in lateral recumbency, the zero point is parallel to the sternum at the fourth sternebrae. CVP is measured by filling the manometer with isotonic crystalloid fluid solution and turning the stopcock off in the direction of the fluid port. This procedure allows the pressure of the fluid column in the manometer and the blood in the catheter (vena cava) to reach equilibrium. The reading on the manometer at the equilibrium point is equivalent to the patient's cranial vena cava pressure.

11. What are normal CVP values?

Dogs	0–10 cm H_2O
Cats	0–5 cm H_2O

Single measurements of CVP do not necessarily reflect hemodynamic status. Serial measurements and interpretation of the trends as they correlate with treatment regimen are generally more informative about blood volume, cardiovascular function, and vascular tone.

12. When should CVP be monitored?

The measurement of CVP allows titration of fluid therapy in animals with poor perfusion, circulatory failure, lung disease with pulmonary hypertension, decreases in systemic vascular resistance, leaky capillaries, cardiac compromise, or questionable renal function.

13. What are critical point CVP values?

CVP reading (cm H_2O)	Interpretation
< 0	Patient needs fluids. If signs of vasoconstriction or hypotension exist, recommend bolus to reach 5–10 cm H_2O.
0–10	Normal range.
10–15	Venous return is more than adequate; recommend conservative fluid therapy.
> 15	Fluid therapy should cease; cardiac compromise is likely. Persistently high CVP values in conjunction with vasoconstriction or hypotension are suggestive of heart failure.

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119. INDIRECT ARTERIAL BLOOD PRESSURE MONITORING

Wayne E. *Wingfield*, M.S., D.V.M.

1. List the three methods for measurement of arterial blood pressure.

1. Doppler ultrasound
2. Oscillometric measurement
3. Direct measurement with a pressure transducer

2. How does Doppler blood pressure monitoring work?

Doppler pulse detection systems detect either the flow of blood through a vessel or the motion in the wall of the artery.

3. What are the disadvantages of Doppler blood pressure monitoring?

1. Usually only systolic pressure is determined accurately.
2. Detection of Doppler flow requires that the crystal be held over the vessel for prolonged intervals. Often the vessel is hard to locate (i.e., in cats or poorly perfused animals). Attempts can be time-consuming and frustrating.

4. How do oscillometric devices detect arterial blood pressure?

A cuff is inflated to various pressures. At each cuff pressure, oscillations within the cuff caused by the pulse are detected. The pressure at which oscillations are first detected is the systolic arterial pressure (SAP), the pressure at which the amplitude of the oscillation is maximal is the mean arterial pressure (MAP), and the pressure at which the oscillations decrease rapidly is the diastolic arterial pressure (DAP).

5. Which does oscillometric measurement detect most accurately—SAP, MAP, or DAP?

MAP.

6. What are the major complications of oscillometric techniques?

Patient movement greatly affects the measurement of arterial blood pressure in animals. In addition, cardiac arrhythmias may affect readings via oscillometry. Oscillometric techniques often are unreliable in small dogs and most cats with high heart rates.

7. What are the best locations for Doppler and oscillometric probes in dogs?

Artery	Location
Superficial palmar	Proximal to metacarpal pad
Superficial plantar	Proximal to metatarsal pad
Lingual	Ventral aspect of the tongue
Brachial	Medial aspect of the humerus
Common carotid	Lateral aspect of the hock
Femoral	Medial aspect of the thigh
Cranial tibial	Lateral aspect of the tibia
Aorta	Flank region
Ophthalmic arterial plexus	Cornea (use plenty of ultrasound jelly)

8. What are the best locations for blood pressure measurement in cats?

Oscillometric technique	Tail
	Cranial tibial artery

Doppler technique	Tail
	Hind limb (cranial tibial artery)
	Palmar or plantar arteries

9. When using the oscillometric or Doppler method of indirect blood pressure measurement, how does one calculate the ideal cuff size for a given animal?

- Cuff width/limb circumference = 0.40

or

- Optimal cuff bladder width = 40% of circumference of extremity

and

- Optimal cuff length = 150% of limb circumference

10. How is error introduced into indirect blood pressure measurements?

If one uses a cuff that is too large or applies a cuff too tightly, artifactually low blood pressure readings are obtained. Alternatively, if the cuff is undersized or applied too loosely, blood pressure readings are artifactually high.

11. What is the gold standard for arterial blood pressure monitoring?

Direct arterial blood pressure monitoring.

12. What are the advantages of direct arterial blood pressure monitoring?

1. It is accurate, even at very low or high pressures.
2. SAP, DAP, and MAP can be recorded.
3. Readings can be displayed continuously on an oscilloscope.

13. What are the disadvantages of direct arterial blood pressure monitoring?

1. Thrombosis of the artery and possible occlusion of flow to the extremity
2. Imposed patient immobility due to the number of lines connected to the animal
3. Expense of the monitor and transducer
4. Technical expertise in placement of arterial catheters
5. More painful procedure for the patient

14. How is MAP calculated?

$$MAP = \frac{SAP - DAP}{3} + DAP$$

15. Of what clinical significance is MAP?

Adequate MAP establishes a perfusion pressure for the major organs. An MAP of 60 mmHg is required to ensure adequate minimal blood flow to kidneys, brain, and liver. In addition, a minimal diastolic pressure of 40 mmHg is needed to ensure adequate coronary arterial blood flow.

16. What are the normal values for arterial blood pressure in dogs and cats?

	DOG	CAT
Systolic (mm Hg)	100–160	120–180
Diastolic (mm Hg)	80–120	70–130
Mean (mm Hg)	90–120	100–150

17 What pressures are consistent with a diagnosis of hypertension?

Dog: > 200/110 mm Hg
Cat: > 170/100 mm Hg

18. Does aging in dogs result in increasing blood pressure?

Yes. In a study of 1,782 dogs, increasing age was related to increased arterial blood pressure. The increment of increase in systolic and diastolic blood pressure per year for each year of age between 1 and 16 was 1–3 mm Hg.

19. Do indirect blood pressure values accurately predict direct arterial values?

No. Ultrasonic and oscillometric values do not accurately predict direct values, but mean values of systolic and mean pressures are similar between the methods.

20. Does the arterial pressure reflect changes in blood flow or volume?

No. Arterial pressues do not directly measure reductions of blood flow or volume but rather the failure of circulatory compensations. Because blood pressure, flow, and volume interactions are extremely complex, only the grossest aspects of the circulatory status are reflected by serial blood pressure measurements. In short, arterial pressure measurements are useful for screening and rapid assessment of trends in emergency conditions, but in and of themselves they are of dubious physiologic import.

21. What is the pulse pressure? Why is it important?

Pulse pressure is the difference between systolic and diastolic pressures. Decreased pulse pressure often precedes decreases in diastolic pressure in patients developing hypovolemic shock and is one of the first clinical signs of blood volume loss. Increased pulse pressure is an early sign of volume restoration.

22. Who first recorded mean blood pressure in an unanesthetized horse?

In *Statistical Essays* (1733), the Rev. Stephen Hales includes the following account:

In December I laid a common field gate on the ground, on which a white mare was cast on her right side, and in that posture bound fast to the gate . . . . Then laying bare the left Carotid Artery, I fixed to it towards the Heart the Brass Pipe, and to that the Wind Pipe of a Goose; to the other End of which a Glass Tube was fixed which was twelve Feet nine Inches long. . . . The blood rose to the Tube in the same manner as in the Case of The two former Horses, till it reached to nine Feet six Inches Height.

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120. MECHANICAL VENTILATION

Elizabeth Rozanski, D.V.M., DACVECC, DACVIM

1. When is mechanical ventilation indicated?

Mechanical ventilation is indicated in (1) an animal that cannot maintain a partial pressure of oxygen in arterial blood (PaO_2) > 50 mmHg despite supplementary oxygen (via face mask, nasal oxygen, or oxygen cage) or (2) an animal that cannot maintain a partial pressure of carbon dioxide in arterial blood ($PaCO_2$) < 50 mmHg despite reversal of respiratory depressant drugs or thoracocentesis (as clinically indicated). This may be referred to as the 50/50 rule. Other indications for mechanical ventilation include (1) clinical deterioration to the point that respiratory failure appears imminent and (2) resuscitation from cardiopulmonary arrest.

2. What options are available for mechanical ventilation?

Options for artificial ventilation can be as simple as an Ambu bag or anesthesia machine attached to an endotracheal tube or as complex as a computerized ventilator designed for long-term care. In general, a ventilator designed for long-term respiratory support provides better control of ventilatory variables (e.g., oxygen level, humidity, tidal volume, inspiratory pressures) than either an anesthesia ventilator or manual ventilation.

3. What types of ventilation are commonly used in veterinary medicine?

The two types of ventilation commonly used are volume-limited and pressure-limited ventilation. In volume-limited ventilation, the ventilator delivers a set volume of air to the patient, regardless of the pressure required to do so. Generally, alarms are set to detect sudden increases in airway pressure, which usually signal an obstruction to air flow. In pressure-limited ventilation, the ventilator delivers air to a preset inspiratory pressure, regardless of the volume. Because of the tendency for decreasing tidal volume as airway obstruction or decreased lung compliance develops, $PaCO_2$ as well as tidal volume (via spirometry) must be monitored more closely. Some evidence suggests that pressure-limited ventilation may be more desirable in small animals (< 10 lb).

4. What modes of ventilation are commonly used?

In the **assist-control** mode, the ventilator is set to give a specific number of breaths per minute. The ventilator delivers the breath when the patient generates negative inspiratory pressure or, if the patient is not breathing, at a preset rate. If the patient is breathing rapidly (i.e., panting), hyperventilation may result. In this case, another mode of ventilation may be used.

In the **synchronous intermittent mandatory ventilation** (SIMV) mode, the machine delivers a set number of breaths per minute. The breaths may be initiated by negative inspiratory pressure, but if the patient breathes faster than the set rate, the machine will not deliver another breath. This mode is useful in weaning, because the number of breaths delivered by the ventilator may be slowly decreased.

Spontaneous ventilation is also possible with many ventilators; the ventilator functions similarly to an anesthesia machine. This mode of ventilation is not commonly used in veterinary medicine but may be useful if set concentrations of oxygen are to be given to an animal or during continued monitoring after weaning from ventilatory support.

5. Should a patient be orally intubated, or is a tracheostomy recommended?

The choice for type of airway depends on both the underlying disease and clinician preference. The advantages of an oral airway include speed, familiarity, and decreased tissue trauma. The disadvantages include the need for significant amounts of sedation and immobility and perhaps a higher risk of pneumonia. The advantages of a tracheostomy include less sedation and immobility as well as the potential for oral intake of food and water. The disadvantages include a

surgical procedure in a possibly immunosuppressed patient and the potential need for more careful monitoring than in an anesthetized patient (because of the potential for tracheal tube occlusion or dislodgment). In general, if a patient is to be ventilated for more than 36–48 hours, it is reasonable to consider tracheostomy.

6. What are useful protocols for sedation and anesthesia?

The ideal drug creates minimal cardiovascular depression and is easily titratable and economical. Obviously no such drug exists. In many dogs, pentobarbital (2–16 mg/kg IV every 4–6 hours or 1–2 mg/kg/hr as a CRI) has been used successfully. The principal advantage of pentobarbital is long duration of action; it is also relatively inexpensive. The disadvantages of pentobarbital include a lengthy recovery phase and lack of reversal agents. Other commonly used drugs include a combination of oxymorphone (0.05–0.1 mg/kg IV as needed) and diazepam (0.25–0.5 mg/kg IV as needed). The opiates are generally cardiovascular-sparing but require frequent dosing and are expensive. Other protocols include continuous-rate infusions (to effect) of fentanyl or propofol. Occasionally, paralytics such as atracurium (0.2 mg/kg IV) are used to facilitate mechanical ventilation. It is important to use paralytics in conjunction with sufficient analgesic agents.

7. What is PEEP?

Positive end-expiratory pressure (PEEP) may improve oxygenation in patients that are hypoxemic despite a high concentration of inspired oxygen and a normal-to-low $PaCO_2$. PEEP prevents complete expiration and thus increases functional residual capacity, prevents early closure of small airways, and increases alveolar size and recruitment, thereby aiding in matching of ventilation and perfusion. Of importance, PEEP also decreases venous return to the heart and potentially decreases cardiac output.

8. What are the potential problems caused by mechanical ventilation?

Mechanical ventilation is not risk-free. The primary clinical problems are barotrauma and infection. **Barotrauma** results from excessive positive pressure (or volume) in certain areas of the lung, causing rupture and formation of pneumothorax (or pneumomediastinum). One of the most common causes of oxyhemoglobin desaturation in a previously stable ventilator patient is development of a significant pneumothorax. A pneumothorax should be anticipated in animals with significant lung disease. Clients and staff should be counseled not to consider it a major setback if a ventilator patient requires a chest tube.

Infection is another significant problem in ventilated patients. Infections often spread to the lungs from the contamination of the upper airway and oropharynx because the normal upper airway defense mechanisms are bypassed. In addition, ventilated patients are often immunosuppressed and immobile, which also increases risk of infection. Every effort should be made to be as clean or sterile as possible. Cultures of the airway should be performed regularly (every 24–48 hours) and used in combination with clinical signs to direct antimicrobial therapy.

Other potential concerns with mechanical ventilation include decreased venous return, oxygen toxicity, upper airway damage or irritation, and musculoskeletal problems associated with prolonged recumbency.

9. What is the prognosis for ventilated animals?

The underlying prognosis for ventilated patients depends largely on the underlying disease. For example, a 15-year-old dog with recurrent aspiration pneumonia secondary to megaesophagus with rapidly progressive respiratory failure has a grave prognosis, whereas a young dog with a traumatic flail chest and pulmonary contusions may have a fair prognosis. A recent report documents successful mechanical ventilation in a dog with respiratory failure due to ingestion of a dewormer. In the author's experience, a survival rate greater than 30–40% with good quality of life should be the goal.

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121. INITIAL OPHTHALMIC EVALUATION

Cynthia C. *Powell*, M.S., D.V.M., *Dip.* ACVO

1. What is an ocular emergency?

An ocular emergency is any condition or event that threatens to or causes visual impairment, blindness, loss of globe integrity, or serious loss of periocular tissue integrity and function. Ocular emergencies are not life-threatening but require rapid diagnosis and appropriate management to maximize the chance of preserving or restoring ocular function. Ocular emergencies may be associated with life-threatening emergencies that require immediate management.

2. Which types of ocular conditions represent a true emergency?

Many ocular problems present as an acutely painful and red eye. Such cases must be evaluated to determine their urgency and need for immediate treatment. Although the following list is not all-inclusive, it is a good starting point to categorize most general practice ocular emergencies:

- Blunt trauma
- Corneal ulceration
- Eyelid laceration
- Glaucoma (acute)
- Globe perforation or laceration
- Ocular foreign body
- Ocular hemorrhage
- Ocular proptosis
- Sudden blindness
- Uveitis

3. What is the first step after the patient arrives?

A history of the current problem should be quickly collected. Determine whether the patient has a previous history of ocular disease, trauma, chemical ocular irritation, drug use that may cause reactions, or indications of systemic disease. Many eye problems are related to systemic disease or trauma; do not forget that more than the obvious may be going on. Begin by performing a thorough physical examination, making sure that no systemic disease or life-threatening conditions require immediate attention; then proceed with the eye examination.

4. Describe appropriate overall procedures in approaching an ocular emergency.

Ocular disorders are often misdiagnosed, partially diagnosed, undiagnosed, or diagnosed and inappropriately emphasized. To a large degree, such mistakes can be minimized by performing a sequential stepwise examination to incorporate all ocular regions. It is more important to be thorough and accurate than to implement immediate but inappropriate or incorrect treatment. Delaying treatment a few minutes usually does not adversely alter outcome but may improve chances of successful overall treatment.

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5. What ophthalmic equipment should be available?

- Bright light source
- Culture swabs
- Fluorescein stain strips
- Magnification aid (e.g., head loupe or slit-lamp)
- Microscope slides
- Mydriatic agent
- Schirmer tear test strips
- Spatula for cytology specimens
- Tonometer (e.g., Schiotz)
- Topical anesthetic

6. What restraint techniques should be used?

The pros and cons of chemical and physical restraint should be considered for each case. Excessive physical restraint may dramatically increase intraocular pressure by increasing central venous pressure or skeletal muscle and tissue tension on the globe. If the globe structure is weakened, ocular rupture may result. In high-risk patients, in whom general sedation and anesthesia are not advisable, topical and/or regional anesthesia may be adequate. Dogs often become submissive if muzzled, and cats become more complacent if placed in a cat bag.

7. How is the examination best performed?

First, determine whether a microbial culture of the cornea or conjunctival surface is needed. Next, determine whether a Schirmer test is indicated. The balance of the examination is performed in a logical progression from the outside to the inside. A prepared eye examination form is helpful to decrease the chance of accidental omissions in gathering information (see figure at top of next page).

Compare the abnormal with the normal eye, if possible. Avoid pressure on the globe until the possibility of perforation has been excluded. After pupillary light reflexes (PLR) have been evaluated, a short-acting mydriatic (e.g., tropicamide) may be instilled for pupil dilation. Mydriatic use is contraindicated if glaucoma is suspected.

8. If an injured eye appears dry, what should be done?

Ocular trauma or patient sedation may result in a decreased blink reflex and tear film production rate. Ocular lubrication may be achieved with artificial tears, ocular lubricants, or antibiotic ophthalmic ointment. Topical agents should be avoided until after measuring the Schirmer test or collecting microbial culture material. Ointment should be avoided if the globe is perforated or suspected to be perforated.

9. What are the major indications of a ruptured globe?

Uveal prolapse and collapse of the anterior chamber often accompany rupture of the globe, especially if the rupture is corneal or near the limbus. Prolapsed uveal tissue appears dark in color and may be covered by a layer of fibrin. If the rupture is large, the globe is soft (hypotonic). Aqueous humor may be observed leaking from the perforation site. Other signs include severe ocular pain, aqueous flare, hyphema, miosis, irregular pupil shape, iritis, retinal or vitreal hemorrhage, and retinal detachment.

10. When are culture and cytology specimens indicated?

Septic, purulent, or unusual tissue reactions are indications for sample collection for culture, microbial sensitivity testing, and cytologic evaluation. Deep corneal ulcers, especially those with white infiltrates or smooth, melted-appearing edges, should be suspected of infection. Such ulcers first should be swabbed for culture, followed by application of a topical anesthetic, and then scraped to obtain a cytology specimen. Aqueous humor may be evaluated for evidence of purulent inflammation, sepsis, neoplastic cells, free photoreceptor disk segments (indicating retinal detachment), and lens material (indicating lens rupture).

11. How rapidly should treatment be started? What first-line treatments are safe?

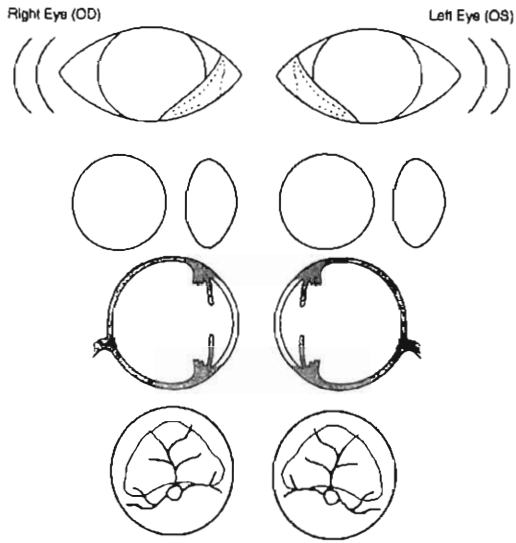
Rapid treatment is important, but a delay in implementation of minutes to hours will not seriously alter most ocular emergencies (one exception to this is globe proptosis). It is more important to be sure of the animal's entire state than to risk inappropriate or contraindicated treatment.

Ophthalmology History and Examination Form

Date: History:

Temp.: Pulse: Chest Auscultation: Resp. Rate: Muc. membranes: Weight:

Right Eye Nrm	Ab		Left Eye Nrm	Ab
☐	☐	Visual Function	☐	☐
☐	☐	PLR	☐	☐
		direct		
		indirect		
☐	☐	Orbit	☐	☐
☐	☐	Eyelids	☐	☐
☐	☐	Nict. Membrane	☐	☐
☐	☐	Nasolacrimal Sys.	☐	☐
☐	☐	STT/60s	☐	☐
		STTa/60s		
☐	☐	Excretory	☐	☐
☐	☐	Conjunctiva (culture / cytology)	☐	☐
☐	☐	Episclera & Sclera	☐	☐
☐	☐	Cornea (fluorescein stain)	☐	☐
☐	☐	Anterior Chamber IOP	☐	☐
		Schiotz, PTG, Tonopen		
☐	☐	Iris	☐	☐
		Gonioscopy:		
☐	☐	Lens	☐	☐
☐	☐	Ciliary Body	☐	☐
☐	☐	Vitreous	☐	☐
☐	☐	Fundus	☐	☐
		ERG:		



Temp. Problem List	Initial Plan	Treatment

Clinician(s): [Resident / Faculty]

Because inflammation and potential infection are paramount concerns, rapid administration of intravenous antibiotics (e.g., first-generation cephalosporins) and corticosteroids (e.g., methylprednisolone sodium succinate or dexamethasone) is usually safe. If ocular tissues have not suffered wounds or lacerations, the antibiotic use may be unnecessary.

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Appendix I: Emergency Drugs

Drug	*Formulation*	*Indications*	*Dosage*	*Actions*
Acepromazine (ProAce)	10 mg/ml	Preanesthesia, sedation	0.062–0.25 mg/kg parenteral (maximal IV dose = 3mg/dog or 1 mg/cat)	Sedative
Aminophylline	25 mg/ml; 100 mg tablet	Asthma, pulmonary edema	Dogs: 10 mg/kg every 8 hr orally, IM, or IV Cats: 5 mg/kg every 12 hr IM or IV	Coronary and bronchial dilator, diuretic
Amlodipine	2.5 mg tablet	Supraventricular tachycardia, hypertrophic cardiomyopathy, systemic hypertension	Cats: 0.625 mg/cat (¼ tablet) once daily orally Dogs: 0.2 mg/kg once daily orally	Calcium channel blocker
Antivenin	10 ml vial	Rattlesnake envenomation	1–5 vials every 2 hr IV	Antivenom antidote
Atenolol	25 mg tablet	Systemic hypertension, cardiac arrhythmia	Dogs: 0.5–1 mg/kg twice daily orally Cats: 6.25 mg/cat daily orally	Beta$_1$ antagonist
Atropine sulfate	0.5 mg/dl	Sinus bradycardia, AV nodal block, ventricular asystole	0.04 mg/kg IV, SQ 0.1 mg/kg IT	Parasympatholytic
Bretylium tosylate	50 mg/ml	Ventricular tachycardia, ventricular fibrillation	10 mg/kg IV 1–2 mg/min CRI	Chemical defibrillator, ventricular antiarrhythmic
Butorphanol (Torbugesic, Torbutrol)	10 mg/ml	Analgesia	Dogs: 0.1 mg/kg IV; 0.1–0.4 mg/kg every 6–12 hr SQ or IM 0.55 mg/kg every 6–12 hr PO	Centrally acting analgesic, narcotic agonist-antagonist
Calcium chloride	10% solution	Hyperkalemia, hypocalcemia, calcium channel blocker toxicity, hypermagnesemia	0.1 mg/kg IV to effect; observe EKG closely	Positive inotrope
Captopril (Capoten)	Tablet: 12.5, 25, 50, 100 mg	Arterial and venous vasodilation	Dogs: 0.5–2 mg/kg orally 2–3 times/day Cats: 0.5–1.5 mg/kg orally 2–3 times/day	Angiotensin-converting enzyme (ACE) inhibitor
Charcoal, activated	1 lb bag; suspension, 200 mg/ml, 240 ml bottle	Absorption of toxin	2–8 gm/kg orally (repeat as necessary)	Absorbent for any orally ingested toxin
Chlorpheniramine (Aller-Chlor, Chlortrimeton)	4 mg tablet	Antihistamine	Dogs: 4–8 mg 2–3 times/day Cats: 2–4 mg 1–2 times/day	Antihistamine
Cimetidine (Tagamet)	Injection: 150 mg/ml Oral: 60 mg/ml solution, 200 and 300 mg tablets	To block release of gastric HCl	Dogs: 4 mg/kg every 6 hr orally or IV Cats: 2.5 mg/kg twice daily orally	H_2 receptor-blocking agent
Desmopressin (DDAVP)	0.01% solution	von Willebrand's disease; antidiuretic hormone derivative	Dogs: 1 µg/kg SQ	Increases release of factor VIII in von Willebrand's disease

Table continued on next page.

Drug	*Formulation*	*Indications*	*Dosage*	*Actions*
Desoxycorticosterone	25 mg/ml pivalate salt	Hypoadrenocorticism	Dogs: 2.2 mg/kg pivalate every 4 wk	Mineralocorticoid
Dexamethasone sodium phosphate	4 mg/ml	Shock	2–4 mg/kgIV	Glucocorticoid
Dextromethorphan	3 mg/ml syrup with guaifenesin 20 mg/ml (Robitussin DM)	Cough	Dogs: 1–5 ml as needed	Antitussive
Diazepam (Valium)	Injection: 5 mg/ml	Seizures, convulsions, appetite stimulation	Dogs: 1 mg/kg IV, intranasally, or rectally to effect; 0.1–0.04 mg/kg/hr CRI Cats: 0.75 mg/kg IV; as appetite stimulant: 0.05–0.1 mg/kg IV	Benzodiazepine; anticonvulsant, ataractic
Digoxin (Cardoxin, Lanoxin)	Tablet: 0.125, 0.25, 0.5 mg Injection: 0.25 mg/ml Elixir: 0.05, 0.15 mg/ml Capsule: 0.05, 0.1, 0.2 mg	Supraventricular tachyarrhythmias, myocardial failure	Dogs: 0.22 mg/M^2 twice daily oral tablets, 0.18 mg/M^2 twice daily elixir; **or** 0.005–0.01 mg/kg twice daily (do not exceed 0.25 mg twice daily) Cats: Use 0.125 mg tablet; 4–7 lb, ¼ tab every 48 hr; 7–13 lb, ¼ tab daily; > 13, lb, ¼ tab twice daily. With Lasix, 0.007 mg/kg every 48 hr	Positive inotrope, decreased conduction through AV node
Diltiazem (Cardiazem)	Tablet: 30 mg; 60 mg extended release (Dilacor XR)	Supraventricular tachycardia, hypertrophic cardiomyopathy	Dogs: 0.5–1.5 mg/kg 3 times/day orally Cats: 1.75 mg/kg 3 times/day orally; 60 mg extended release once daily	Calcium channel blocker
Diphenhydramine (Benadryl)	Injection: 50 mg/ml	Antihistamine	Dogs: 2–4 mg/kg every 6–8 hr IV or IM; 2–4 mg/kg every 8 hr PO	Antihistamine
Dobutamine (Dobutrex)	12.5 mg/dl	Myocardial failure	5–20 µg/kg/min CRI	Synthetic catecholamine, positive inotrope
Dopamine (Intropin)	40 mg/ml	Low cardiac output, low renal or mesenteric blood flow	3–5 µg/kg/min CRI to increase renal blood flow 5–10 µg/kg min CRI to increase cardiac output and blood pressure	Dopaminergic, $beta_1$ agonist, norepinephrine precursor
Doxapram (Dopram-V)	20 mg/ml	Central respiratory stimulation	Dogs, cats: 1–5 mg/kg IV	Central respiratory stimulant
Edrophonium chloride	10 mg/ml	Diagnostic aid for myasthenia gravis	Dogs: 0.1–0.2 mg/kg IV; do not exceed 2 mg total dose	Anticholinesterase

Table continued on next page.

Drug	*Formulation*	*Indications*	*Dosage*	*Actions*
Electrical therapy (defibrillation)	1–400 joules	Electrical defibrillation	1–2 joules/kg	Simultaneous myocardial depolarization
Enalapril (Enacard, Vasorec)	2.5, 10 mg tablets	Arterial and venous vasodilatation; congestive heart failure	Dogs: 0.25–0.5 mg/kg 1–2 times/day orally Cats: 0.25–0.5 mg/kg every 12–24 hr orally	Vasodilator
Epinephrine	1:1000 solution	Ventricular fibrillation, ventricular asystole, electromechanical dissociation	0.1 mg/kg IV 0.2–0.4 mg/kg IT	Alpha and beta agonist
Fentanyl (Sublimaze)	Injection: 0.05 mg/ml Transdermal: 2.5, 5 mg patch	Analgesia	Dogs: 4 µg/kg IV; 1–4 µg/kg/hr CRI; 10–25 lb, 2.5 mg patch; 26–50 lb, 5.0 mg patch; > 75 lb, 10 mg patch	Narcotic analgesic
Furosemide (Lasix)	Tablet: 12.5, 20, 40, 50, 80 mg Injection: 10, 50 mg/ml Oral solution: 10 mg/ml	Pulmonary edema, congestive heart failure, hypertension, anuria, oliguria	Dogs: 2–4 mg/kg every other day to 3 times/day orally, IM, IV Cats: 1–2 mg/kg every other day to twice daily, orally, IM, IV	Loop diuretic
Heparin sodium	1000 U/ml	Anticoagulation, disseminated intravascular coagulation	300 U/kg IV bolus, 600 U/kg/day CRI	Acts on coagulation factors in both intrinsic and extrinsic pathways
Hydralazine (Apresoline)	10 mg tablet	Arterial vasodilation, congestive heart failure	Dogs: 0.5–2.0 mg/kg 2-3 times/day	Arterial vasodilator
Insulin	100 U/ml regular, Lente, NPH, Ultra-Lente	Diabetes mellitus, hyperkalemia	0.5–1 U/kg SQ	Hormone
Isoproterenol (Isuprel)	Injection: 0.2 mg/ml	Severe atropine-resistant bradycardia	0.0025 mg/kg CRI; 0.1–0.2 mg every 6 hr IM or SQ	Beta adrenergic agonist
Lidocaine (Xylocaine)	Injection: 20 mg/ml (2%)	Ventricular arrhythmias	Dogs: 2–8 mg/kg IV bolus followed by 50–100 µg/kg/min CRI	Ventricular antiarrhythmic
Lisinopril (Zestril)	20 mg tablet	ACE inhibition, vasodilation	Dogs: 0.25–0.5 mg/kg once daily orally	ACE inhibitor
Magnesium chloride	Injection: 200 mg/ml	Unresponsive ventricular dysrhythmias, chemical defibrillation, severe hypotension	0.15–0.3 mEq/kg IV given over 2–10 min; 0.75–1.0 mEq/kg/day	Electrolyte, chemical defibrillator
Mannitol	25% solution	Diuresis, cerebral edema	0.25–1 gm/kg IV	Osmotic diuretic
Meclizine	25 mg tablet	Antiemetic for vestibular disease	Dogs: 25 mg/dog once daily Cats: 6.25–12.5 mg/cat once daily	Antihistamine
Meperidine (Demerol)	50 mg/ml	Analgesia	Dogs, cats: 11 mg/kg IM	Analgesic
Methylprednisolone sodium succinate (Solu-Medrol)	500 mg vial	Spinal trauma	Dogs: 30 mg/kg IV	Glucocorticoid

Table continued on next page.

Drug	*Formulation*	*Indications*	*Dosage*	*Actions*
Metoclopramide (Reglan)	Injection: 5 mg/ml Oral: 10 mg tablet, 1 mg/ml solution	Gastric motility stimulation, vomiting, nausea	Dogs: 1–2 mg/kg/day CRI IV Dogs, cats: 0.2–0.4 mg/kg 3 times/day orally	Gastrointestinal stimulant, antiemetic
Misoprostol (Cytotec)	100 µg tablet	Prevention of gastric ulceration, reduction of cyclosporin-induced nephrotoxicity, treatment of NSAID-induced GI ulceration	Dogs: 2–4 µg/kg 3–4 times/day orally	Synthetic prostaglandin E_1 analog
Morphine sulfate	Injection: 0.5 mg/ml or 15 mg/ml	Analgesia, vasodilation, pulmonary edema, sedation	Dogs: 0.5–2 mg/kg IM, SQ; 0.05–0.1 mg/kg for pulmonary edema Cats: 0.1 mg/kg IM,SQ	Narcotic analgesic
Naloxone	Injection: 400 µg/ml	Narcotic antagonism, electromechanical dissociation (EMD) in cardiac arrest	Dogs: 15 µg/kg IV; 30 µg/kg IV for EMD	Narcotic antagonist
Nitroglycerin (Nitro-BID, Nitrol)	2% ointment	Venodilation for congestive heart failure	Dogs: 0.25 inch/kg cutaneously 3–4 times/day Cats: ⅛ to ¼ inch cutaneously 3–4 times/day	Venodilator
Nitroprusside (Nipride)	200 µg/ml	Congestive heart failure, pulmonary edema	1–5 µg/kg/min CRI	Venous and arterial vasodilator
Oxymorphone (Numorphan)	1.5 mg/ml	Narcotic analgesia	Dogs: 0.11–0.22 mg/kg IM, SQ, IV (maximal dose = 4.5 mg/dog) Cats: 0.06 mg/kg every 4 hr SQ	Narcotic analgesic
Pentobarbital, sodium	50 mg/ml; 390 mg/ml	Sedation, IV anesthesia	Dogs, cats: 25–30 mg/kg IV for anesthesia; 3–15 mg/kg given slowly IV	Barbiturate
Phenobarbital	Injection: 130 mg/ml Tablet: 15, 30, 60, and 100 mg	Sedation, convulsions, seizures	Dogs, cats: 2–4 mg/kg twice daily orally; 6–20 mg/kg IV loading dose	Barbiturate
Potassium bromide	250 mg/ml	Convulsions, seizures	Dogs: 10–30 mg/kg orally twice daily May want to provide loading dose of sodium bromide (350–520 mg/kg)	Anticonvulsant
Prednisone (Deltasone)	Tablet: 5, 20 mg; 1 mg/ml oral solution	Corticosteroid therapy, hypoadrenocorticism, inflammatory disease, immune-mediated diseases	Dogs, cats: 0.5–2.2 mg/kg/day orally	Glucocorticoid
Procainamide (Procan SR, Pronestyl)	Capsule: 250, 375, 500 mg Tablet: 250, 375, 500 mg SR tablet: 250, 500, 750, 1000 mg Injection: 100, 500 mg/ml	Ventricular arrhythmia, supraventricular arrhythmias	Dogs: 8–30 mg/kg IM, orally 4 times/day (SR = 3 times/day); 6–8 mg/kg IV over 3–5 min to total dose of 15 mg/kg; 20–50 µg/kg/min CRI	Antiarrhythmic
Propofol (Diprivan)	10 mg/ml	Short-duration anesthesia	Dogs: 4–6 mg/kg IV to effect Cats: 6–8 mg/kg IV to effect	Short-acting hypnotic

Table continued on next page.

Drug	*Formulation*	*Indications*	*Dosage*	*Actions*
Propranolol (Inderal)	Tablet: 10, 20, 40, 80, 90 mg Injection: 1 mg/ml	Atrial and ventricular arrhythmias, hypertrophic cardiomyopathy, hypertension, myocardial infarction, thyrotoxicosis	Dogs: 0.2–1.0 mg/kg orally 3 times/day; 0.02–0.06 mg/kg IV Cats: < 4.5 kg, 2.5–5 mg orally 2 or 3 times/day; > 4.5 kg, 5 mg orally 2 or 3 times/day; 0.02–0.06 mg/kg IV	Beta adrenergic blocker
Ranitidine (Zantac)	Injection: 25 mg/ml Tablet: 15 mg/ml Syrup: 150 mg	To decrease gastric acid secretion, as in patients with gastric ulcers	Dogs: 2 mg/kg 2–3 times/day orally, IV, SQ Cats: 3.5 mg/kg twice daily orally; 2.5 mg/kg twice daily IV	H_2 receptor-blocking agent
Sodium bicarbonate	1 mEq/ml	Severe metabolic acidosis	0.5–2 mEq/kg IV	Alkalinizing agent
Sucralfate (Carafate)	1 gm tablet	Duodenal ulcer	Dogs: 0.5– 1 gm 3 times/day orally	Reacts with gastric HCl to form pastelike complex that binds to proteinaceous exudates around ulcers
Theophylline (Theo-Dur)	Tablet: 100, 200, 300, 450 mg Capsule: 50, 75, 125, 200 mg	Asthma, chronic obstructive lung disease	Dogs: 9 mg/kg orally 2–3 times/day; Theo-Dur, 20 mg/kg orally twice daily Cats: 4 mg/kg orally 2–3 times/day; Theo-Dur, 25 mg/kg orally at night	Bronchodilator
Thiacetarsamide, sodium	Injection: 10 mg/ml	Adult dirofilariasis	Dogs: 2.2 mg/kg twice daily IV for 2 days	Organic arsenical compound
Verapamil (Calan, Isoptin)	Injection: 2.5 mg/ml	Supraventricular tachycardias, calcium overdose	0.05–0.15 mg/kg IV slowly over 15 min; 2–10 µg/kg/min CRI	Calcium channel blocker
Vitamin K (Phytonadione)	Injection: 10 mg/ml	Warfarin antidote	Dogs, cats: 1 mg/kg IM or orally; 2.5–5 mg/kg for long-acting rodenticide toxicity	Promotes coagulation
Xylazine (Rompun, AnaSed, Tranquived)	Injection: 20 or 100 mg/ml	Sedation, analgesia; emesis in cats	Dogs: 1 mg/kg IM or IV Cats: 0.44 mg/kg IV	Sedative, anesthetic
Yohimbine (Yobine)	Injection: 2 mg/dl	To reverse effects of xyalzine or amatraz	Dogs, cats: 0.1–0.5 mg/kg IV	$Alpha_2$ antagonist

IV = intravenously, IM = intramuscularly, SQ = subcutaneously, IT = intratracheally, CRI = constant-rate infusion, NSAID = nonsteroidal antiinflammatory drug, EMD = electromechanical dissociation, ACE = angiotensin-converting enzyme, AV = atrioventricular, NPH = neutral protamine Hagedorn [insulin].

Appendix II: Constant-Rate Infusions

A constant-rate infusion (CRI) is a precisely calculated amount of drug added to a specific volume and type of fluid. The mixture is then delivered as a continuous intravenous infusion. The efficacy of CRI drugs is increased through maintenance of steady-state concentrations of the drug.

Drugs Administered Via Constant-Rate Infusions

DRUG	FORMULATION	CRI DOSAGE	ACTIONS
Diazepam	5 mg/ml	0.1–0.04 mg/kg/hr	Anticonvulsant, ataractic
Diltiazem	5 mg/ml	0.2–0.5 mg/kg/hr	Calcium channel blocker
Dobutamine	12.5 mg/ml	2–20 µg/kg/min	Synthetic catecholamine, positive inotrope
Dopamine	40 mg/ml	2–20 µg/kg/min	Dopaminergic, beta agonist, norepinephrine precursor
Epinephrine	1:1000	1 µg/kg/min	Alpha and beta agonist
Fentanyl	0.05 mg/ml	1–5 µg/kg/hr	Narcotic analgesic
Insulin (regular)	100 U/ml	1.1–2.2 U/kg/day	Hormone
Isoproterenol	0.2 mg/ml	0.04 µg/kg/hr	Beta-adrenergic agonist
Ketamine	100 mg/ml	1–3 µg/kg/min	Neuroleptoanalgesia
Lidocaine	20 mg/ml (2%)	50–100 µg/kg/min	Ventricular antiarrhythmic
Metoclopramide	5 mg/ml	1–2 mg/kg/day	Gastrointestinal stimulant, antiemetic
Nitroprusside	200 mg/ml	1–5 µg/kg/min	Venous and arterial vasodilator
Procainamide	100 or 500 mg/ml	20–50 µg/kg/min	Antiarrhythmic
Propofol	10 mg/ml	0.05–0.2 mg/kg/min	Short-acting hypnotic

CALCULATIONS OF CONSTANT-RATE INFUSIONS

The objective of CRI dosages is to determine how much drug must be added to a specific volume of intravenous fluid to achieve the required dosage. If the dosage is in µg/kg/minute, the following equation applies:

$$\mu g \times kg \times minute = \mu g \text{ required drug}$$

Since µg are given in the dosage orders and kg for the specific patient, only the number of minutes that a given volume of intravenous fluids will last must be calculated. Calculate the number of hours that an infusion will last by dividing the volume in the bag by the fluid administration rate per hour. Then multiply the number of hours by 60 min/hr to determine the number of minutes. Next, solve the following equation:

$$\mu g \times kg \times minutes = \mu g \text{ of required drug}$$

Then divide the number of µg needed by 1000 to convert µg to mg.

Example: Give lidocaine CRI at 60 µg/kg/min to a 15-kg dog. Add the lidocaine to 1000 ml of Normosol-R, which is running at a rate of 41 ml/hr. How much lidocaine do you add to the 1000 ml of Normosol-R?

1. Calculate the number of minutes that the 1000 ml of Normosol-R will last:

$$1000 \text{ ml} / 41 \text{ ml/hr} = 24 \text{ hr}$$
$$24 \text{ hr} \times 60 \text{ min/hr} = 1440 \text{ min}$$

2. Solve the equation:

$$60 \mu g \times 15 \text{ kg} \times 1440 \text{ min} = 1{,}296{,}000 \mu g$$

3. Convert µg to mg:

$$1{,}296{,}000/1000 = 1296 \text{ mg}$$

4. Calculate the amount of drug needed per 1000-ml bag by dividing the amount of drug needed by the concentration of drug that you are using (2% lidocaine):

$$1296 \text{ mg}/20 \text{ mg/ml} = 64.8 \text{ ml of lidocaine}$$

To be precise in your dosage, 64.8 ml of Normosol-R should be discarded; then the 64.8 ml of lidocaine should be added to the bag.

SAMPLE PROBLEMS

Work out the following problems, and then see the correct answer at the bottom of the page:

1. Goldie, a 30-kg golden retriever, is in oliguric renal failure. The doctor has ordered a dopamine CRI at 5 µg/kg/min and a fluid rate of 121 ml/hr. How much dopamine should you add to 1000 ml of 0.9% sodium chloride solution?
2. Maggie, a 25-kg Labrador retriever, was hit by a tractor. The electrocardiographic monitor shows a continuous run of multiform ventricular tachycardia. The doctor orders a lidocaine CRI to be given at a rate of 80 µg/kg/min. The fluid rate is set at 34 ml/hr. How much lidocaine should you add to 1000 ml of Normosol-R?
3. Gretchen, a 7-kg miniature schnauzer, has pancreatitis and has been vomiting frequently. The doctor orders a metoclopramide CRI at 2 mg/kg/day. The fluid volume is set at 23 ml/hr. How much metoclopramide should you add to 1000 ml of Normosol-R?
4. Sage, a 42-kg yellow Labrador retriever, is in recovery after abdominal exploratory surgery. The doctor orders a fentanyl CRI at 4 µg/kg/hr. The fluid volume is set at 55 ml/hr. How much fentanyl should you add to 1000 ml of 0.9% sodium chloride?

Correct answers for sample problems:

1. 1.72 ml of 40 mg/ml dopamine
2. 146.4 ml of 20 mg/ml (2%) lidocaine
3. 2.3 ml of 5 mg/ml metoclopramide
4. 27.77 ml of 0.05 mg/ml fentanyl

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