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VETERINARY DIAGNOSTIC IMAGING: BIRDS, EXOTIC PETS, AND WILDLIFE
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Preface

INTRODUCTION

Since radiology, and later, other forms of medical imaging have become integral parts of veterinary curricula, course content has become increasingly narrowed to the point that it now focuses almost exclusively on dogs and cats. For its part, the teaching of equine radiology has been largely relinquished to surgery, while the radiology of farm animals such as cattle, sheep, pigs, and goats is approaching extinction.

Quite understandably, zoo, wildlife, and poultry science courses continue to concentrate on the herd or flock, rather than on the individual animal, with instructors devoting their pedagogical energies to matters of nutrition, parasitism, and contagious disease. But from this latter group, a relatively new entity has emerged, the so-called exotic species, or simply the *exotics*. A highly diverse alliance, the exotics comprise cage and wild birds, small mammals and reptiles, acreage pets, and a smattering of theatrical and demonstration animals. It is to this most fascinating assemblage, and its medical imaging, that these pages are devoted.

INTENDED READERSHIP

Undoubtedly, the content of this book will improve the radiodiagnostic skills of most veterinarians, particularly those in community practice who see and radiograph exotics only occasionally and currently lack a comprehensive reference. But perhaps more importantly, this book builds on what most veterinarians already know about the radiology of common pets, such as dogs and cats, and shows how such existing knowledge can be expanded and applied to birds and exotics in a coherent and organized fashion.

Biologists and zoologists, anatomists and ornithologists are often hard pressed when attempting to transition between the living animals they observe in the field and those on their dissection tables. *Veterinary Diagnostic Imaging: Birds, Exotic Pets, and Wildlife* fills this void by providing these scientists with the "living" link necessary to fully understand the vital anatomy and infer related function of the creatures they so painstakingly study.

Physical anthropologists and archeologists are just as likely to find this book useful—perhaps even indispensable—when it comes to sorting out and categorizing the small bones and bone fragments accumulated from a typical day's screenings.

Finally, any comprehensive department, college, or university library would be incomplete without at least one copy of this book, and the valuable reference material it contains, on its shelves.

ORGANIZATION AND CONTENT

The book is divided into three sections: the first on birds, the second on mammals, and the third on reptiles. Only animals that I have actually worked with are included.

Wherever possible, photographs of the actual patients are provided, not only to aid in identification, but also to at least partially overcome the *clinical detachment* that unfortunately often accompanies the consideration of medical images exclusive of their sources.

A brief account of the aerodynamics of flight has also been included to enable the reader to better appreciate the consequences of wing injuries and to weigh the benefits and risks of contemplated surgery, especially as it may pertain to rehabilitation and, hopefully, eventual release.

DIAGNOSTIC STRATEGY

As in past books I have continued to stress the diagnostic superiority of *radiographic disease indicators* (RDIs) over less flexible alternatives such as medical algorithms or paradigms. Although of some value in the past, the sign-oriented approach lacks the comprehensive qualities needed to deal with the complexity of modern medical imaging.

Once mastered, the use of RDIs and their *patterns of occurrence* not only lends itself to a speedier and more accurate radiographic diagnosis, but also solidifies and improves related cognitive strategies, in particular the ability to discriminate between relevant and irrelevant radiographic information. Furthermore, RDIs are like open-source code: they can be regularly modified and refined according to user experience and the discovery of new knowledge.

ANATOMICAL SPECIMENS AND CONTEXTUAL NORMALS

Wherever possible, anatomical specimens are included to clarify unusual, complex, or confusing anatomy: for example, the bones of a bird's shoulder joint compared with those of a dog or cat. Convenient, timesaving, normal comparison radiographs have been included with many individual cases, especially when the major radiographic observation is not pronounced. From the standpoint of information retention, I have found this method far more effective than simple lesion annotation.

ORIENTATION AND DETAILED CLOSE-UP VIEWS

Furthermore, concerning retained knowledge: I have once again made generous use of *orientation images*, in addition to close-ups and ultra-close views. My work and that of others have clearly shown that the inclusion of orientation views greatly enhances the understanding of close-ups, and this enhanced understanding leads in turn to improved information retention as well as recall.

REFERENCES

Simply put, there are none. In writing this book—and I must admit in all candor that initially I was quite reluctant to take on the project—I was determined to see the imagery of exotics through fresh eyes. That is to say that I never had any formal teaching on the subject, even though I hold a degree in Zoology and many years ago completed a radiology residency.

It has always seemed to me that the exotics were little more than an afterthought, especially in what has now come to be known as Medical Imaging (formerly Radiology, and later, Radiology and Alternate Imaging). There are surprisingly few publications that deal expressly with the *methodology* of radiographic diagnosis. Most have a medical or surgical focus, including related medical images under the heading of ancillary diagnostics, much as one might incorporate abnormal laboratory values.

Although I could have turned to the comparatively scant contributions of colleagues, my feeling was that such an effort would constitute little more than a brief and probably lackluster catalogue of information—like so many loosely related articles in a folder rather than a coherent, integrated, and, most importantly, practical clinical reference.

Accordingly, I have set out my personal approach to the radiographic, sometimes sonographic, occasionally computed tomographic diagnosis of the injuries and diseases that can afflict birds and exotics, an approach forged in the fires of more than 3 decades as an academic radiologist. But make no mistake: this is not the final word on the subject, far from it, but for better or worse it is *my* word. I hope you come to value it.

Charles S. Farrow

SECTION I

The Birds

Chapter 1

Avian Radiography and Radiographic Diagnosis

SMALL CAGE BIRDS: LIMITED IMAGING OPTIONS

Our practice focus is on wild birds, and consequently we radiograph comparatively few small cage birds such as parakeets, canaries, and the like. Many of these small birds have occult disease, with radiography serving as a screening procedure. Older birds with localized swellings are often believed to have tumors and are radiographed in the hope of obtaining more information such as whether there is bone involvement. Because many of these birds are quite fragile medically, as well as physically, they are often examined with little or no restraint, with full realization of the effect that this will have on radiographic quality.

We prefer to image small unrestrained birds in the perching position (Figure 1-1), provided they are strong enough. If a bird is too weak to perch, it can be radiographed in a disposable cardboard box (Figure 1-2), with its movement limited by adjustable inserts. In this latter situation, obtaining more than a dorsoventral view is difficult. The principal drawback associated with these methods is that the wings and legs will be superimposed on the trunk, concealing portions of the viscera.

MEDIUM-SIZED CAGE BIRDS

Small-sized parrots, mostly Amazons and African Grays, are the most common medium-sized cage birds seen in our practice. Like the majority of wild birds we image, parrots are imaged by radiographs and occasionally ultrasound while anesthetized with gas (Figure 1-3), which also provides an additional opportunity to further examine any known or suspected injuries. In special circumstances, we may radiograph these birds while perched (Figure 1-4).

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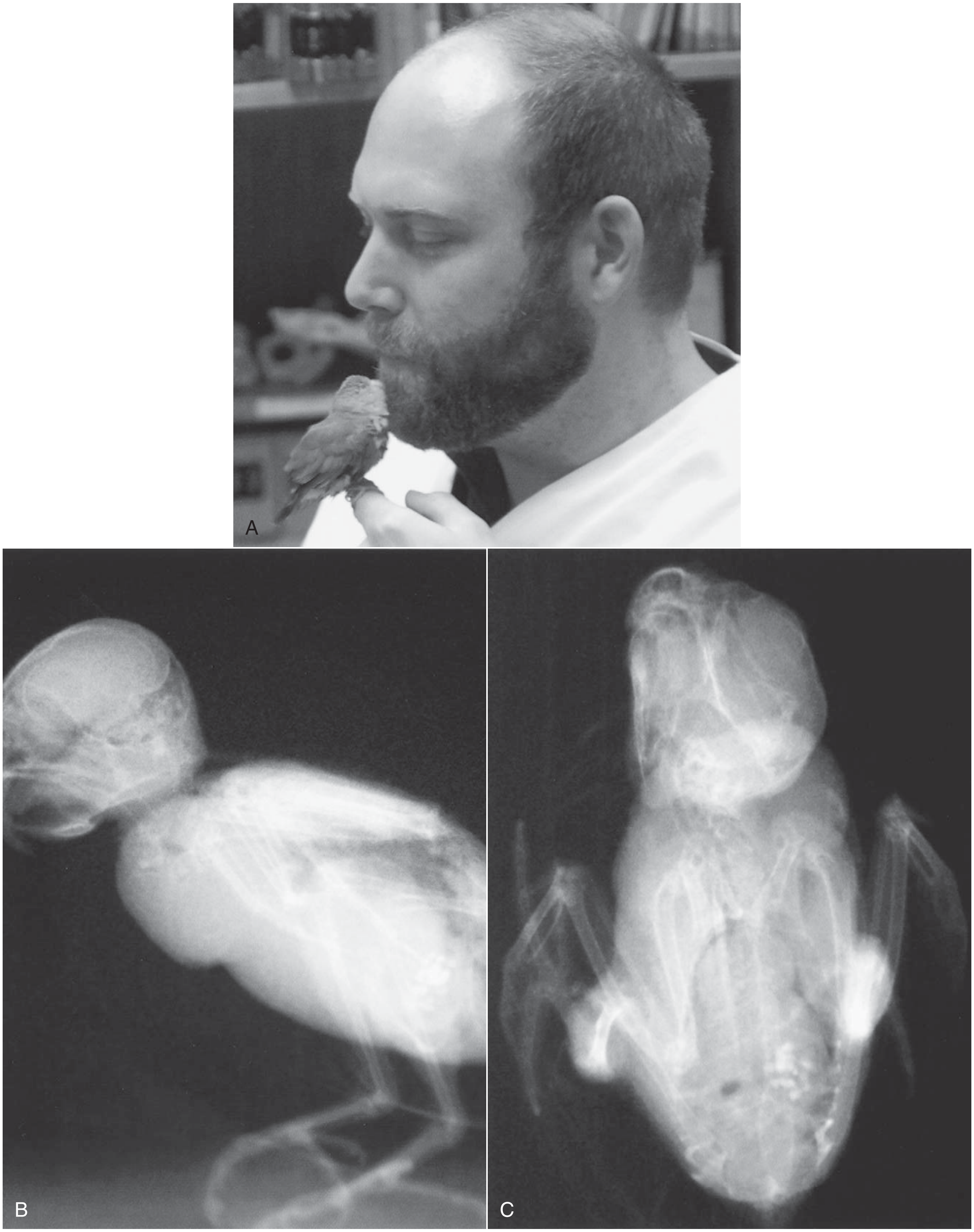


Figure 1-1 • A, Lovebird exploring the beard of its handler before being imaged. The bird was subsequently radiographed while perched, producing both lateral **(B)** and dorsoventral **(C)** projections. Because the wings are positioned naturally, they are superimposed on the torso in both views.

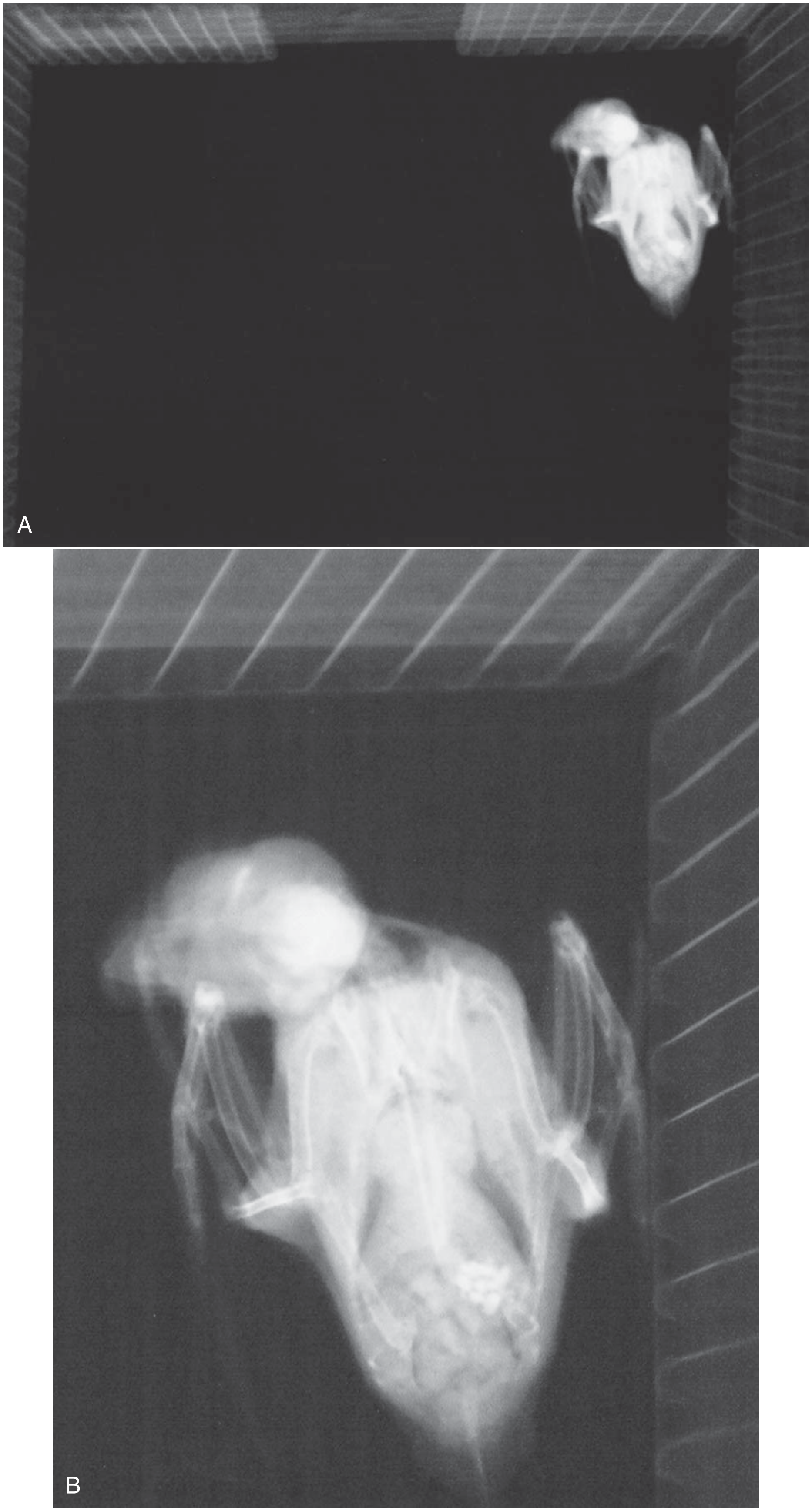


Figure 1-2 • A, Orientation and close-up **(B)** views of a small bird radiographed within a disposable cardboard box, using a vertically oriented x-ray beam. Obviously, this is not an ideal view, but it was the safest way to initially screen for injuries.

Figure 1-3 • A, An Amazon parrot warily eyes the recently removed anesthetic mask as it regains consciousness after radiographic examination that revealed a displaced fracture of the proximal tarsometatarsus **(B).**

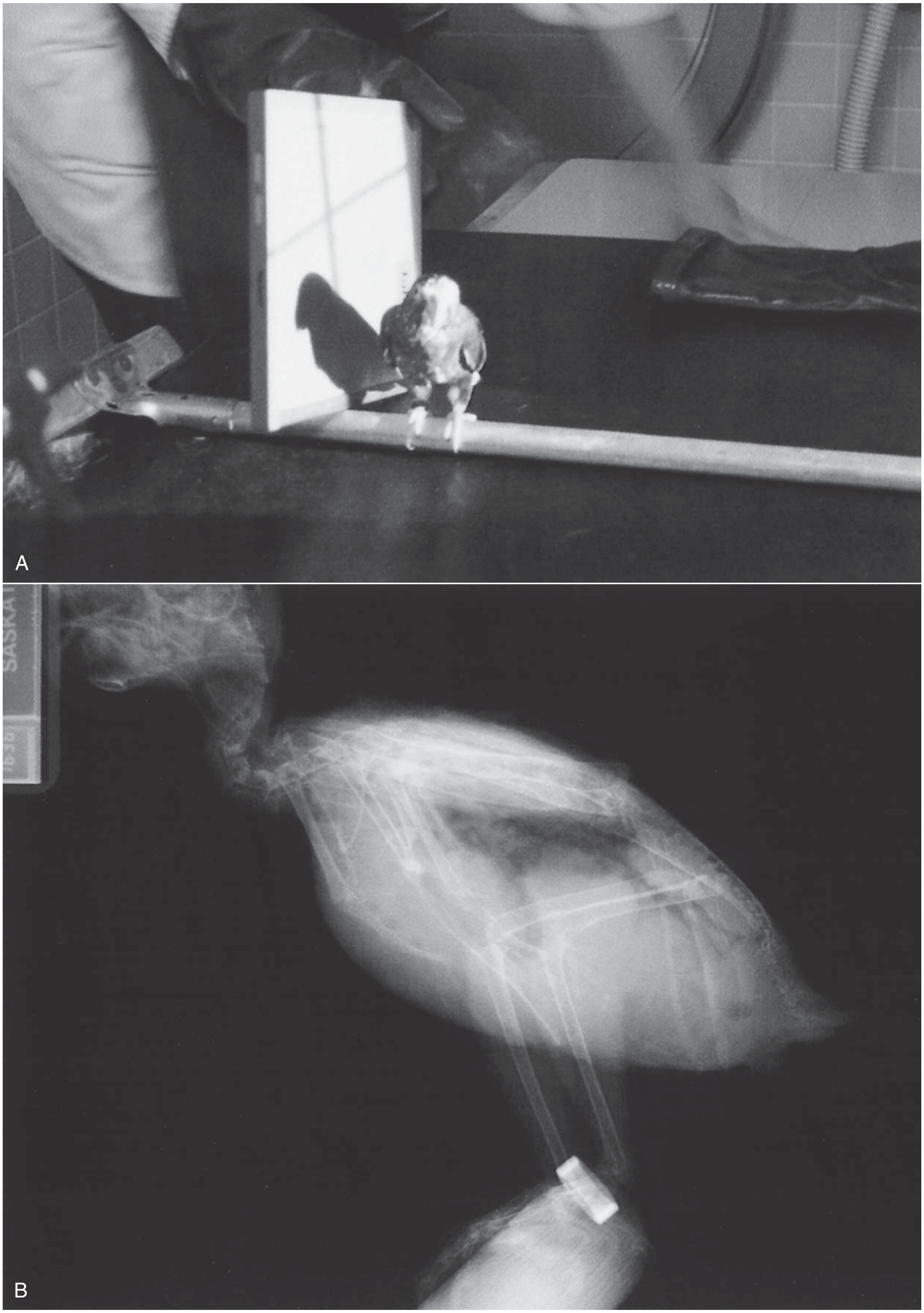


Figure 1-4 • A, A small parrot is imaged while in a perched position, using a horizontally directed x-ray beam. **B,** The result is a lateral radiograph.

WILD BIRDS: DIAGNOSTIC QUALITY—THE PRIME DIRECTIVE

Diagnostic quality depends on two essential ingredients: (1) appearance and (2) positioning. Appearance refers to image contrast and detail, and positioning refers to how well a standard projection approaches the ideal. For example, a quality ventrodorsal (VD) radiograph of an owl should show a clear difference in the appearance of bones compared with the adjacent muscle: the former appearing nearly white and the latter a medium to dark shade of gray (Figure 1-5). A lighter film designed to evaluate the feathers and soft tissues can be obtained by decreasing the exposure (Figure 1-6).

The background lung and air sacs should appear dark gray, except where overlain by muscle, in which case they become invisible. For the most part, the edges of the bones and cardiohepatic silhouette should appear sharply outlined without the benefit of an intensity lamp (Figure 1-7). A VD image of a medium-sized raptor on a large film with the wings partially extended should be sufficiently symmetrical to allow for a close comparison between the injured and normal wings (Figure 1-8).

PRECAUTIONS WHEN RADIOGRAPHING BIRDS

When handling fully conscious birds, especially large wild birds, the following precautions should be taken:

- Work should be done in reasonably dim light.
- Unnecessary noise should be avoided.
- Appropriate protective clothing, gloves, headgear, and eye shields should be worn until the bird is fully incapacitated.

Figure 1-5 • Close-up ventrodorsal view of the right elbow region of an owl with a large-gauge shotgun pellet embedded in the muscles between its right radius and ulna.

Figure 1-6 • A lighter film of the gunshot wound shown in Figure 1-5 indicates that there are no further soft tissue or feather injuries.

- The bird's head and torso should be covered with a medium-sized towel.
- All escape routes from radiology should be closed off and secured before handling the bird.
- If a bird does escape, containment should be achieved first, then capture.
- When recapturing an escaped bird, everything possible should be done to make the experience as nonstressful as possible, even if it means giving the bird some quiet time to settle down before reattempting the radiographic examination.
- If a bird is anesthetized and maintained on gas while being radiographed, it should be monitored closely and regularly. Ideally, anesthesia should be one person's priority.
- The radiographer should stay focused and get the job done as quickly as possible but not at the expense of thoroughness and completeness.
- The bird should not be recovered, and the radiographer should not leave radiology until the radiographs are deemed satisfactory and additional views have been made.

Figure 1-9 illustrates some of the precautions taken to ensure the safety of the bird and radiographers when being imaged. Figure 1-10 shows how even a momentary lapse in concentration can lead to escape by a determined bird. Figure 1-11 shows one of the hazards that awaits the unwary radiographer. When handling a large bird with powerful wings, it is best to remember that these wings, too, are potentially dangerous, especially blows to the face (Figure 1-12). Taking detailed photographs of unconscious or barely conscious birds after radiography should be done only with the assistance of an experienced handler (Figure 1-13).

Text continued on p. 13.

Figure 1-7 • Ventrodorsal radiograph of a burrowing owl under gas anesthesia appears normal in all respects.

Figure 1-8 • Ventrodorsal radiograph of a hawk with a displaced, comminuted fracture of its left humerus (viewer's right). Comparison with the uninjured right wing reveals not only swelling but the absence of a left clavicular air sac, which most likely indicates rupture, hemorrhage, or compression.

Figure 1-9 • A, A resident, wearing surround-type protective eyewear, brings a great blue heron to radiology draped in a towel. **B,** After the towel has been removed, the bird's long, potentially dangerous beak is revealed, as are the resident's protective gloves. **C,** Anesthetic gas is administered by an assistant, while the resident secures the bird's beak, wings, and feet. **D,** Once the bird becomes unconscious, it is placed on the cassette, positioned, secured with nonadhesive tape, and radiographed.

Figure 1-10 • A, A resident prepares to remove a Canadian goose from its carrier, but as she towels the bird, it leaps forward, almost escaping **(B). C,** The bird has stopped struggling, evidence that the resident has seemingly regained full control. **D,** However, just as she is about to mask the goose down, it suddenly leaps from her arms, sheds the towel, and seeks refuge in the far corner of the room behind the x-ray machine. **E,** The resident checks that all the exits are blocked, allows the bird to calm down, and then quietly recaptures the bird.

Figure 1-10, cont'd • For legend see opposite page.

Figure 1-11 • As one of the radiographers restrains the duck while the other gloves up, she momentarily takes her eyes off the duck, giving it just enough time to reach over and clamp down on one of her fingers.

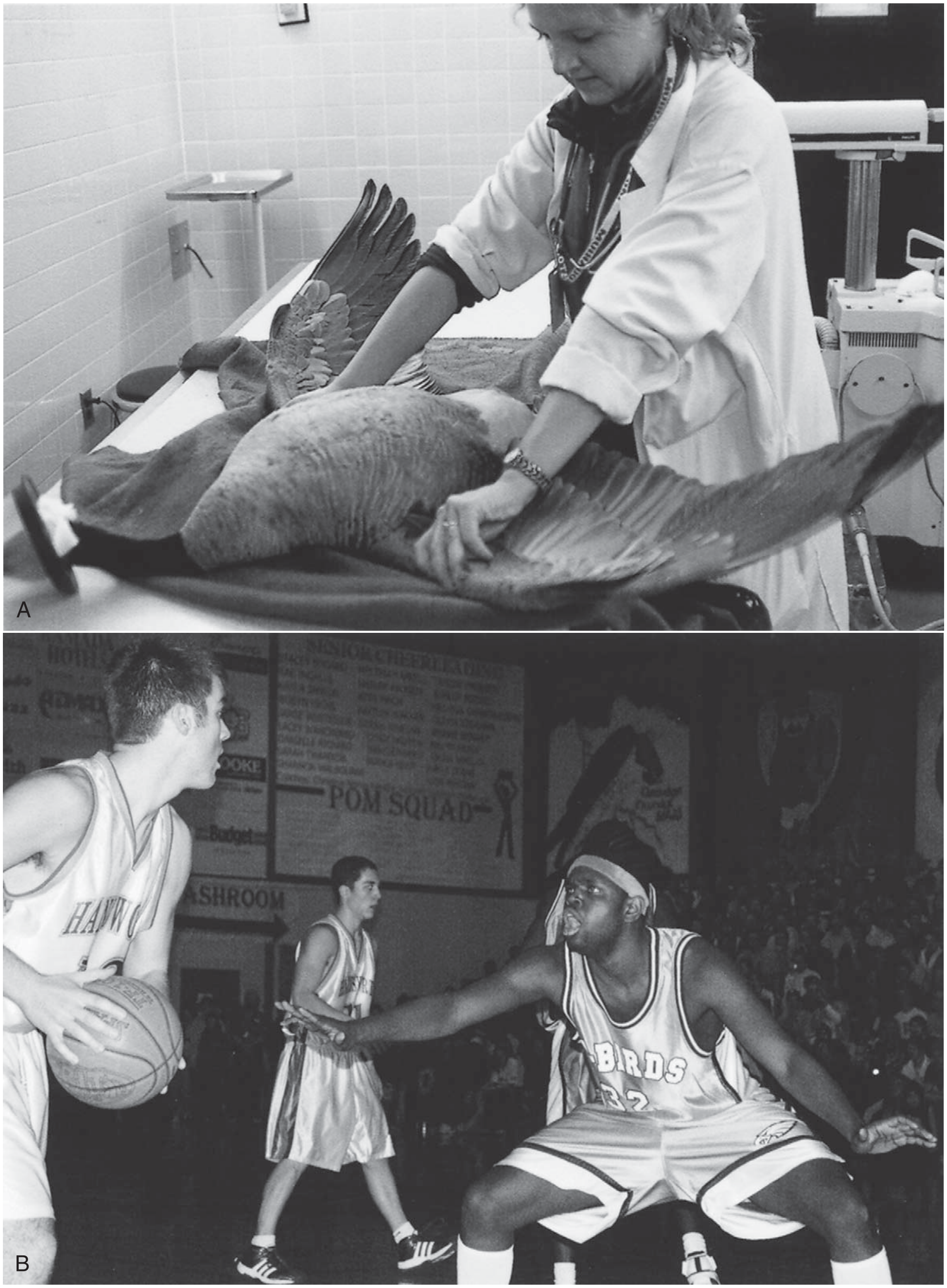


Figure 1-12 • A, Facing a threat, a large and powerful bird like a Canadian goose will use its wings defensively, much like a basketball player **(B).**

Figure 1-13 • A wildlife veterinarian holds an unconscious rough-legged hawk for a photograph immediately after radiography.

STANDARD FILM PROTOCOLS

Our standard radiographic protocol consists of at least two views: (1) VD, with the bird on its back, wings spread, facing the x-ray tube, and (2) lateral, with the bird on its side, wings upraised, torso perpendicular to the x-ray tube. These standard positions and the resultant radiographic projections are shown in Figures 1-14 through 1-16.

SUPPLEMENTARY VIEWS

Our most common supplementary view of the injured wing is the frontal projection, which we also term the *leading edge* or *hanging drop view,* in which the leading edge of the extended wing is placed over and just above the surface of the receiver (Figure 1-17). This view often proves indispensable in establishing the actual position of fracture fragments.

COMPARATIVE NORMALS

Normal radiographs serve two important purposes: (1) they aid in the analysis of complex injury and (2) they reduce or eliminate uncertainty in the case of unfamiliar anatomy. The value of one or more normal comparison views cannot be overstressed, especially for complex parts such as the humeral joint (shoulder), which comprises four bones—three primary articular elements and one secondary medial stabilizer.

THE PATIENT-TAILORED, SIGN-DIRECTED EXAMINATION

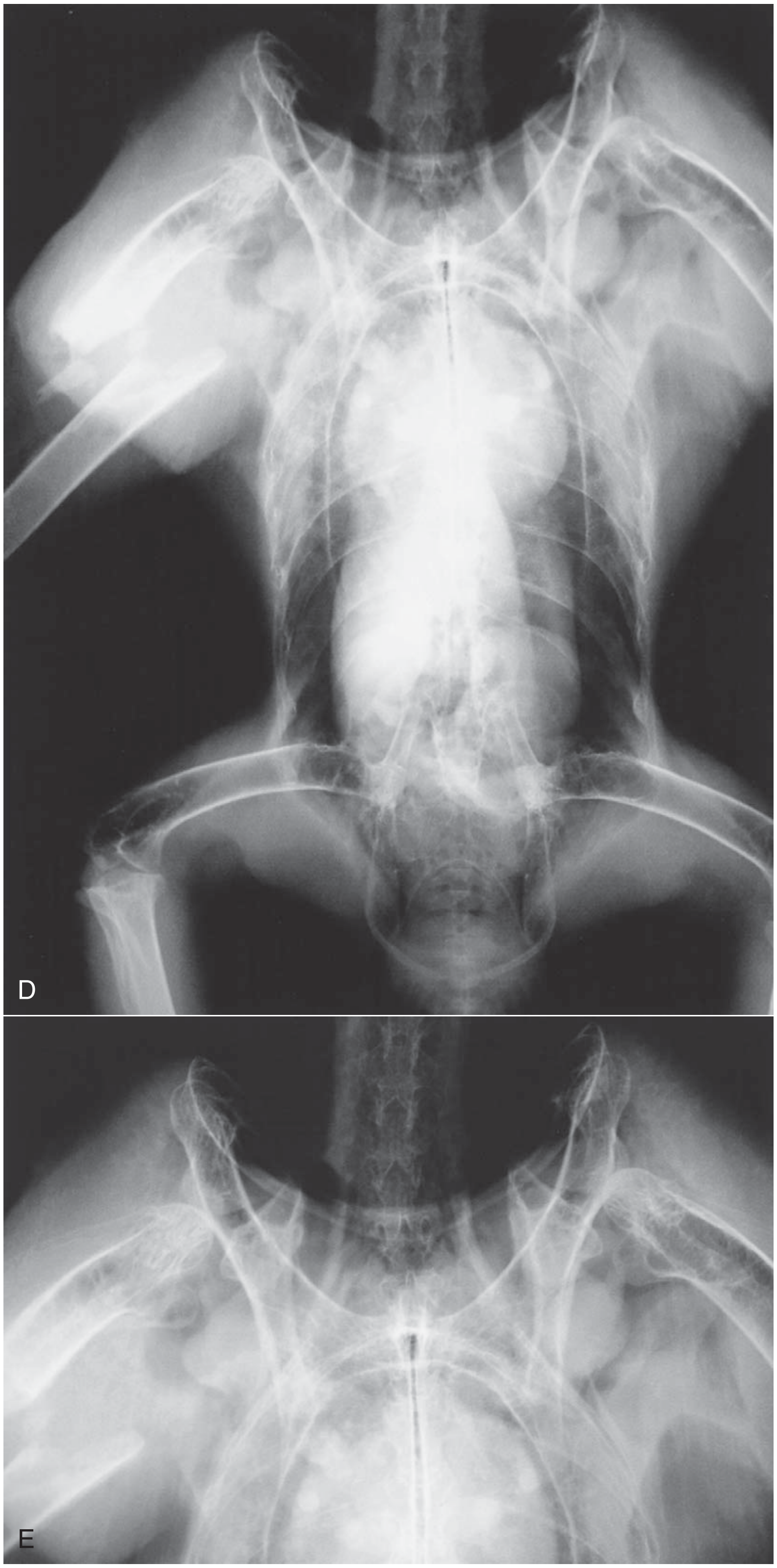
Whenever possible, it is best to perform *patient-tailored, sign-directed* radiographic examinations in birds. Just as with domesticated animals, diagnostic screens are often not informative and arguably wasteful, as strongly suggested by an extraordinarily high rate of unremarkable examinations. The radiographic screen should become neither a substitute for a comprehensive physical examination nor an offering on the altar of the complete database.

WHERE AND WHAT TO LOOK FOR

The diagnostic process in medical imaging as employed by experienced veterinarians and experts can be

Text continued on p. 22.

Figure 1-14 • Radiographing an eagle with a fractured wing. Once the bird is unconscious, it is placed on the x-ray receiver **(A),** taped into position **(B),** maintained on gas anesthesia **(C),** and radiographed **(D-F),** including a supplementary leading edge view **(G).**



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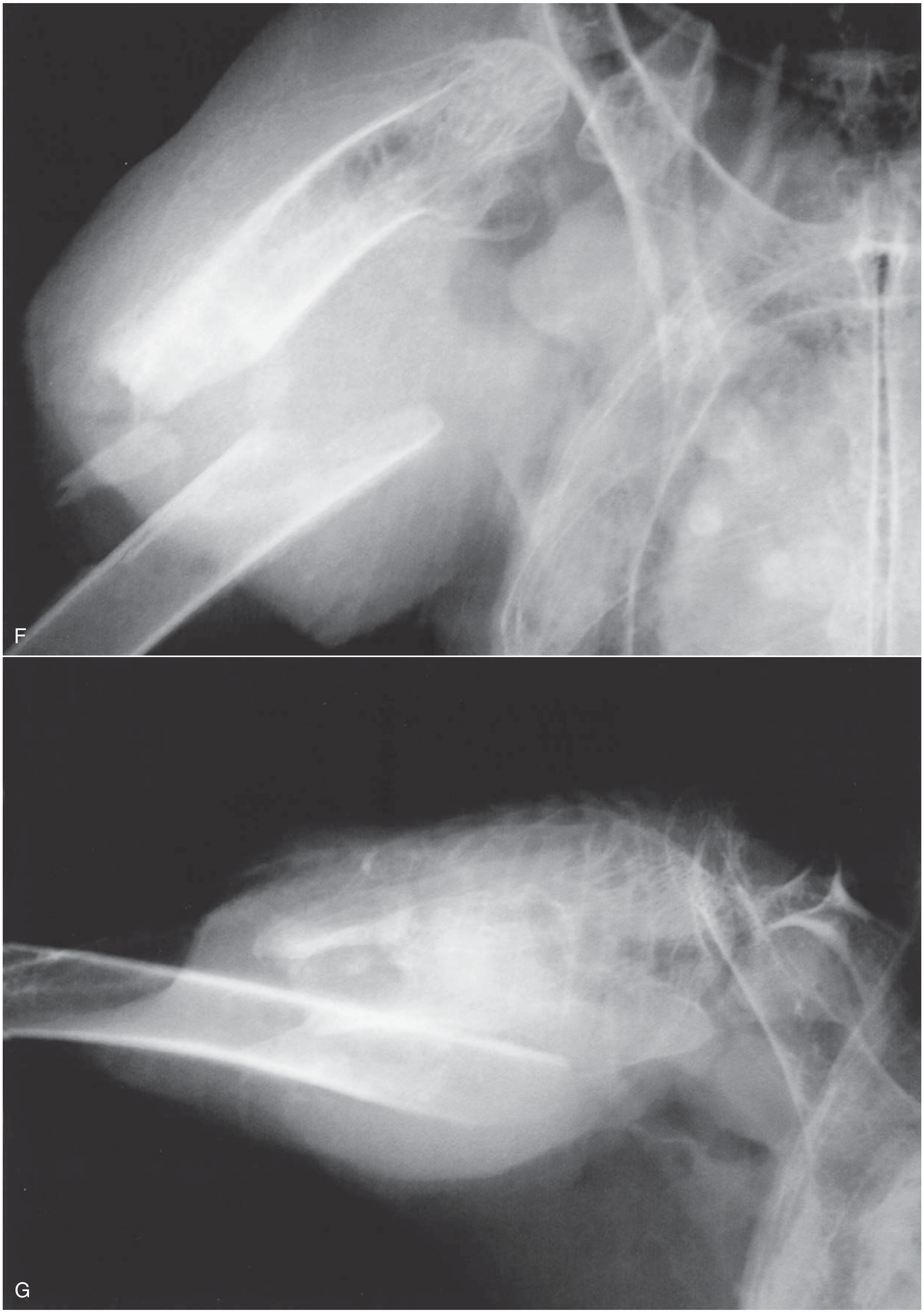

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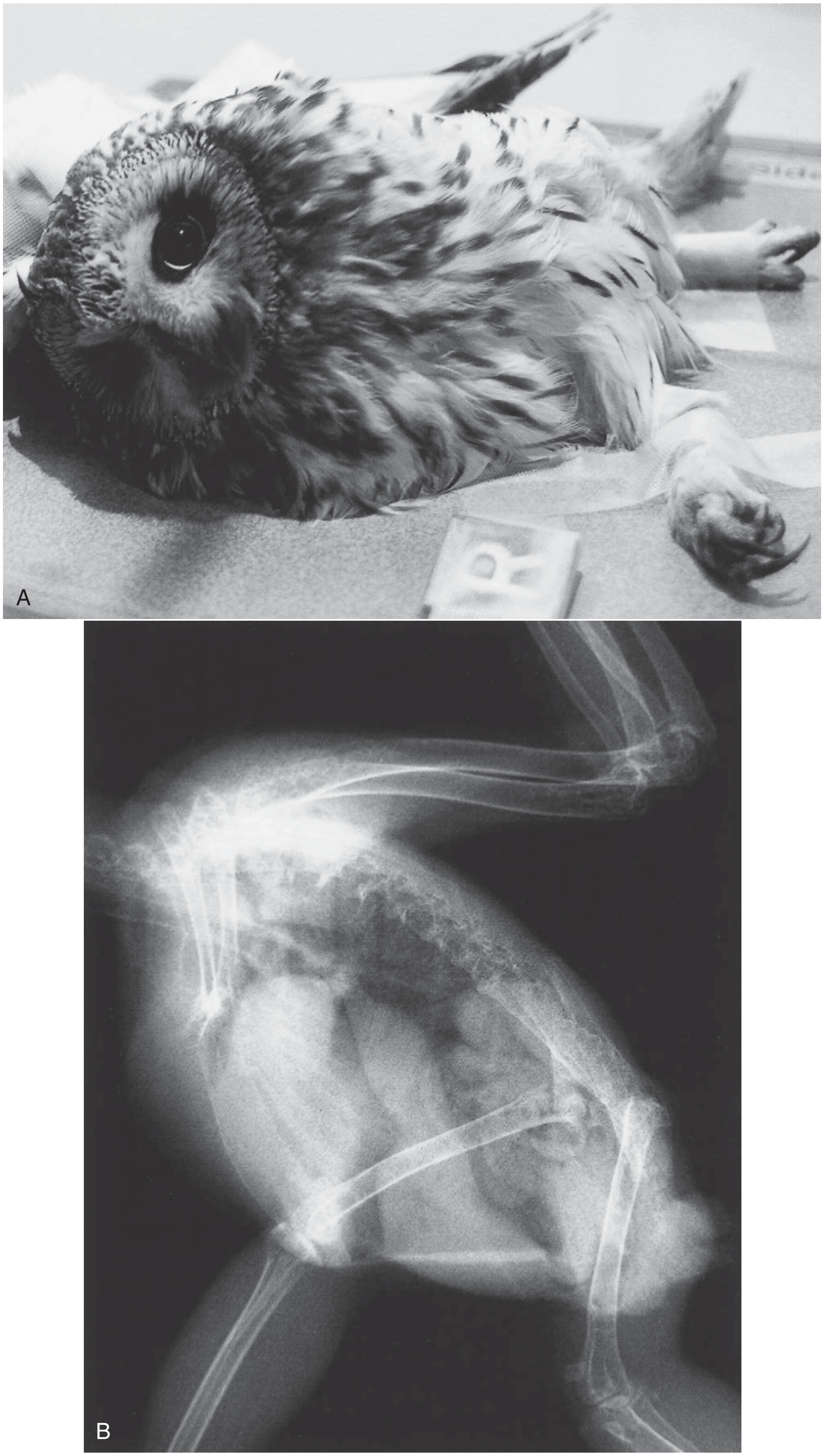


Figure 1-15 • Radiographing a burrowing owl for suspected skeletal and internal injuries. Because of the bird's diminutive size the anesthetic cone has been removed while the bird is being radiographed. Note that the legs are spread apart to reduce concentrated visceral superimposition and that an "R" has been placed on the surface of the cassette to indicate which side the bird is lying on **(A). B,** The resultant right lateral projection. No injuries were detected.

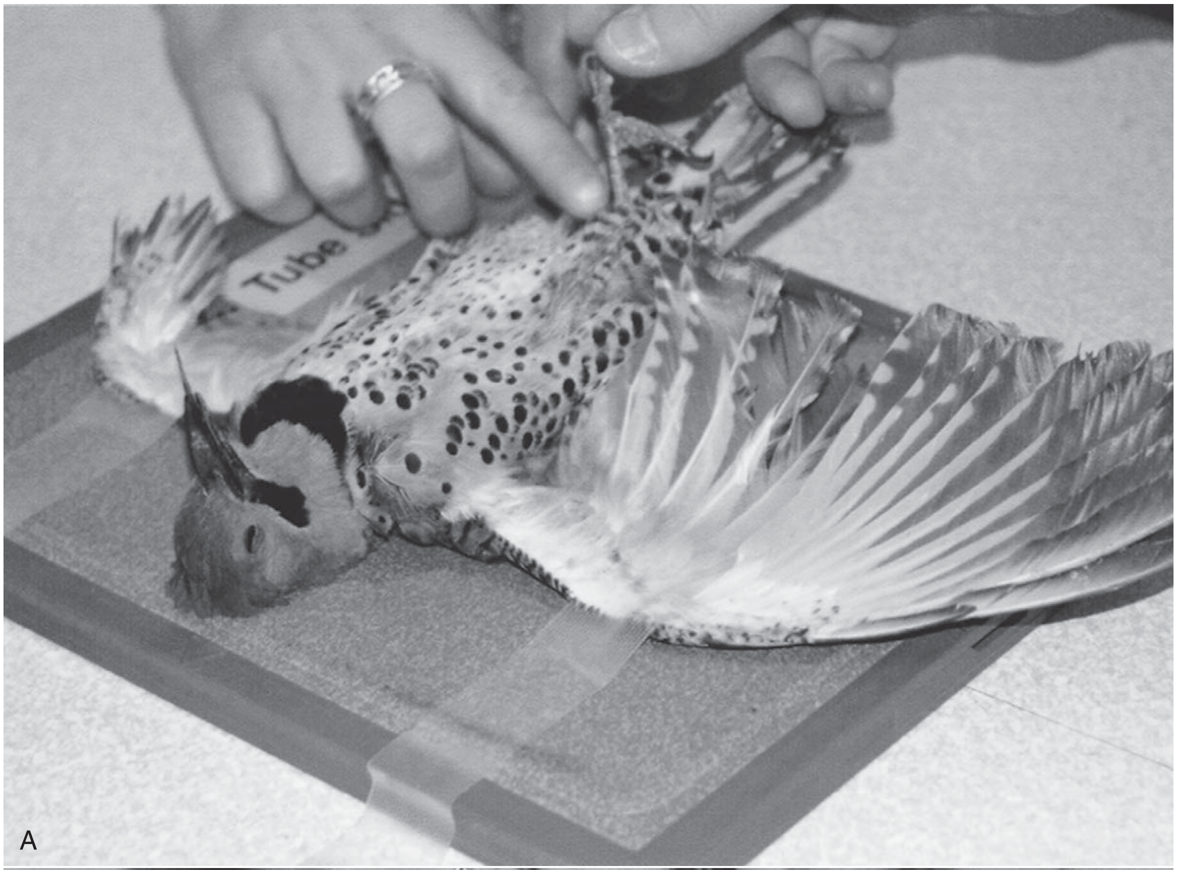
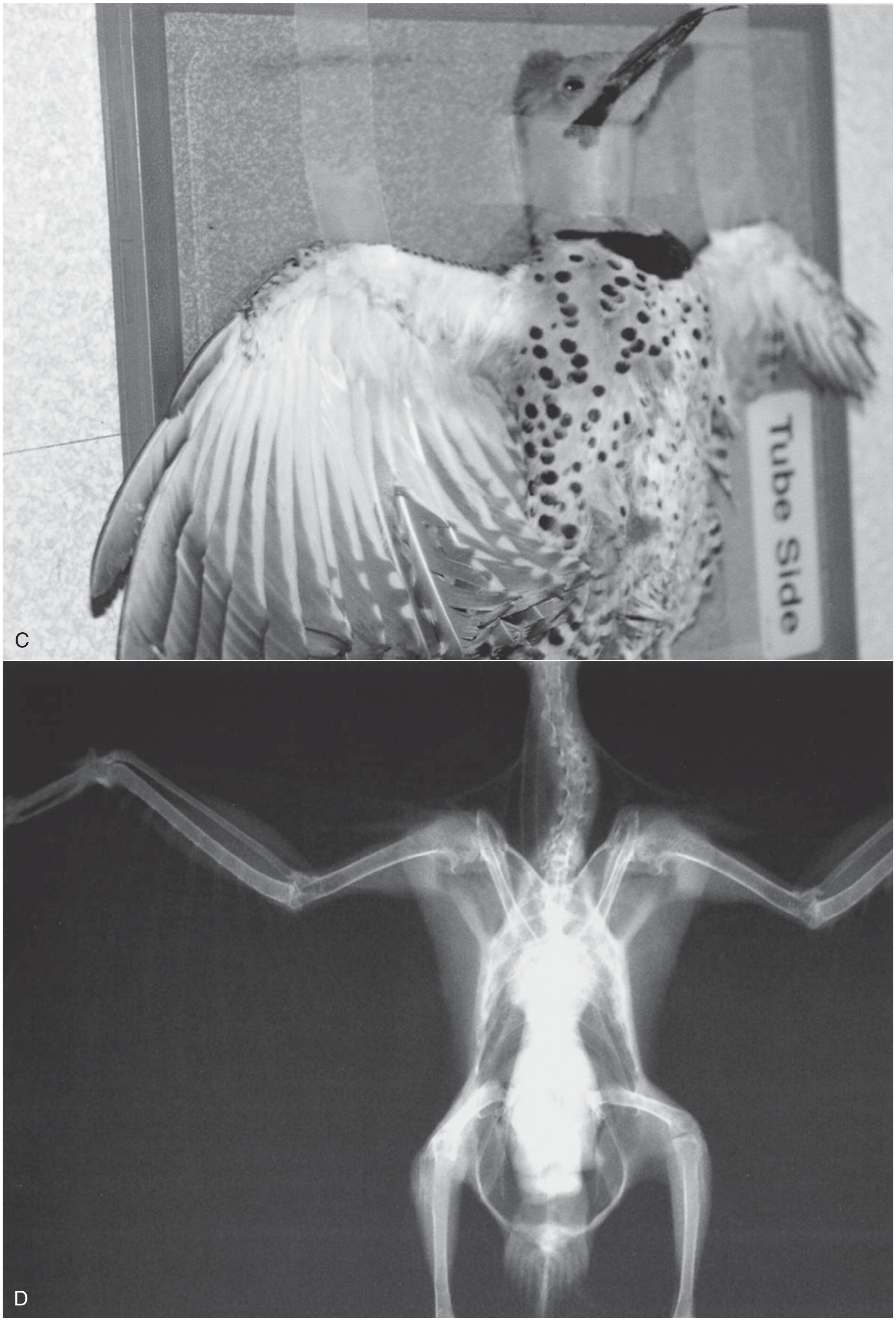


Figure 1-16 • Positioning and securing a flicker for radiography. **A-C,** A flicker is positioned on the cassette with its head, wings, and legs extended and then secured with tape. A ventrodorsal radiograph is made, shown here as orientation **(D)** and close-up **(E)** views. **F-H,** The process is repeated with the bird positioned laterally.



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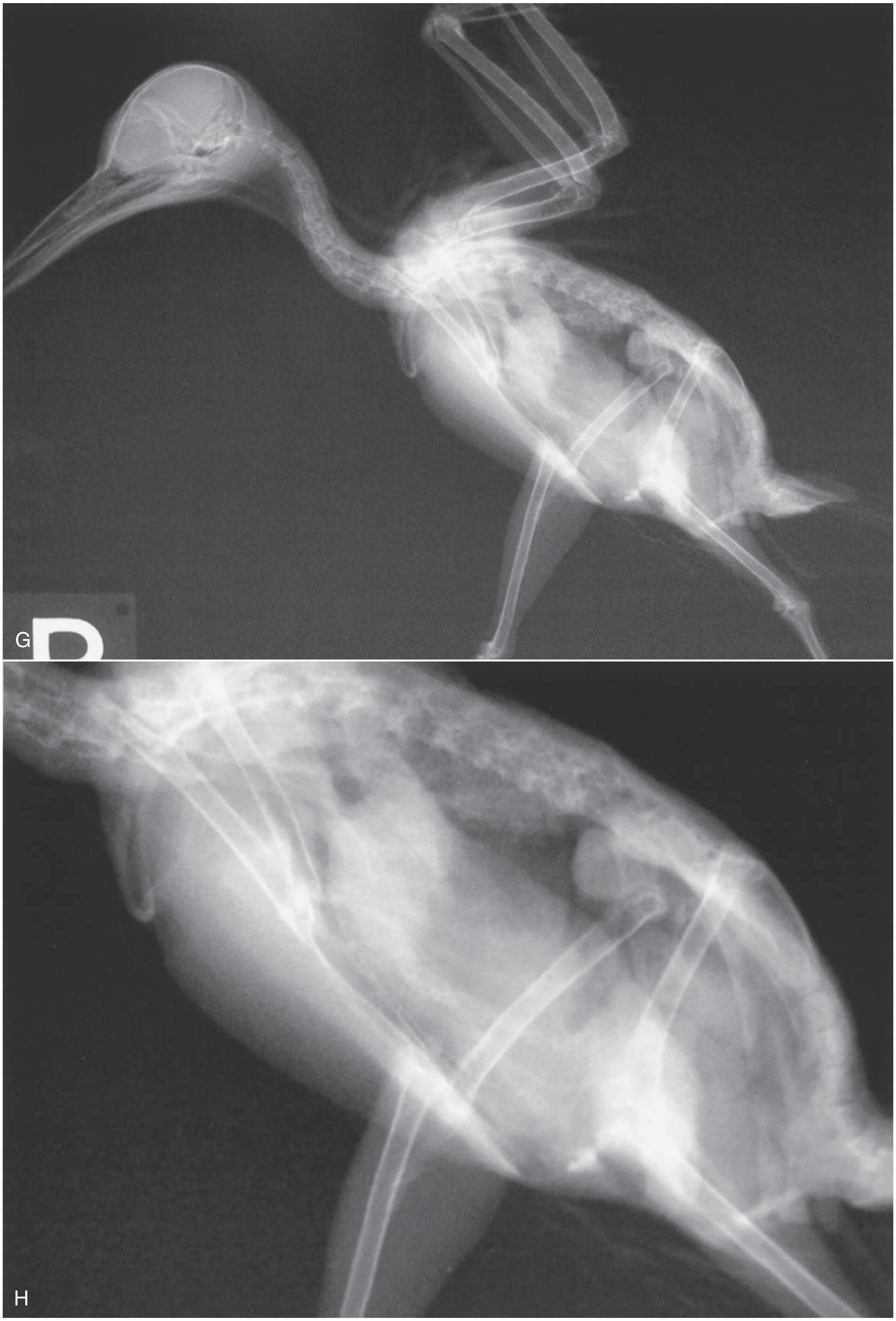

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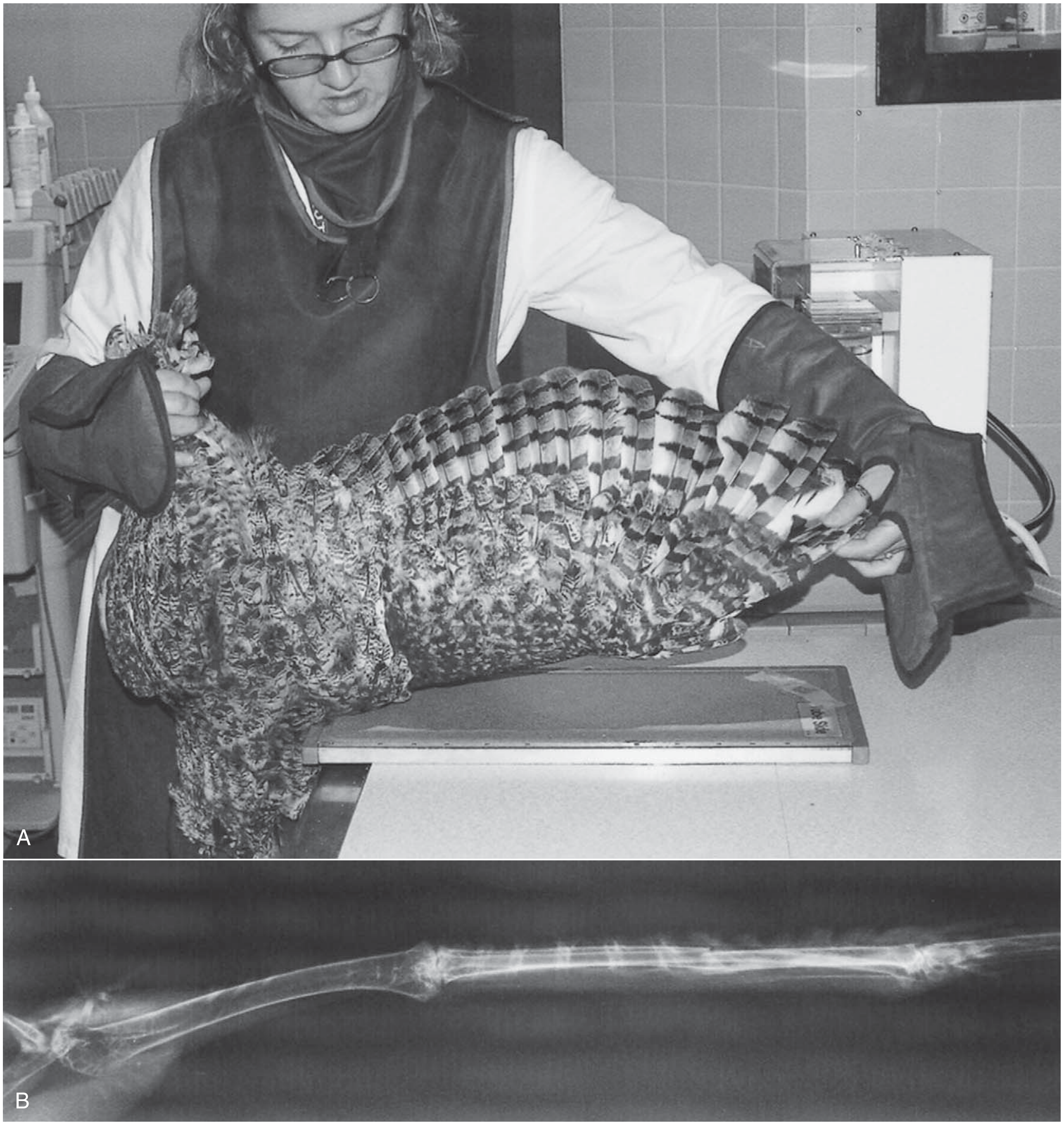


Figure 1-17 • Leading edge or hanging drop projection. Radiographer extends the leading (front) edge of the hawk's wing over and just above the surface of the cassette, with the bird's head hanging over the edge of the table. Once the bird is positioned satisfactorily, an assistant will cover the radiographer's fingers and any exposed parts of the hands with the glove's adjustable flaps **(A),** closely collimate the x-ray beam, and make the exposure **(B).**

distilled down to two essential actions: (1) where to look and (2) what to look for. In other words, the individual performing the analysis relies on background knowledge, as well as film-reading experience, to make the diagnosis. This is the way experts make the majority of their diagnoses: read or hear the history, search the area of the film most likely to contain abnormalities, look for one or more characteristic lesions, search medical images stored in the brain, and find a match.

If the diagnosis is not immediately obvious through this process (simple recognition-recall) or if there are two or more closely contending alternative diagnoses, then clinical reasoning comes into play in which alternatives are weighed in light of their relative merits or probabilities. It may also be possible to sort the various possibilities on the basis of other abnormalities that were identified, especially those typically found with the principal lesion, a process called *pattern recognition.*

Figure 1-18 • A, A Halloween bat hangs in the front window of a home, as seen from the front steps. **B,** Viewed directly from the living room of the home, the details of the bat become clear, although the blinds, control rod, and a Christmas star are overlying it. **C** and **D,** However, when the shadow of the bat, which is projected on the wall above the couch, is examined, it appears quite differently. This is because the bat, along with the other objects in the window, is being projected on a surface that is approximately 6 feet away and oriented at right angles to the incoming sunlight. **E,** Examine the bat again, as it appeared in the window and subsequently as it appeared as a shadow on the wall. The phenomena of magnification, geometric distortion, and blur are all relevant potential sources of misdiagnosis when analyzing avian radiographs.

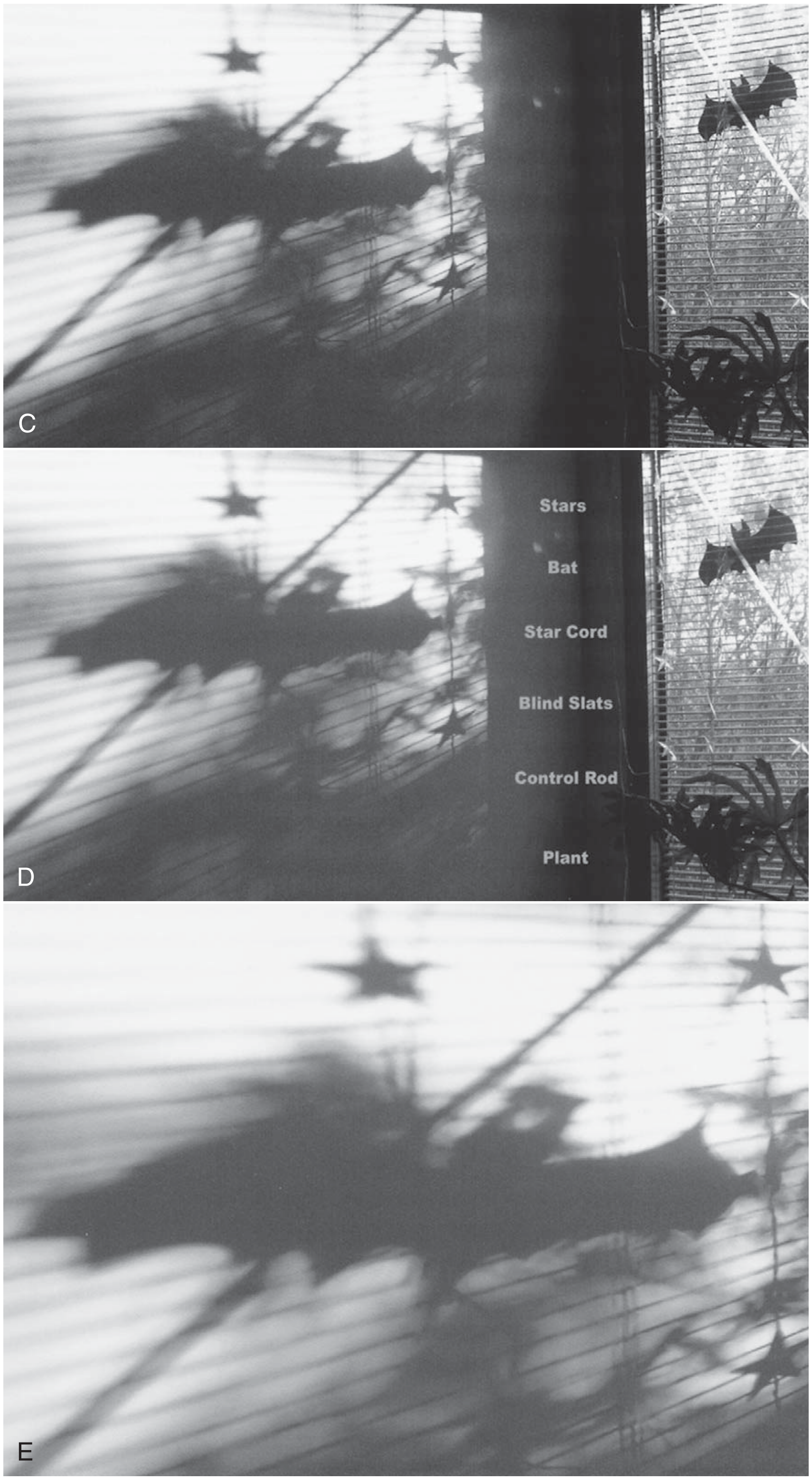
Continued

IMAGE ASSESSMENT: A SHADOWY BUSINESS

Imaging birds, and in particular their extended wings, often results in less than accurate imagery. For example, it is often impossible to position the wing flush on the face of the cassette, which results in variable object-film distances. This in turn leads to some portions of the wing magnified as a result of being farther from the film, thus they appear less distinct, even blurred.

Another difficulty lies in the fact that only the central third of the wing lies beneath the most functional part of the x-ray beam, that is, the part of the beam that lies most perpendicular to the wing. Because of beam divergence in the outer thirds of the wing, some anatomical distortion is inevitable, which often conveys the impression of a blurred image, similar to magnification.

These film flaws must be recognized for what they are, differentiated from genuine disease-based alterations, and factored out of the analytical process before reaching any meaningful diagnostic conclusion. Figure 1-18 illustrates some of the important diagnostic considerations detailed previously, including magnification, geometric distortion, blur, and summation.



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Chapter 2

Wild Birds

CROWS, MAGPIES, AND JAYS

Crows, magpies, and jays belong to the Corvidae family, within the order Passeriformes. Crows are relatively large black brassy birds that are equally at home in populated or wilderness environments (Figure 2-1). Their distinctive call reminds many of time spent hiking or camping in the woodlands. Crows are particularly bold, feeding fearlessly on roadkill and seemingly impervious to the presence of passing vehicles. Their northern relative, the raven, is noticeably larger and considerably more difficult to handle in a hospital setting.

While in the care of veterinarians, crows may subsist comfortably on elements of their natural diet, including seeds, berries, insects, meat, or chicken. Eye protection is a wise precaution when handling crows because of their large powerful beaks.

Magpies are somewhat smaller than crows, but they have a most attractive plumage comprised of a black cloak, white vest, and long dark blue-green tail (Figure 2-2). Like crows, magpies have a disproportionately large head. However, unlike crows, which have a conventional flight pattern, magpies often swoop from point to point, giving some the impression of a wing injury.

Jays are stunning, predominately blue and white birds with a distinctive collapsible crest atop their heads (Figures 2-3 and 2-4). When foraging for food, jays characteristically announce their presence with a sharp cry before beginning to feed (presumably a signal to other birds in the area). Commercial wild birdseed, supplemented by unsalted, roasted, unshelled peanuts, makes an excellent hospital ration.

GEESE AND DUCKS

In western Canada, Canadian geese abound on rivers, lakes, and wetlands. Their annual arrival gratefully signals the coming of spring, but later and more ominously, their departure forecasts winter freeze-up. Their overflights, which sometimes number in the thousands, are arranged in V-shaped, bomberlike formations often separated by only a few yards; their herringbone trails in the sky seem almost endless (Figure 2-5).

Geese with young goslings can be very aggressive (Figure 2-6). A large male once attacked my partner and me during a marathon canoe race when we inadvertently got between it and its offspring. The gander hurled itself into my bowman's chest, beating him with its large heavy wings (Figure 2-7) about the chest and head, nearly knocking him overboard and capsizing our boat.

In the fall, hunters wait in ambush along the water's edge, dressed in camouflage and concealed in blinds, with their dogs fidgeting nervously at their sides. Wounded birds that survive their fall to earth and are not retrieved usually are taken by opportunistic predators or die of starvation; however, some are discovered by hikers and taken to a veterinarian.

Although we have an equally large number of ducks in our region (Figure 2-8), comparatively few are brought to our hospital for medical attention. Conscious ducks can be surprisingly aggressive when being handled, frequently biting those handling them (Figure 2-9). Both geese and ducks belong to the family Anatidae, order Anseriformes.

BLACKBIRDS (COWBIRDS, GRACKLES, AND NORTHERN ORIOLES)

Cowbirds and grackles are ubiquitous in western Canada. The grackle is a particularly attractive bird, especially in bright sunlight where its bright metallic blue and lavender head positively gleams (Figure

Text continued on p. 30.

Figure 2-1 • An inquisitive crow banks sharply, executing a low-speed turn, and avoids a stall by opening its wingtips to the onrushing wind.

Figure 2-2 • A magpie is profiled against a snowy backdrop as it leans forward and prepares to feed.

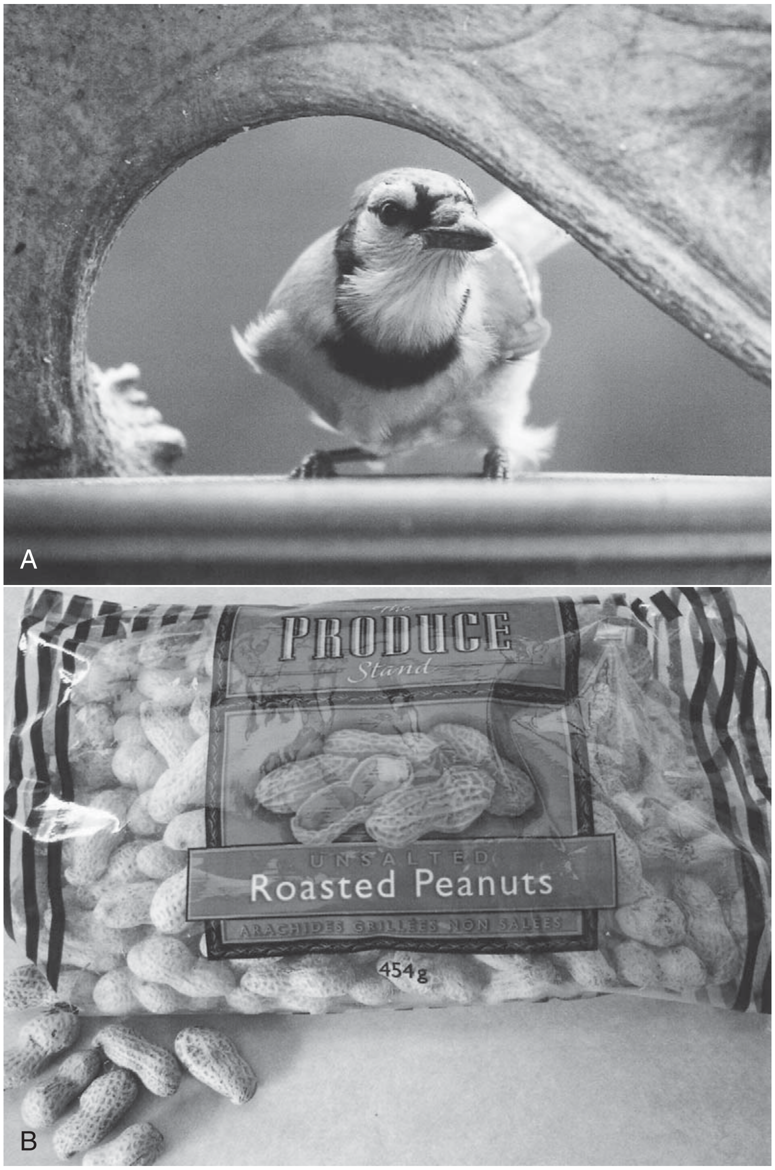

Figure 2-3 • A, Frontal view of an adult jay, its characteristic dorsal crest collapsed as it dips beneath the arch of a moose antler to take a peanut. **B,** Roasted peanuts are an excellent, no fuss, short-term food source for hospitalized jays and magpies but should be unsalted.

Figure 2-4 • Portrait view of an adult jay with raised dorsal crest ready to take a peanut from a feeder.

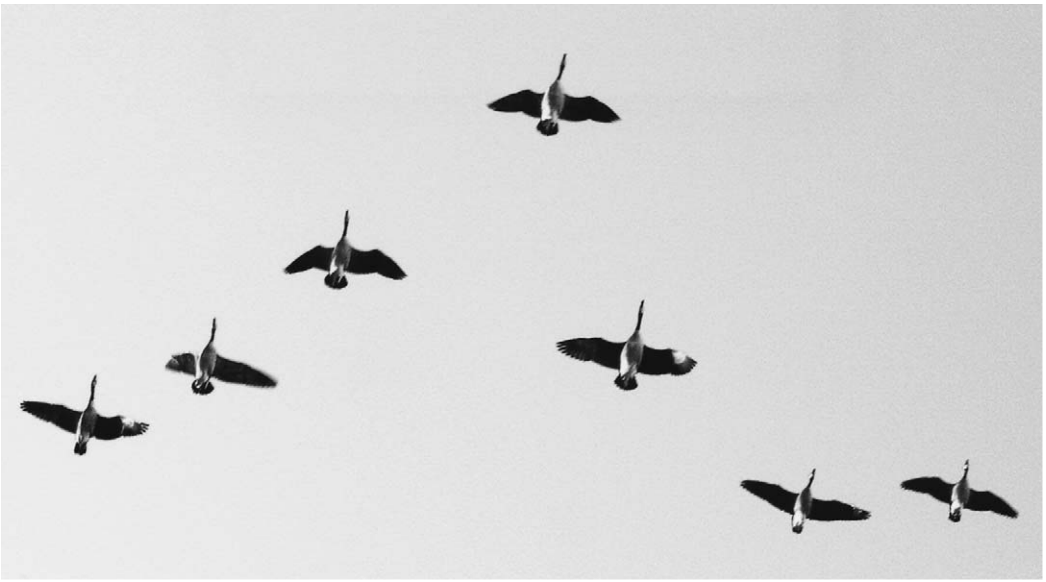

Figure 2-5 • Canadian geese in formation.

Figure 2-6 • A gander oversees a small *super family* as they feed along the riverbank.

Figure 2-7 • An unconscious Canadian goose being examined before being radiographed. The size of its large, powerful wing compared with the size of the veterinarian's hand helps one imagine how it might feel to be struck in the face by a bird attempting to defend itself while being handled.

Figure 2-8 • A pair of mallards swimming in the river (the drake is on the left).

Figure 2-9 • A duck clamps down on a radiographer's finger.

Figure 2-10 • A grackle keeps a wary eye out.

2-10). Northern orioles are seen for a brief period during the spring in our part of Saskatchewan on their way to northern feeding and nesting grounds (Figure 2-11). These birds belong to the family Icteridae and are sometimes called blackbirds, although many, such as the oriole, are not truly black.

EAGLES, HAWKS, AND OWLS

Eagles, hawks, and owls, so-called birds of prey, are spectacular creatures whether seen soaring in the sky or perched high in a wilderness spruce. Arguably the most magnificent of these, the bald eagle *(Haliaeetus leucocephalus)*, is the national symbol of the United States and quite plentiful in central Saskatchewan (Figure 2-12).

Hawks are more morphologically diverse than many realize, featuring specimens nearly as large as eagles, such as Swainson's hawk (Figure 2-13), or as small as robins, such as the kestrel (Figure 2-14). A Merlin may nest atop a downtown office building, in a tree along a suburban bike trail, or on a power pole along the highway.

It has been said of owls that they are heard more often than seen, although their prey probably likely sense neither, only the bite of the owl's talons a fraction of a second before being carried away (Figure 2-15).

HERONS, LOONS, GREBES, AND KINGFISHERS

I group herons, loons, grebes, and kingfishers together because of my experience on western Canadian waterways rather than because of any taxonomical organization. I recall the slow-motion wing beat of the great blue heron or the distinctive call of the loon as it reverberates across a northern lake at sunset (Figure 2-16).

PELICANS, CORMORANTS, AND GULLS

Pelicans, cormorants, and gulls are grouped together here because of personal preference; I have frequently

Figure 2-11 • A startled Northern oriole makes for the protection of a nearby tree.

Figure 2-12 • An exotic animal resident holds a bald eagle recovering from gas anesthesia after being radiographed.

Figure 2-13 • A Swainson's hawk, wings outspread, perched on the bare hand of its handler.

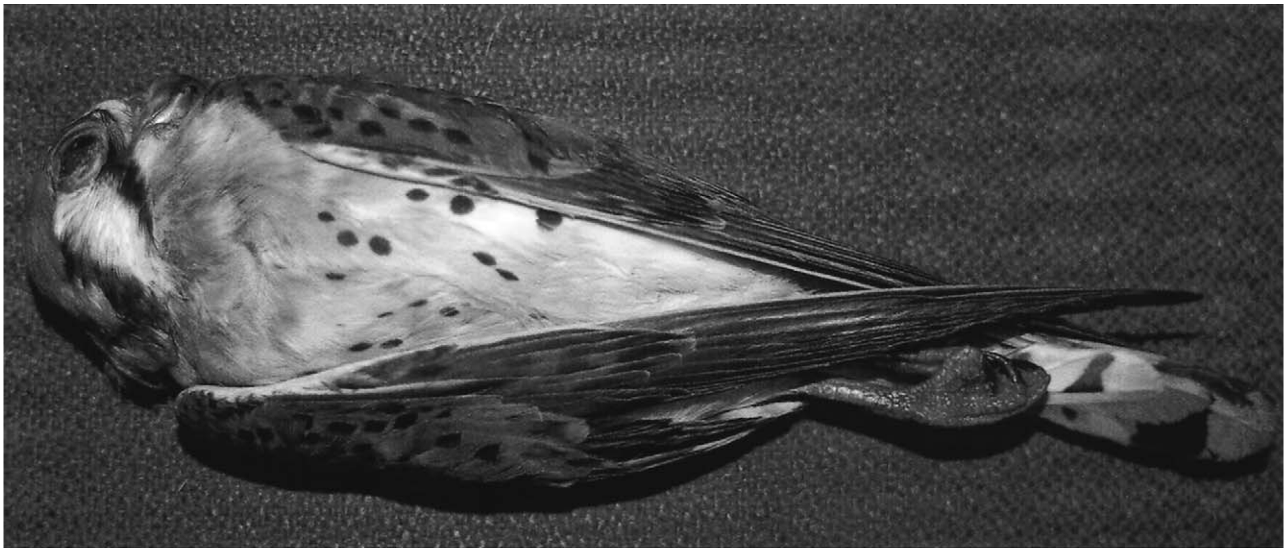

Figure 2-14 • A dead kestrel before being radiographed to see whether there is any evidence that it was shot. The examination proved to be negative.

observed these birds hunting side by side in a river near my home (Figure 2-17). The local pelicans and cormorants prefer to hunt the heavy, convergent hydraulics produced as water streams over and around a weir, just as it meets the reinforced riverbank (Figures 2-18 and 2-19). All prefer the shallows, especially the cormorants, which resemble otters more than birds because they pursue their prey only a few inches beneath the turbulent surface. Minnows, in their desperation to escape, often momentarily beach themselves just long enough to be taken by a gull patiently waiting at the water's edge (Figure 2-20).

PIGEONS

Perhaps no other bird is more at home in cities than the pigeon. It perches on rooftops, beneath bridges, on

Figure 2-15 • Moving not a single feather, a great horned owl scans the ground for gophers.

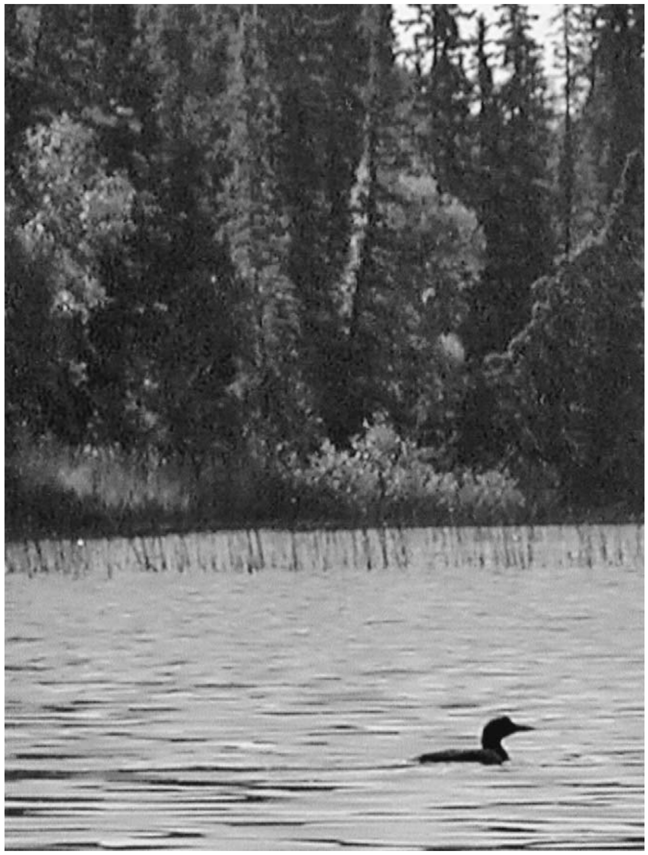

Figure 2-16 • A spotted loon tracks along the outer edge of a weed bed in a central Saskatchewan lake.

Figure 2-17 • A pelican and cormorant hunt side by side in a river near my home.

Figure 2-18 • The shoreline near a hydraulic provides an abundant hunting ground for pelicans.

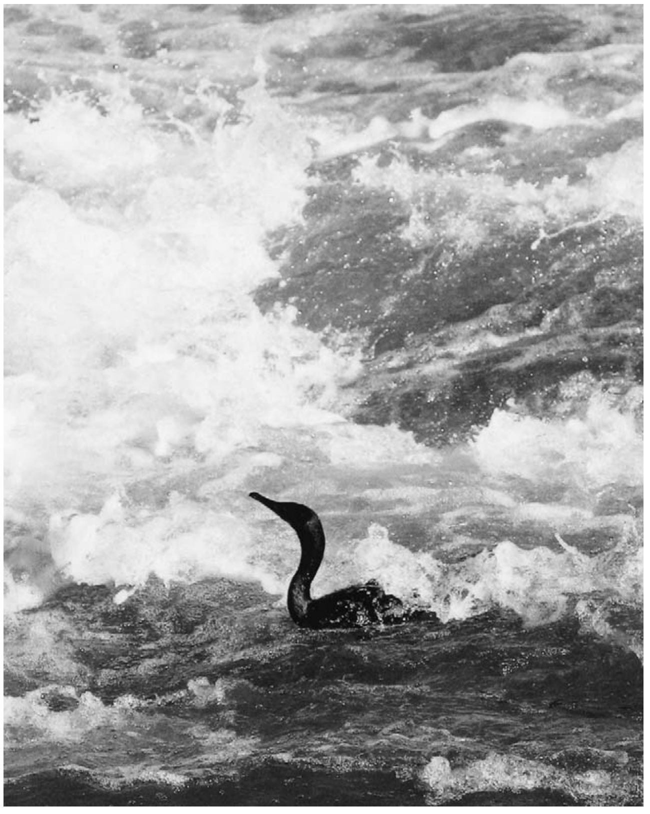

Figure 2-19 • A hunting cormorant surfaces in a heavy swell.

Figure 2-20 • A hopeful seagull watches from the shore as a cormorant cruises by just beneath the surface.

the heads and shoulders of heroic statues, along the backrests of park benches, and in squares and belfries (Figure 2-21). Somewhat of a catchall, the term *pigeon* (family Columbidae) refers to the larger, more statuesque species but also includes the smaller, more delicate dove.

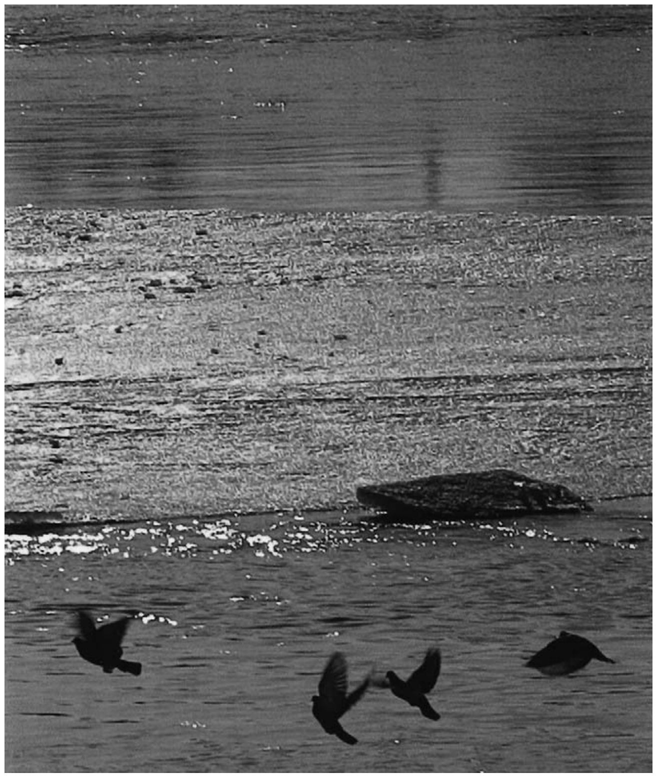

Figure 2-21 • Pigeons, disturbed by a passing train, temporarily vacate their roosts.

SPARROWS, CHICKADEES, AND JUNCOS

Sparrows (order Passeriformes) are indeed the principal residents of our urban bird feeders (Figure 2-22). These small but feisty birds regularly do mock battle with one another over food, females, and territory but rarely sustain substantial injury (Figure 2-23). Chickadees and juncos are also found in abundance but are far less aggressive (Figure 2-24). When hospitalized, these small birds thrive on commercial wild birdseed (Figure 2-25).

ROBINS AND WAXWINGS

There is something electric about the sudden coming of a thousand cedar or bohemian waxwings as they fill every branch of a backyard maple and sound like the lead element in a prairie plough wind (Figures 2-26 and 2-27).

In our part of Canada, robins descend on our lawns in great numbers in the spring. They stay to raise their families during the summer (Figure 2-28) and then head south in the fall. Just before departing the northlands, the birds form enormous flocks, sometimes numbering into the hundreds.

Figure 2-22 • A sparrow gathers dog hair for its nest.

Figure 2-23 • Sparrows "fight large."

Figure 2-24 • A chickadee shares a peaceful meal with a Pine Siskin.

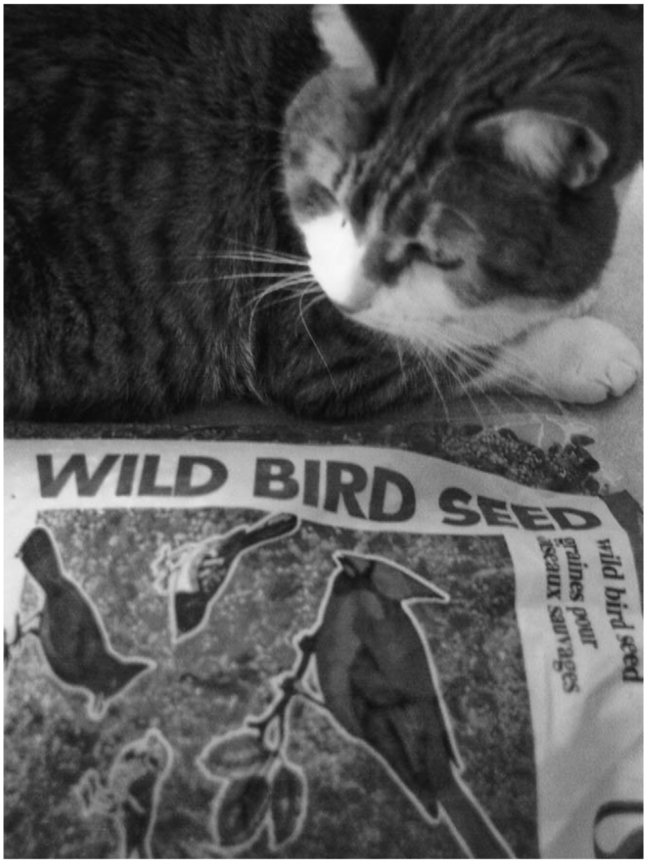

Figure 2-25 • Wild birdseed is an excellent way to observe wild birds in their natural environment and to nourish them when hospitalized.

Figure 2-26 • A solitary waxwing perches on a branch, puffed against the –35°F cold.

Figure 2-27 • Resembling passengers packed into a crowded subway train (except they are arranged vertically), a small flock of waxwings feed on what remains of last year's apples.

Figure 2-28 • An immature robin attempts to maintain its perch in a stiff prairie wind.

Figure 2-29 • A Northern flicker eats seed from a feeder.

WOODPECKERS

The Northern flicker (order Piciformes) is the most common large woodpecker in western Canada. Although insects are the staple of their diet, flickers are quite capable of eating from a cage floor while recuperating from an injury, as evidenced by regular feeding from urban lawns and feeders (Figure 2-29). When performing an oral examination on a flicker, the technician should remember that it has a highly specialized, elongated tongue used for extracting insects from within trees.

Chapter 3

Cage Birds

We see few cage birds in our practice compared with wild birds. Among these, parrots are the most popular, interspersed with the occasional canary or Mynah bird. Accordingly, this chapter is quite brief compared with some of the others. Nevertheless, I believe there is some useful information that can readily be applied in a practice setting.

Information is also included on small bird radiography and in particular, methods that require no drugs or gas. Although I agree with authorities that tout the advantages of full restraint—and the manual, chemical, or gaseous means of achieving this—I vehemently disagree with the proposition that *every* small bird must be restrained, especially if the bird is seriously ill or injured.

Each bird must be treated as an individual, just as with any other type of patient. Restraint, or lack thereof, must be determined by a number of factors, but above all, by the risk to the bird's well-being. There are times for an optimal image, and there are times for something less. An unsatisfactory film can always be repeated, but a dead bird cannot be brought back to life.

Canaries, lovebirds, and parakeets can be quite fragile, especially when they are seriously ill, and in such circumstances, we are reluctant to use gas restraint unless absolutely necessary. Some of our minimal and nonrestraint techniques are described here.

SMALL CAGE BIRD RADIOGRAPHY

Restraint

The great majority of our bird radiography is done with the bird taped or held on the cassette while under general anesthesia; the same being true with computed radiography (CR) or digital radiography (DR) systems. The method of tape restraint has been published widely, with numerous examples appearing elsewhere in this book.

Nonrestraint

Small birds that cannot be drugged, anesthetized, or safely restrained manually can be imaged by other means. For example, an extremely ill budgie or canary can easily be radiographed while perched using a horizontally directed x-ray beam. If the bird is too weak to perch, it can be placed in a cardboard shoebox, which is transparent to radiation, and radiographed there.

If a bird refuses to remain still long enough to be radiographed, it can be placed in a corner of the box and corralled with small foam panels, adjusted to best suit the situation, and then radiographed. In such circumstances, it is best to work in a minimally lighted room, with as little noise as possible.

Obviously, images obtained in this manner will likely be far from ideal, especially those made with the bird in a box. Some will appear unfamiliar because of nonstandard projection angles, others will be compromised by superimposition, and most studies will be limited to a single view. Why bother? Because it is prudent and in keeping with the medical adage: first, do no harm! Examples of these radiographic techniques can be found in Chapter 1.

OUR CAGE BIRD PRACTICE

As mentioned earlier, the majority of our avian imaging is of wild birds. Our cage bird practice is compara-

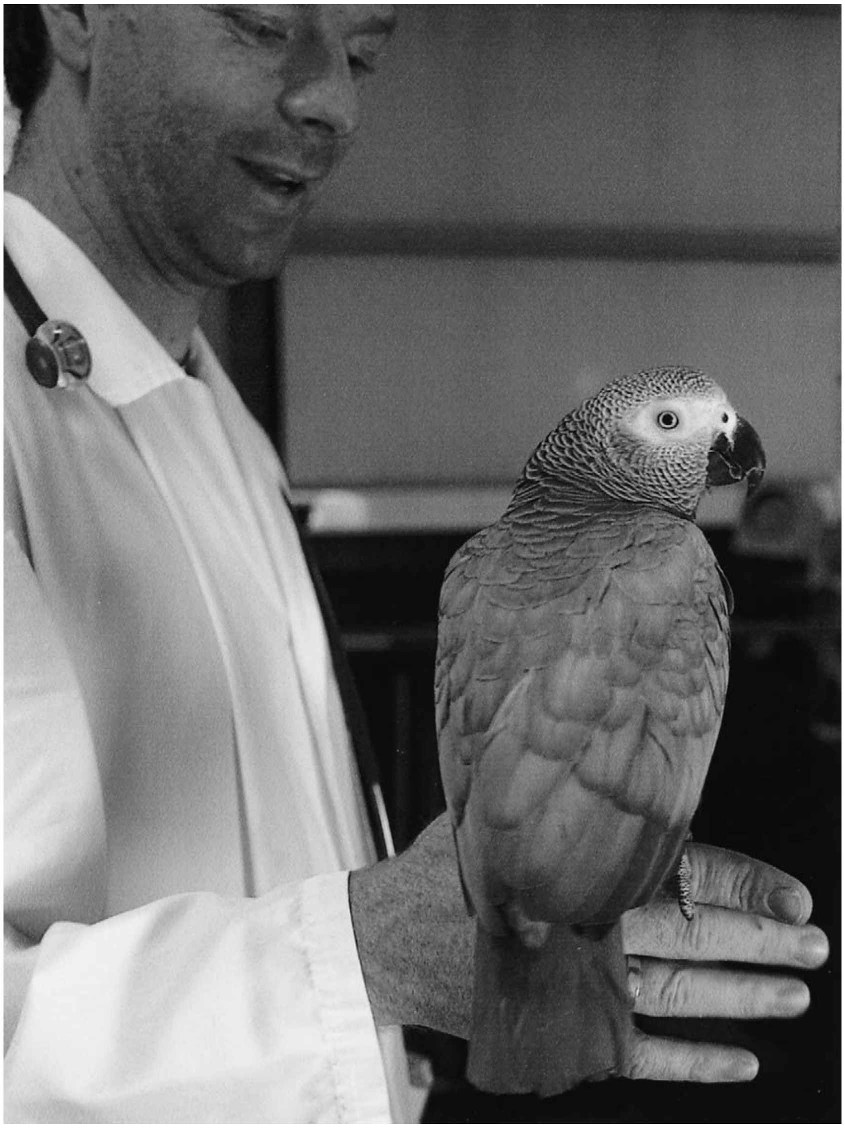

Figure 3-1 • Veterinarian visually inspects a Congo African Gray parrot in the Radiology Department.

tively small, being comprised mainly of medium-sized parrots such as the African Gray (Figure 3-1) and the Amazon (Figure 3-2). We see comparatively few small parrots, such as budgies and lovebirds (Figure 3-3), and almost no canaries. Occasionally, cockatiels are referred for contrast studies related to suspected gastrointestinal disease (Figure 3-4).

Size Matters

Radiographic assessment of small birds is often difficult because of a combination of small size and low contrast. Even when enhanced by CR or DR software, the image quality of a budgie pales in comparison with that of a medium-sized parrot (Figure 3-5).

Figure 3-2 • Veterinarian attempts to coax an Amazon parrot onto his outstretched finger before being radiographed.

Figure 3-3 • A lovebird cleans its owner's teeth, a procedure requiring care on the part of both parties.

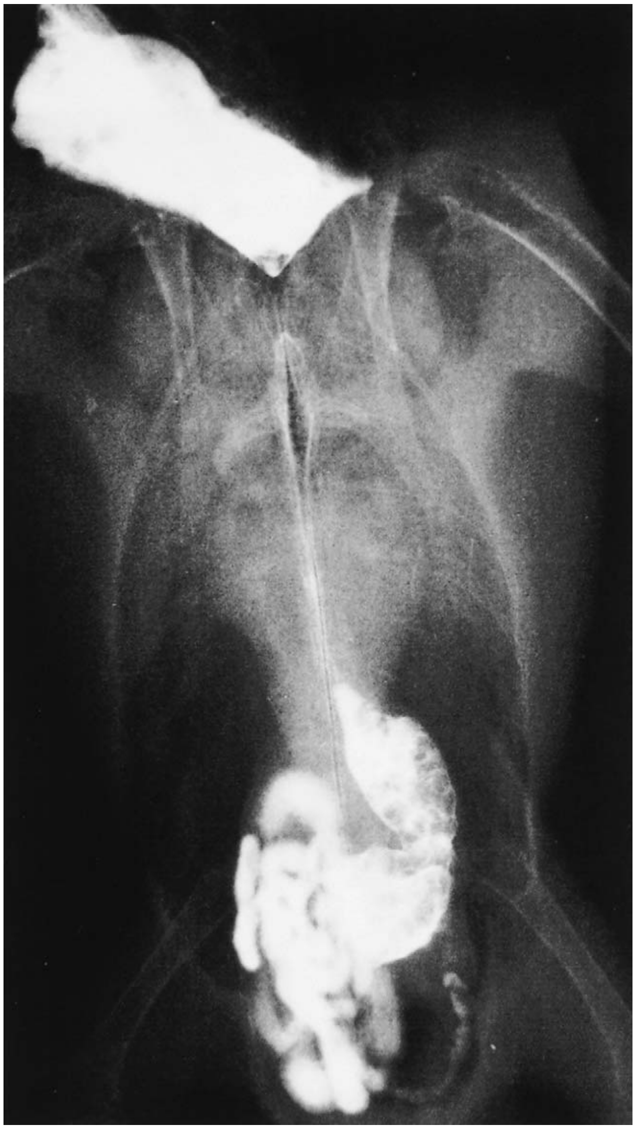

Figure 3-4 • Ventrodorsal view of the torso of a cockatiel given barium an hour earlier to evaluate its gastrointestinal tract shows contrast solution in its crop, esophagus, stomach, and intestine.

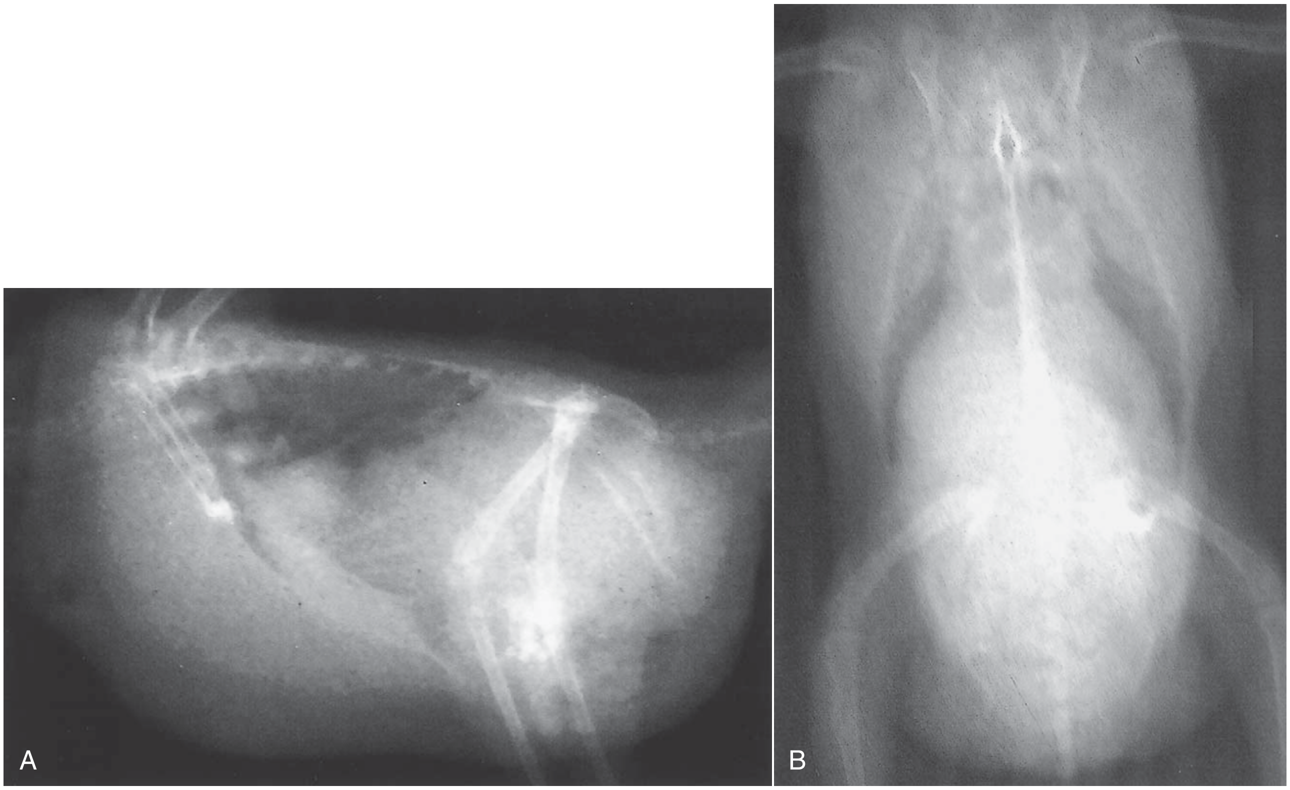

Figure 3-5 • A, Lateral and ventrodorsal **(B)** views of the torso of a budgie with a confirmed abdominal tumor, which is indicated radiographically by (1) increased intraabdominal soft tissue volume; (2) flaring of the liver, presumably caused by a contiguous mass; (3) cranial displacement of the heart; and (4) a lateral shift of the gizzard, also presumably the result of an adjacent mass. All of these disease indicators are circumstantial, and a tumor, as such, is *not* apparent.

Chapter 4

The Wing: Particulars of Flight

WING DESIGN AND AERODYNAMICS

It's a Plane

Imagine a teardrop, sliced in two lengthwise. The resultant object, curved edge up, flat edge down, blunt end forward, and tapered end aft resembles the lateral profile of a classic *airfoil* or wing. This asymmetrical shape causes the air moving over the upper and lower wing surface to exert a net upward pressure or *lift,* which combined with sufficient forward *thrust* enables flight. Weight and the force of gravity oppose lift. Thrust is countered by *drag*.

Some additional flight considerations exist. The greater the wing surface, the greater the lift. The greater the thrust, the less the required lift; alternatively, the less the thrust, the greater the required lift. As the wing is tipped up (termed an increased *angle of attack*), lift increases but only to a point, at which time lift abruptly decreases, causing the wing to *stall,* or cease to fly.

Different wing shapes, or *planforms,* possess different aerodynamic qualities, with the elliptical wing most closely approaching the ideal for subsonic flight (Figure 4-1). As aircraft become faster, their wings become smaller, flatter, more angular, and swept back to decrease drag (Figure 4-2). But fast comes with a price; namely, a need for greater thrust and superior flying skills, especially at low speed.

It's a Bird

The wings of birds obey the same laws of physics as do those of airplanes but with far more sophisticated controls (discussed in a later section), although they are airfoils (Figure 4-3). Also, as with airplanes, the wings of birds come in different shapes with different flight characteristics: elliptical, rectangular, wide, narrow, short, long, slotted, and unslotted (Figures 4-4 and 4-5). Unlike aircraft, the wings of birds provide thrust, as well as lift.

CONTROL SURFACES

Modern aircraft are capable of in-flight modification of both their wings and tail sections. In the case of the wing, leading edge *slats* and trailing edge *flaps* can be deployed to increase both width and *camber,* thus increasing lift, which is required during takeoff and landing when air speed is greatly reduced (Figure 4-6). *Trim tabs* are also available to compensate for various wind conditions. Recently, *winglets* (small fins situated at the end of each wing) have been installed on many commercial airliners to improve their stall characteristics (Figure 4-7).

Birds, however, are capable of innumerable fine, as well as coarse, adjustments in their wings (Figure 4-8). For the most part, the fine flight adjustments are achieved by changing the configuration of the feathers along the wingtip, and in this respect, they far outdistance the capabilities of a static winglet.

To give the reader a better understanding of the complexity of a bird's feathers and thus its control surfaces, I have provided a series of photographs of a great horned owl with its wings fully spread. It is important to pay particular attention to the first digit, also termed the *alular digit* or *bastard wing,* which the bird deploys during flight to help counteract stall forces (Figure 4-9).

TAILS AND RUDDERS

Most private, commercial, and military aircraft have only a single *tail fin* and *rudder* (Figure 4-10). However, there are exceptions, including the F-18 "Hornet," with its aggressive V-shaped dual rudders (Figure 4-11), and the A-10 "Warthog," which features a pair of very large outboard fins (Figure 4-12).

Birds lack tail fins (vertical stabilizers) that provide *positive directional stability* on airplanes by increasing

Text continued on p. 53.

Figure 4-1 • A small, twin-engine commuter on final approach, with flaps and landing gear down, exemplifies the modified elliptical wing shape typical of many such aircraft.

Figure 4-2 • The short triangular wings of an F-15 Eagle, as seen from below, are characteristic of a Mach 2.5 air-superiority fighter.

Figure 4-3 • A gull banks slowly left, its elliptical wings extended in a characteristic arch and its tail spread, with the lateral edges turned slightly upward.

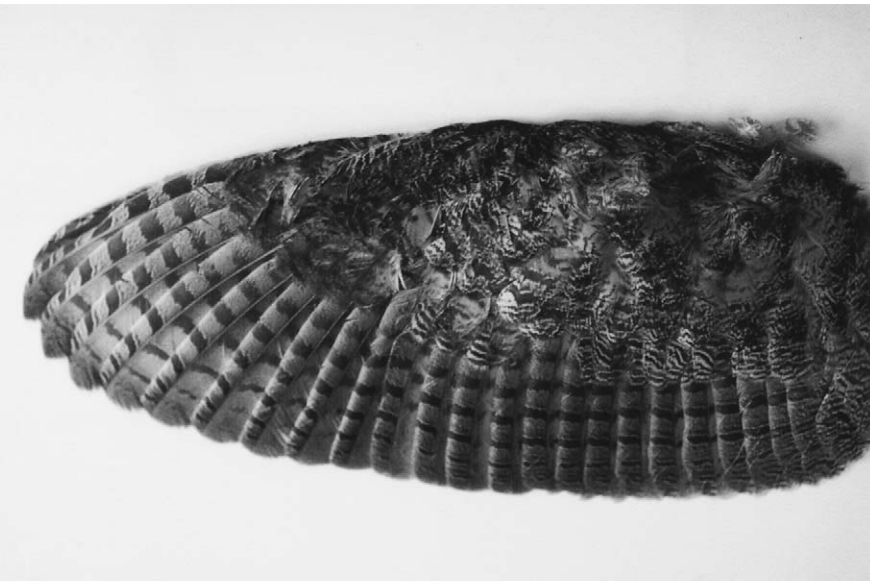

Figure 4-4 • The broad flat flight surface of a hawk's wing, as seen from above.

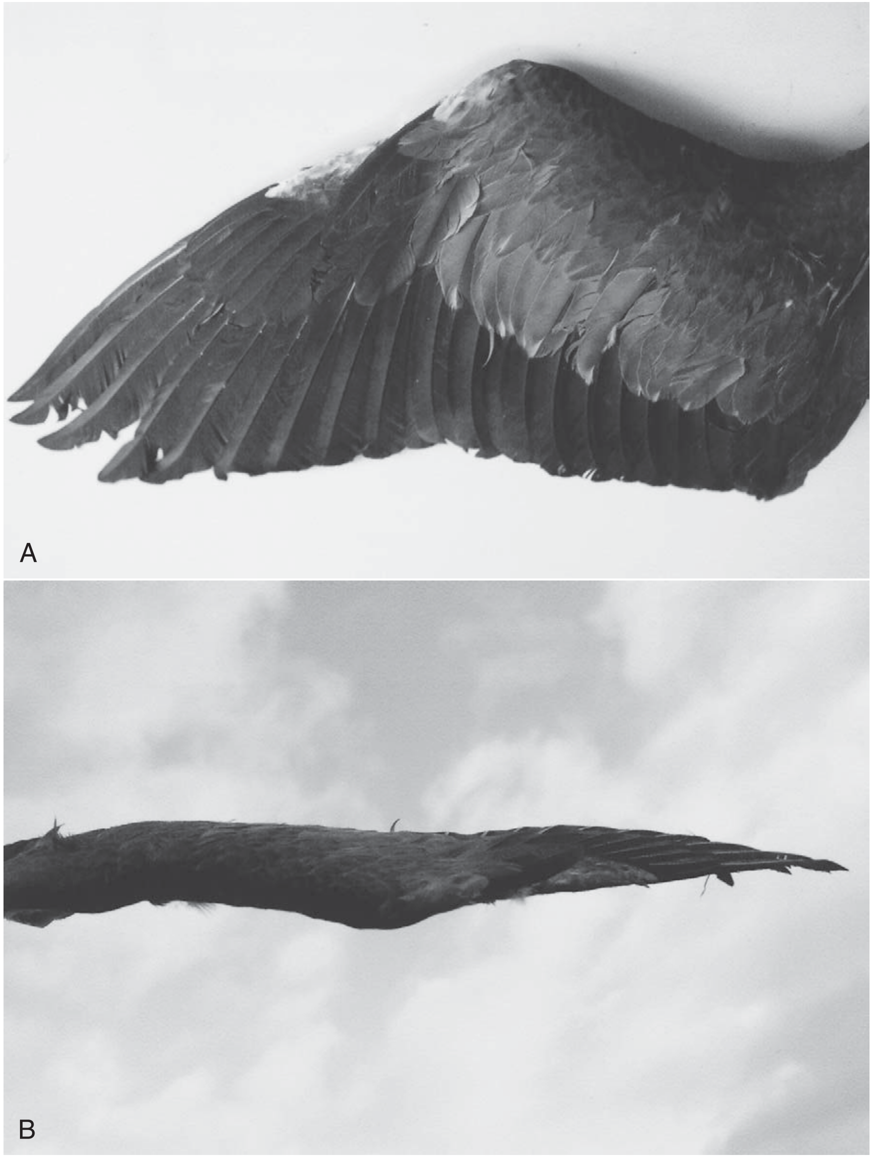

Figure 4-5 • The long broad, somewhat tapered wing of a great blue heron as seen from above **(A)** and from in front **(B).**

Figure 4-6 • A jet airliner on its final approach has deployed both its leading edge slats and trailing edge flaps to increase its lift so that it may reduce its thrust and thus decrease its landing speed.

Figure 4-7 • Most modern jetliners now come equipped with winglets, which are small fins situated at the end of each wing that help the aircraft resist stalling.

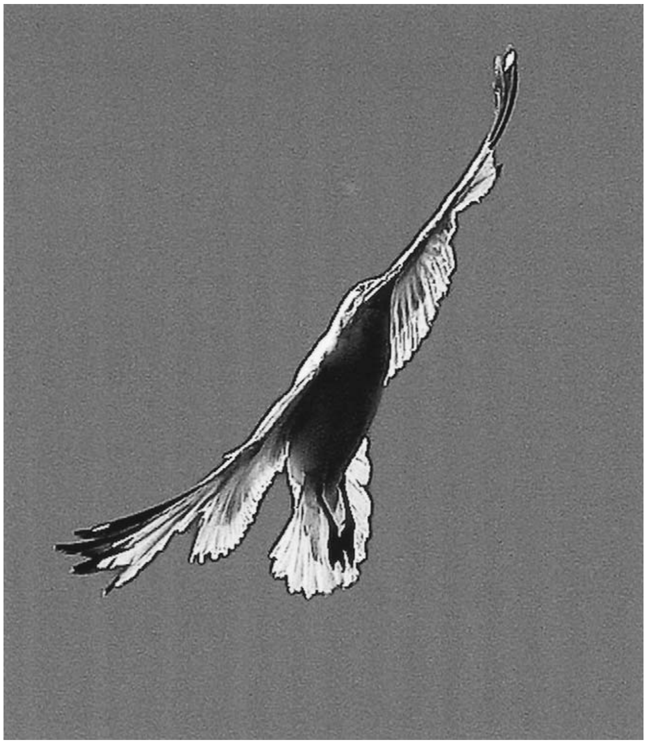

Figure 4-8 • A backlit gull shows off its many different control surfaces as it slowly banks to its right.

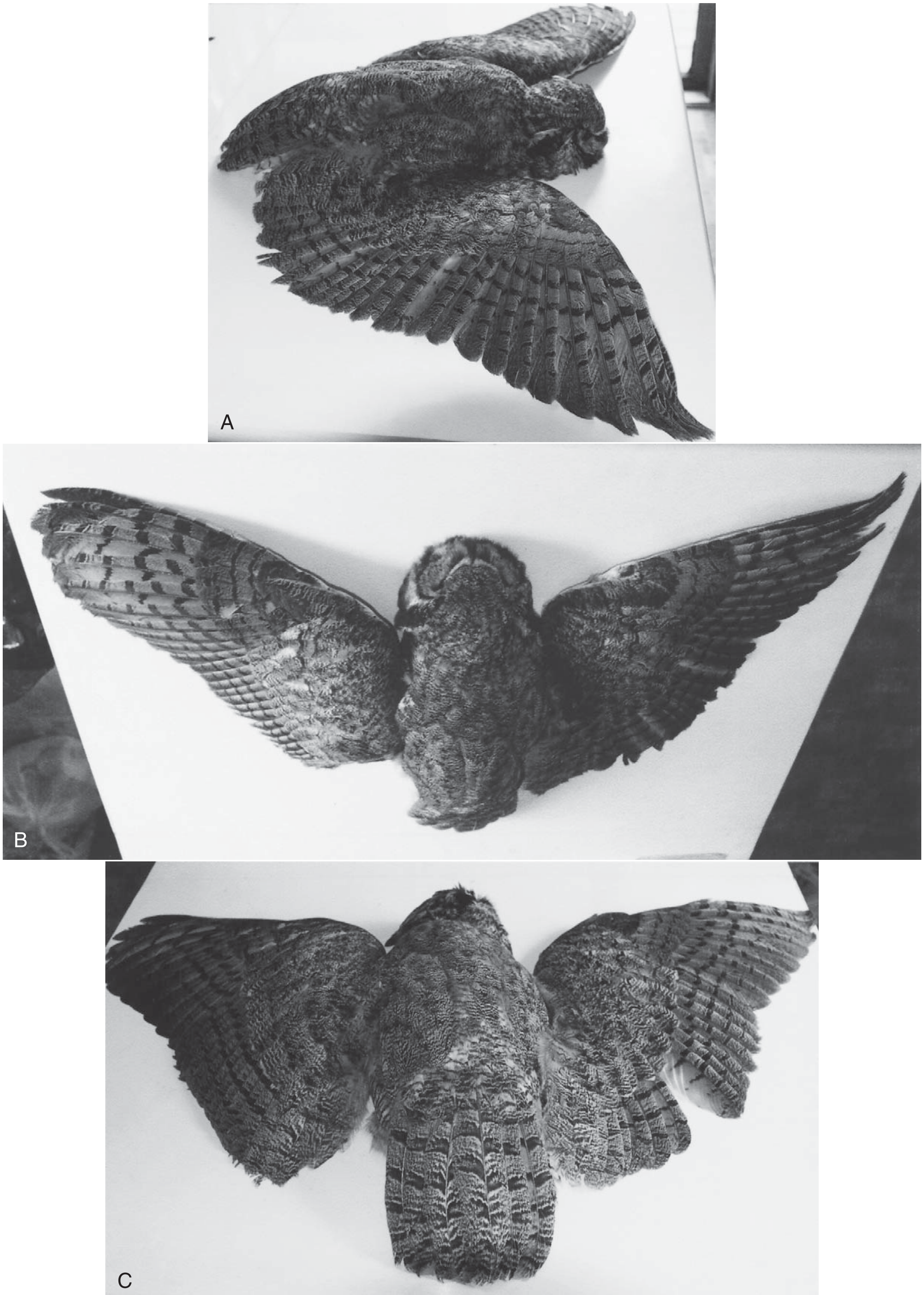

Figure 4-9 • A, A great horned owl, its wings and contour feathers spread, as seen from above side; **(B),** above, wing and tail feathers closed; **(C)** above, wing and tail feathers open; **(D)** above, first digit deployed; **(E)** above, close-up, first digit deployed; **(F)** below, first digit deployed; and **(G)** front. **H,** The owl on its back, its contour feathers extending caudally nearly to its talons. **I,** With its contour feathers spread laterally, exposing its down or insulating feathers.

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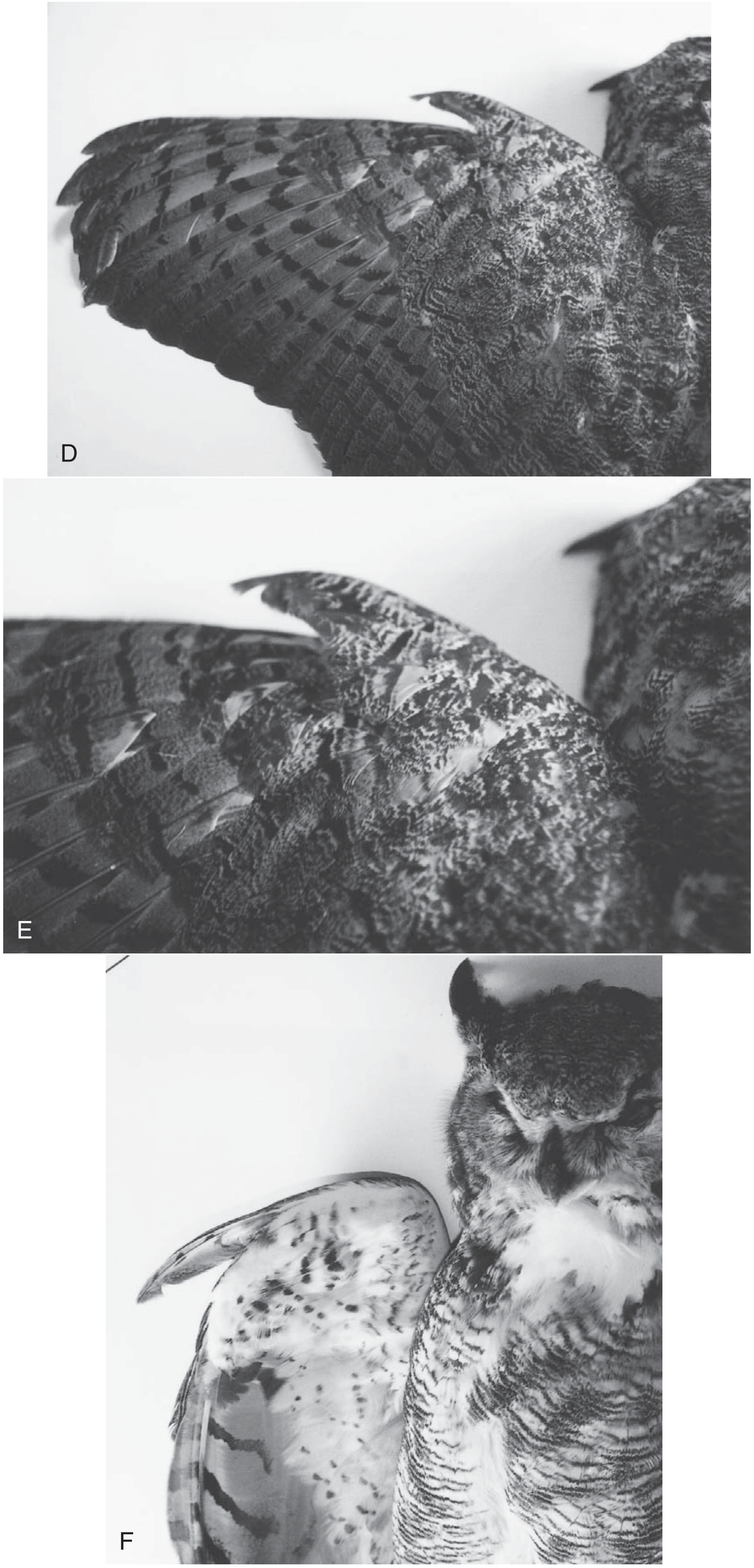

Figure 4-9, cont'd • For legend see p. 49.

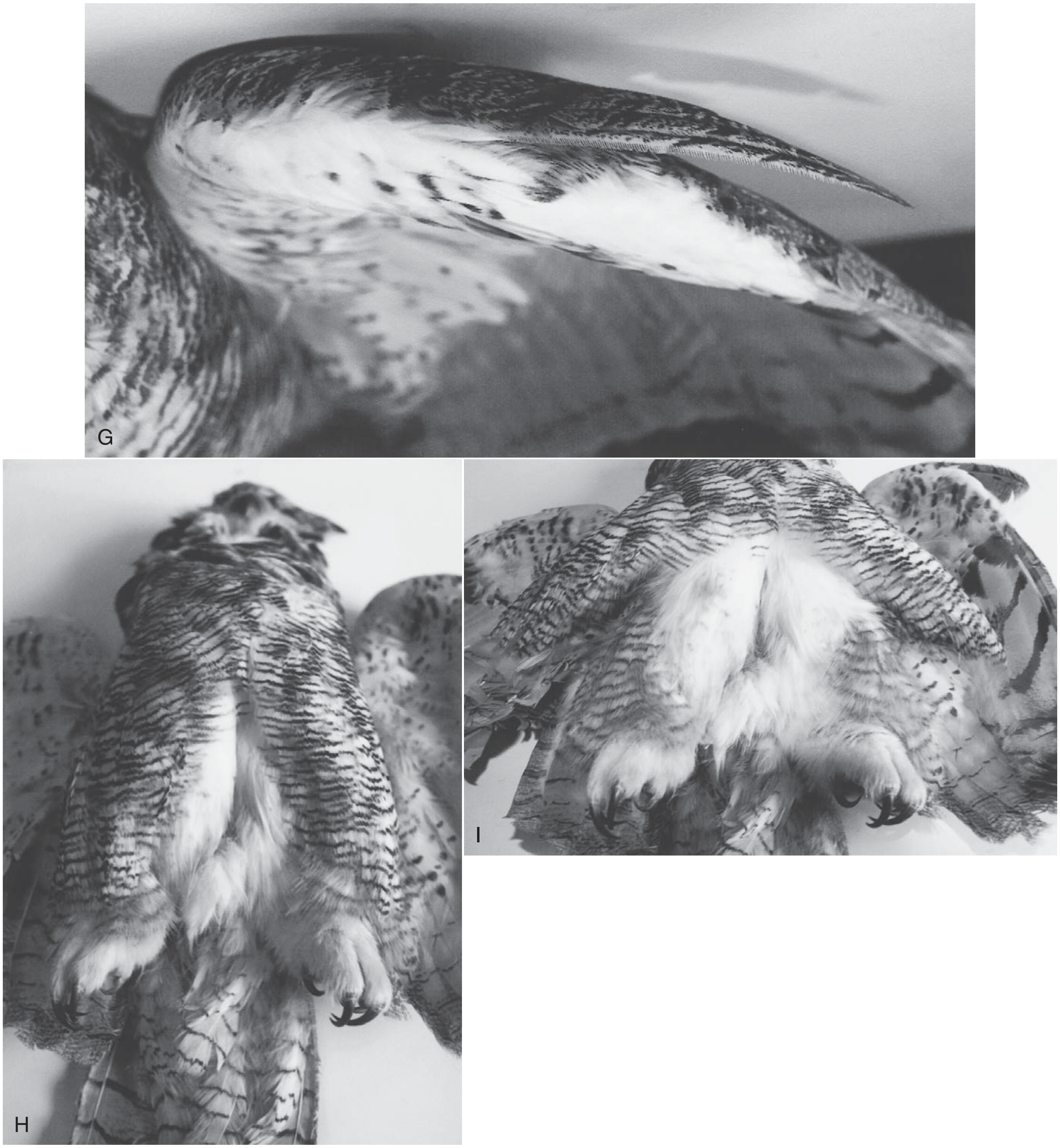

Figure 4-9, cont'd • For legend see p. 49.

Figure 4-10 • Single vertical stabilizer and rudder of a C-135 refueling aircraft.

Figure 4-11 • Dual tail fins characterize the tail of most modern-day supersonic fighters, in this instance an F-18 "Hornet."

Figure 4-12 • An A-10 "Warthog" viewed from behind shows its striking engine nacelles flanked by a pair of large tail fins.

side surface area aft of the plane's center of gravity. However, birds may achieve a similar effect by curling their wingtips (Figure 4-13) and arching their tails horizontally (Figure 4-14).

WING ROTATION, CUPPING, AND TAIL-DROP

With the exception of the V-22 Osprey, which is able to land and take off vertically, airplanes are incapable of independently rotating their wings, something birds do routinely when landing. For example, as water birds are about to set down, they rotate and cup their wings and drop their tails, presenting maximum surface area to the wind, and increasing drag. This results in a controlled stall and soft landing (Figures 4-15 and 4-16).

HOVERING

Wing rotation combined with tail fanning enables terns to hover high above the water, locate their prey, and plummet beneath the surface of the water for the capture (Figure 4-17).

Figure 4-13 • A goose flares, curling its wingtips and extending its neck and feet, just as it is about to touch down.

Figure 4-14 • A goose begins a slow shallow turn before landing. Note that both the wings and tail are arched.

Figure 4-15 • Three geese demonstrate the proper technique for a low-speed water landing.

Figure 4-16 • A pelican hangs in the air moments before touching down on a small bit of sand in the middle of a river while a companion looks on.

Figure 4-17 • A, A tern hovers above the water's surface searching for minnows. Spotting its prey, the tern plummets toward the water's surface **(B),** folding its wings upward at the moment of entry **(C). D,** After a successful attack, the tern flies off to complete its meal in calmer waters.

PROPULSION

Most birds fly with an action that loosely resembles swimming, specifically a hybrid stroke, combining elements of the breast and butterfly strokes. Birds literally pull themselves through the air. They maintain their course by continually adjusting their control surfaces, as described in an earlier section. When birds fly long distances, they alternate between flying and gliding, similar to a cyclist who alternates between peddling and coasting. Drafting is common, with the lead position of the V-formation changing frequently. When possible, birds rest and feed regularly. Figure 4-18 illustrates the elements involved in avian flight.

Figure 4-18 • Wave after wave of Canadian geese pass overhead on their way to a nearby stubble field to feed, rest, and spend the night before continuing their journey south.

Chapter 5

The Wing: Normal Gross Anatomy

TERMINOLOGY: HUMERAL JOINT OR SHOULDER GIRDLE?

It is my studied opinion that the term *shoulder girdle,* as used by some authorities to describe the scapula, coracoid, and clavicle of birds, is misleading because it suggests functional independence from the humerus, which is not the case. It is my view that all four bones that form the humeral joint and its medial support—the clavicle—should be considered a single functional unit (or dysfunctional unit, in the case of injury).

HUMERAL JOINT

The humeral joint (shoulder) of a bird comprises four bones: the humerus, scapula, coracoid, and clavicle. The scapula and coracoid form a common glenoid, which is supported medially by the clavicle. The principal articular element, the humeral head, is compressed laterally, unlike its mammalian counterpart.

Viewed from below with the wing extended (Figure 5-1), the disklike humeral head appears nearly end-on, barely perceptible, and snugged in between the large blocky humeral tubercle and the proximal portions of the coracoid and scapula, which together form the glenoid.

Seen from in front with the wing extended (the leading edge or hanging drop view), the proximal humerus resembles the blade of a shovel topped by its three appendages: the clavicle, coracoid, and scapula (Figure 5-2).

TRIOSSEAL CANAL

The triosseal canal is formed by the confluence of three of the four shoulder bones: the scapula, coracoid, and clavicle. The canal transmits the flight-critical supracoracoideus tendon to its point of attachment on the upper edge of the humeral tubercle (Figure 5-3).

HUMERUS

When extended for flight and viewed from above, the humeral shaft appears gracefully recurved, convex along its upper half, and concave along its lower portion (Figure 5-4). Distally, the humeral metaphysis flares abruptly, forming the humeral condyle, which is composed of lateral and medial halves to accommodate the articular portions of the ulna and radius, respectively (Figure 5-5).

CUBITAL JOINT

The avian cubital joint, or elbow, is conceptually similar to the elbow of a mammal but differs markedly with respect to the relative sizes of the radius and ulna (Figures 5-6 and 5-7), which in a bird are just the opposite of those of a dog, for example. The avian olecranon is also much different than its mammalian counterpart because it is short and broad rather than tall and narrow (Figure 5-8).

RADIUS AND ULNA

The physical relationship between the radial and ulna bodies somewhat resembles that of an unstrung bow, the ulna being gently arched and the radius nearly straight (Figure 5-9). The radius and ulna of most birds are about 15% longer than the humerus. Distally, the radial epiphysis resembles a knob, extending well beyond the adjacent ulna. For its part, the lateral aspect of the ulnar epiphysis looks like a blunted spade affixed to a facet in the inner side of the radius (Figure 5-10).

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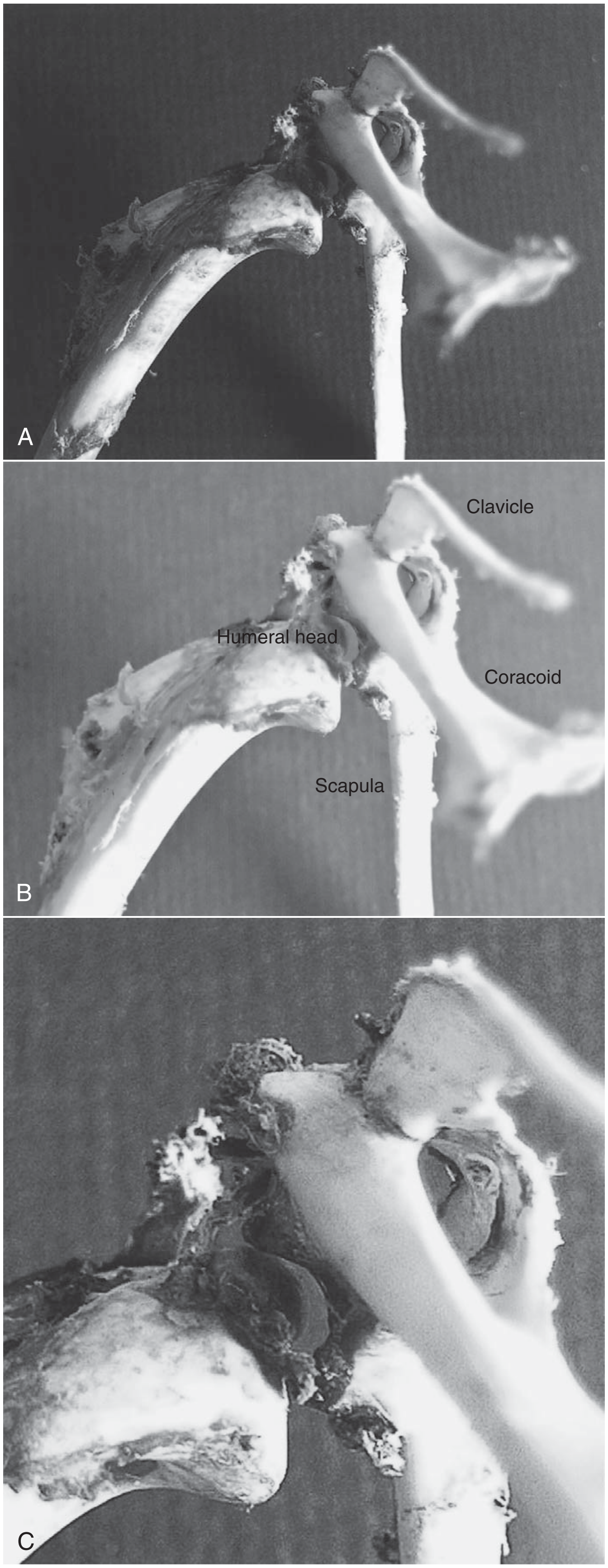

Figure 5-1 • The defleshed shoulder joint of a great horned owl, seen from below with the wing extended. **A,** Unlabeled. **B,** Labeled. **C,** Close-up.

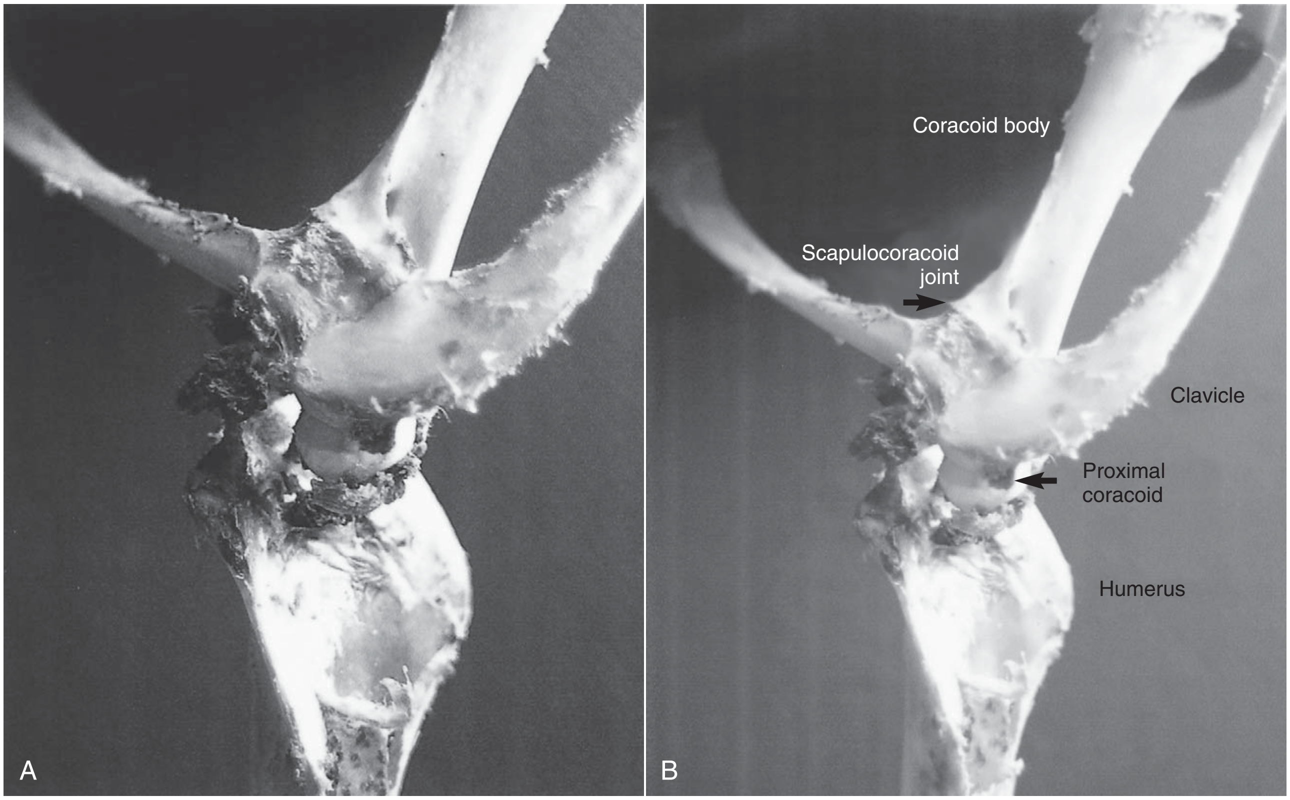

Figure 5-2 • The defleshed shoulder joint of a great horned owl, seen from in front with the wing extended in the leading edge, or hanging drop, view. **A,** Unlabeled. **B,** Labeled.

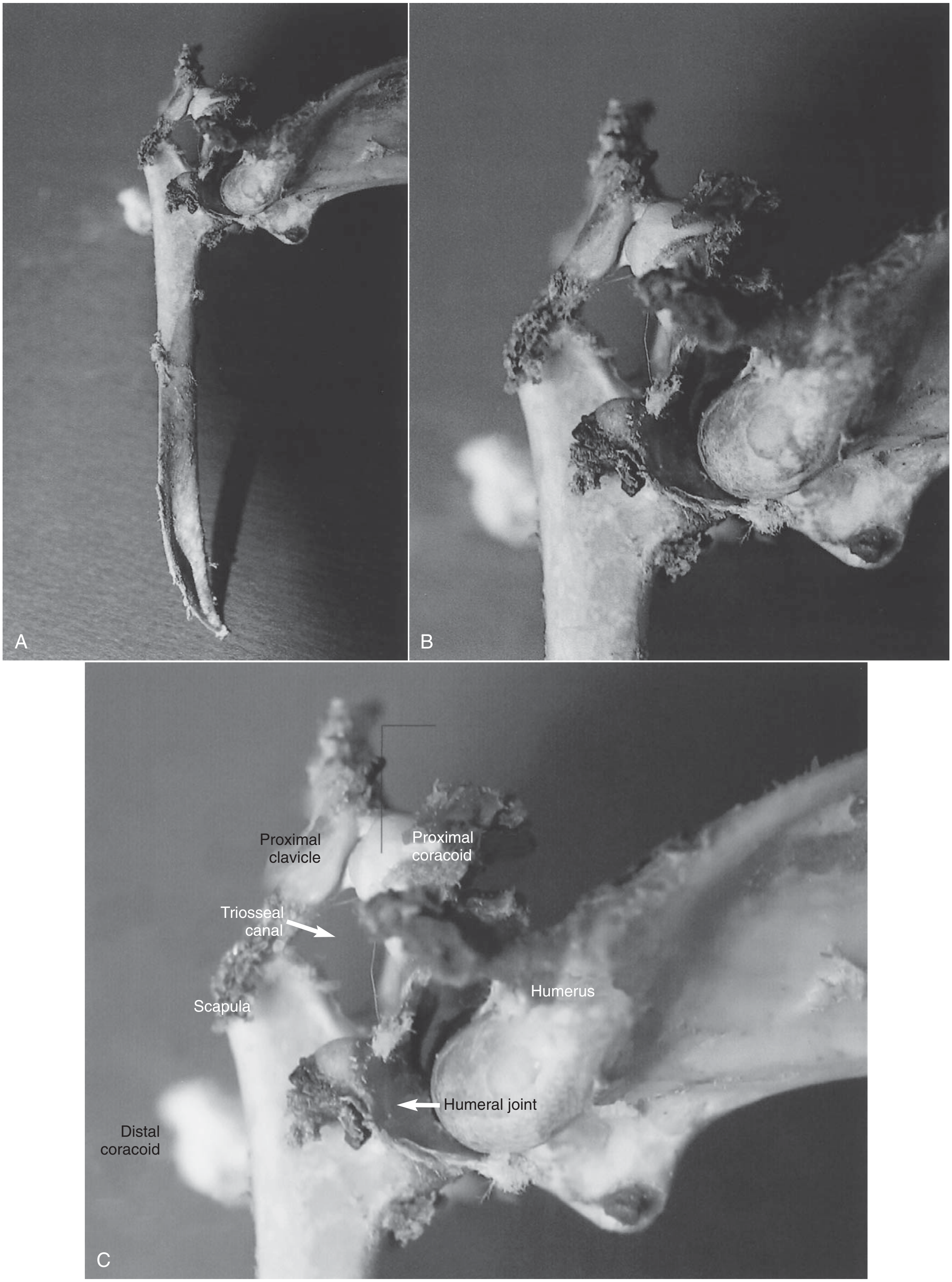

Figure 5-3 • The defleshed shoulder joint of a great horned owl seen from above with the wing extended and showing the triosseal canal and its constituent parts. **A,** Orientation. **B,** Unlabeled close-up. **C,** Labeled close-up.

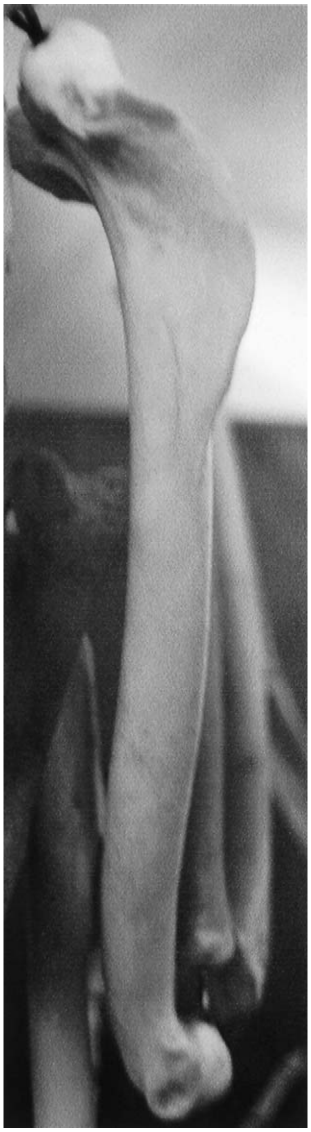

Figure 5-4 • Full-length view of the humerus of a Canadian goose (prepared specimen) as seen from a lateral perspective. Note the large, graceful pectoral crest extending downward from the base of the humeral head.

Figure 5-5 • Close-up view of the distal humerus of a Canadian goose seen from the ventral aspect (prepared specimen). The distal radius and ulna have been reflected, revealing the distinctive differences in the size and shape of the two halves of the distal humeral condyle.

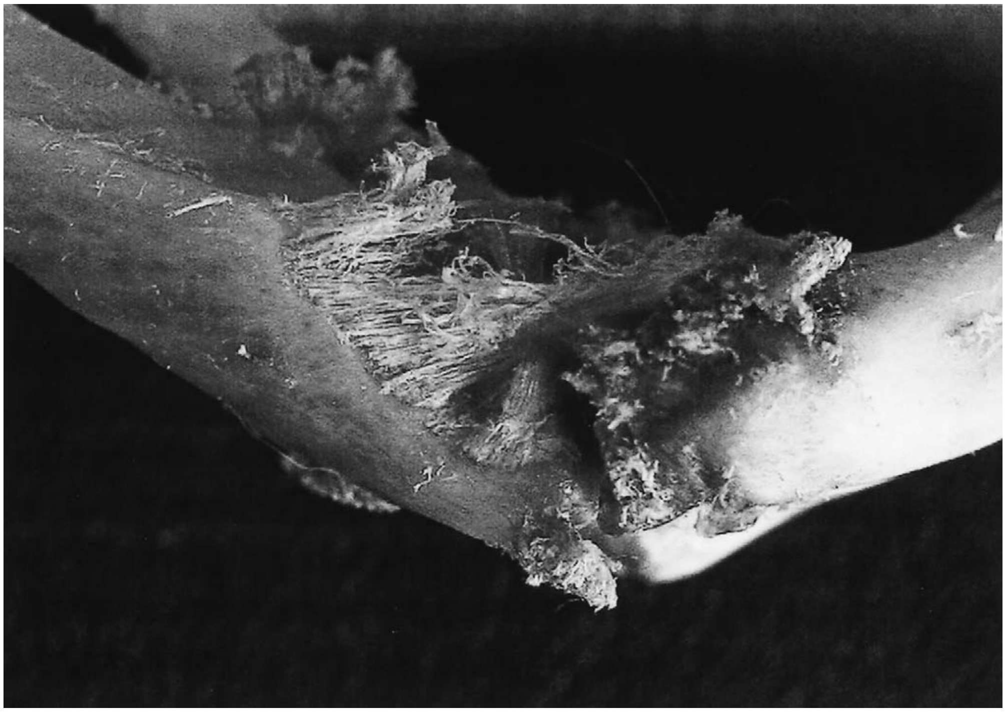

Figure 5-6 • Close-up lateral view of the cubital joint of a great horned owl showing the undersized olecranon typical of most birds.

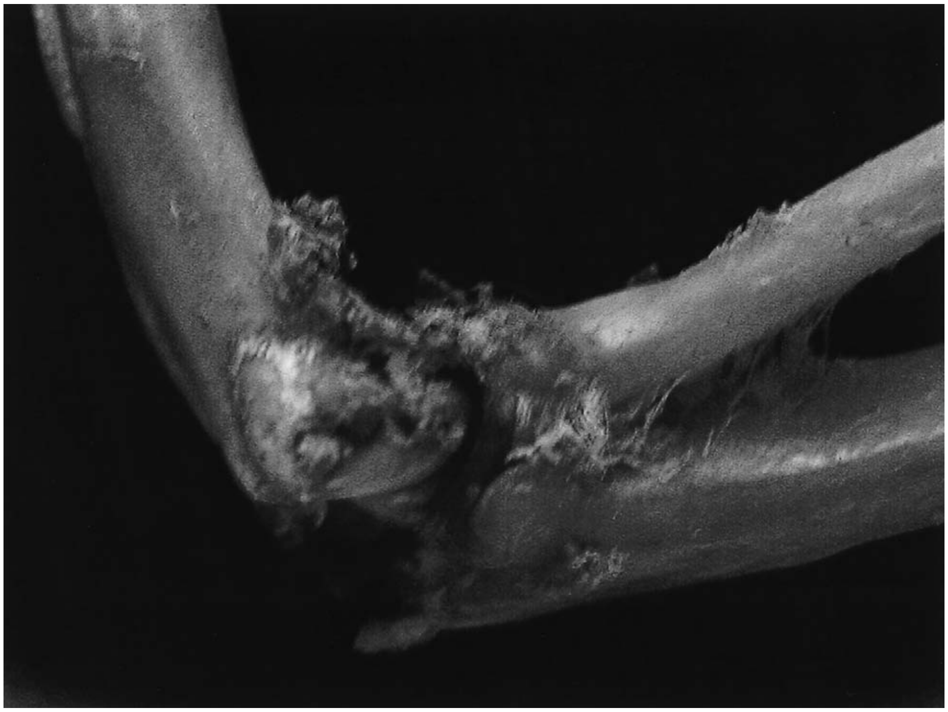

Figure 5-7 • Close-up medial view of the cubital joint of a great horned owl showing the relative difference in the size of the radius compared with that of the ulna.

Figure 5-8 • The defleshed elbow of a great horned owl seen from a flexed, caudolateral perspective shows that (1) the lateral half of the distal humeral condyle is about twice the width of its medial counterpart and (2) the olecranon is little more than a pair of partially fused tubercles forming a shallow ledge.

Figure 5-9 • Lateral view of the radius and ulna in a Canadian goose (prepared specimen). Note that the ulna, *left center,* is approximately twice as thick as the adjacent radius.

Figure 5-10 • Close-up view of the lateral aspect of the distal ulna in a Canadian goose (prepared specimen). Note the distinctive shape of the ulnar epiphysis and its spatial relationship to the adjacent, flexed carpometacarpus.

Figure 5-11 • A great horned owl (recently deceased) with its feathers and most of its flesh removed from the proximal half of the wing, revealing the shoulder, humerus, elbow, radius, and ulna. It then becomes apparent that the interior support for better than 50% of the wing is composed of its smallest bones: the carpus, metacarpus, and digits.

CARPUS, METACARPUS, AND DIGITS

Although their true functional importance often goes unrecognized, the distal skeletal elements of the wing—the carpus, metacarpus, and digits—support and control the largest of the flight feathers, which constitute more than half the total length of the wing (Figure 5-11). The bones of the distal wing are shown in Figure 5-12.

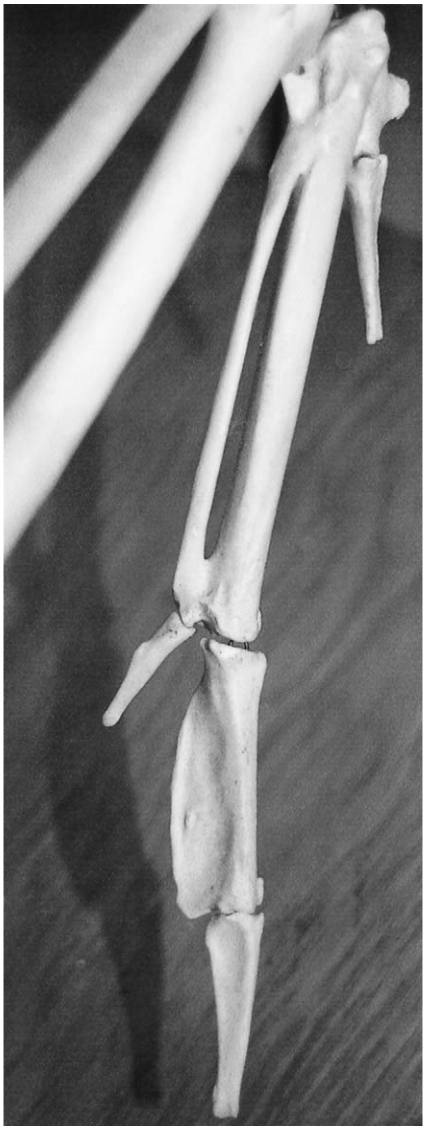

Figure 5-12 • Lateral view of the distal wing bones in a Canadian goose (prepared specimen) from *left to right:* (1) distal radius, (2) distal ulna, (3) minor metacarpal bone, (4) second digit, (5) major metacarpal bone, (6) third digit comprised of proximal and distal phalanges directly below major metacarpal bone, and (7) first digit.

WHY NOT MANUS OR CARPOMETACARPUS?

Again, I wish to briefly discuss anatomical terminology, in this instance that of the terminal wing elements, or as I prefer, the carpus, metacarpus, and digits. Although not universally accepted, the term *manus* has appeared in some recent avian publications. In my view, the term *manus,* meaning hand, is functionally ill suited for all but primates. Carpometacarpus is equally inadequate because it ignores the digits. Consequently, there is no reason to add this ambiguous and often confusing term to the current medical lexicon.

Carpus

There are two carpal bones, a radial and an ulnar. As their names imply, each articulates with the appropriate articular surface of the adjacent radius or ulna. Unlike the typical primate wrist, the carpus of a bird serves as more of a mechanical adaptor than a complex intermediate joint.

Metacarpus

The avian metacarpus is quite distinctive, possessed of major and minor, proximally and distally fused metacarpal bones. The metacarpus is about one third the length of the radius and ulna, thus the size depends on the species.

Digits

Avian digits are equally unique, clearly revealing their adaptation to flight. There are three digits. The first digit is attached to the leading edge of the proximal metacarpus as seen when the wing is deployed in flight and referred to as the *alular,* which serves as a winglet similar to the small rudderlike structures found on the wingtips of some commercial jetliners. The second digit resembles a miniature metacarpus and is attached to the distal aspect of the major metacarpal bone. A second phalanx articulates with the tip of the first, constituting the terminal skeletal element in the wing. A third digit articulates with the distal aspect of the minor metacarpal bone.

Chapter 6

The Wing: Radiography and Normal Radiographic Anatomy

RADIOGRAPHY OF THE WING

Many of the following points on avian radiography were made previously in Chapter 1 but warrant reemphasis because of their importance.

Unlike most forms of radiography, avian radiography often requires less radiation to produce a quality image. The most common faults encountered in wing radiography are excessive darkness and diminished contrast stemming from overpenetration. Great care should be taken to position the bird symmetrically for the ventrodorsal (VD) projection because it provides an excellent comparison view of the opposite (hopefully normal) wing. This opposite view can substantially assist diagnosis of a fracture in a multiple bone joint such as the shoulder.

THE STANDARD EXAMINATION

Ideally, a standard wing examination is comprised of two projections: a VD and a lateral (my preferred term), which is also termed the *leading edge* or *hanging drop* projection. When it comes to articular fractions and subtle dislocations, especially of the humeral or cubital joint, the lateral view frequently proves indispensable.

SUPPLEMENTARY EXAMINATIONS

A supplementary view is usually made to visualize a bone or joint more clearly or from a different perspective. The most common supplementary view used in our practice is made of the shoulder, followed by the elbow. In most instances, these views are oblique projections designed to either reduce or eliminate superimposition or to show a different profile.

RESTRAINT

Gas anesthesia is the ideal way to restrain wild birds during radiography and was used in nearly all of the cases illustrated in this book. Gas anesthesia has the advantages of being easily administered, readily regulated, and quickly eliminated from the system once the examination has been completed.

POSITIONING

We customarily tape the wing of a large bird, such as a bald eagle or great blue heron, to a 14- by 17-inch cassette, flexing or extending it to fully fit on the receiver. In the case of a lateral projection, during which the bird is positioned manually, two or even three films may be necessary because of the need to fully extend the wing, maximizing its length, but making adjustment impossible.

PRECAUTIONS

Some precautions to consider when handling raptors before radiography are to wear protective eyewear and long protective leather gloves that cover as much of the lower arm as possible. For water birds with long beaks, a full-face shield is desirable.

It is best to cover the bird's head with a soft towel while it is conscious, work in dim light, and avoid loud or abrupt noises. All of the necessary equipment should be in place beforehand to reduce examination time and the length of the anesthesia.

▮▮▮ THE SKELETALLY IMMATURE WING

Grossly, the wings of nestlings appear almost vestigial compared with those of adolescent and adult birds (Figure 6-1). Their short, thick, fringelike feathers belie even the remotest possibility of future flight (Figure 6-2).

The skeletally immature wing is characterized by the abbreviated appearance of its long bones, a consequence of its as yet unossified cartilaginous epiphyses, which are nearly transparent to radiation. Accordingly, there are no visible joints per se, merely widely separated, blunted bone ends (Figures 6-3 and 6-4). Failing to recognize this normal radiographic appearance in a nestling can lead to an incorrect diagnosis such as dislocation, infection, or even metabolic or nutritional bone disease.

Shoulder

The immature shoulder or humeral joint is comprised of four bones: the humerus, coracoid, scapula, and clavicle. The clavicle does not actually form a part of the joint but rather acts as a contiguous medial stabilizer. In the spread-wing, VD position, the unossified proximal humerus appears to stand off from the rest of the shoulder bones, which overlap one another medially (Figure 6-5).

Humerus

The immature humerus has a gently recurved body, blunted ends, and ill-defined or invisible epiphyses.

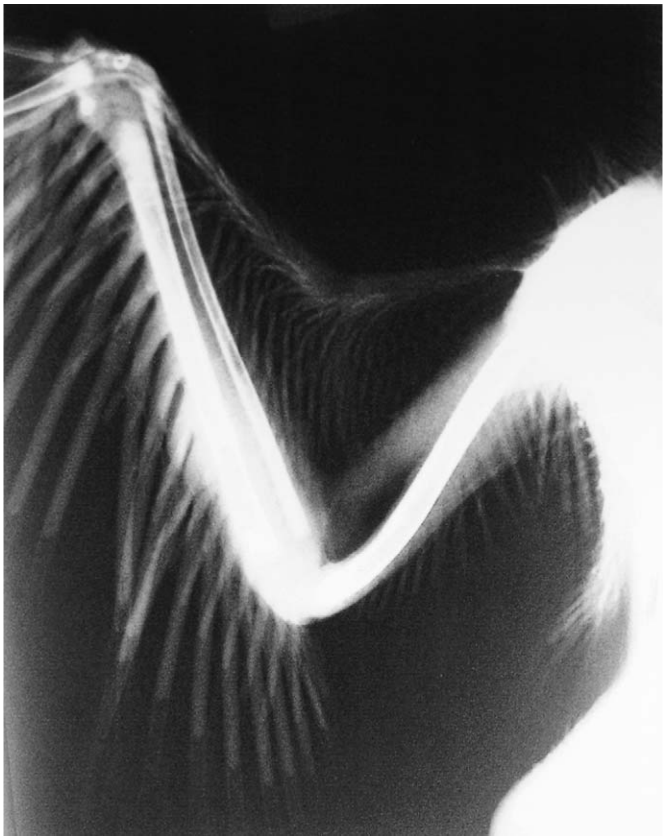

Figure 6-2 • Ventrodorsal view (soft tissue technique) of the uninjured left wing of the nestling owl in Figure 6-1 shows the short, stubby feathers that characterize this stage of development.

Figure 6-1 • The anesthetist extends the small, flipperlike wing of a nestling owl, which fell from its nest while being banded, breaking its right ulna.

Figure 6-3 • Ventrodorsal view of the outspread wings of a nestling owl in Figures 6-1 and 6-2 that shows large lucent gaps in all of the visible joints, reflecting the transparent nature of the unossified epiphyses. The proximal body of the right ulna is fractured as indicated by a dense *overlap band* and slight cortical misalignment *(left)*.

Figure 6-4 • Close-up, ventrodorsal view of the left wing shows an absence of epiphyseal ossification and accordingly, large gaps between the bone ends (emphasis zones) that are characteristic of skeletal immaturity in birds.

Figure 6-5 • Shoulder joints of a nestling snowy owl appear deficient because of the cartilaginous composition of its proximal humeri, which are currently invisible on radiograph. Also note the characteristic diamond shape of the immature cervical vertebrae.

Thus there are no articular surfaces, only large gaps between partially ossified bones filled with vague gray shadows.

Elbow

The elbow, or cubital, joint is comprised of three blunted, widely separated bones: the humerus, radius, and ulna. Because the associated epiphyses have yet to ossify, there are no visible joints, only hazy gaps (Figure 6-6, *A*). As the epiphyses ossify, the bone ends become rounder and the intra-articular gaps become smaller (Figure 6-6, *B*).

Radius and Ulna

The radius and ulna curve gently distally but like the rest of the immature long bones, fall short of establishing a visible articulation with the carpometacarpus because of incomplete ossification.

Radiocarpal Joint

Like other immature wing joints, the radiocarpal joint appears quite abnormal compared with its adult counterpart because the *apparent* joint space is greatly widened and the bone ends are faint, almost cloudlike, and appear incomplete, as if undergoing destruction (Figure 6-7).

THE SKELETALLY MATURE WING

Unlike the immature wing, the skeletally mature wing possesses fully ossified bone ends, and consequently the entire bone is clearly visible, including the intervening joints (Figures 6-8 and 6-9).

Shoulder

The oblong, laterally compressed humeral head is set into a shallow socket formed by the scapula caudally and coracoid cranially; the latter is overlain by a common articular cartilage.

The standard shoulder examination consists of a VD view (Figure 6-10), which can be supplemented by right and left VD oblique projections, especially in cases of complex injury. A lateral view of the shoulder (Figure 6-11) can prove indispensable when trying to confirm or deny injury to the scapulohumeral joint, or to "uncover" superimposed fracture fragments seen in the VD projection.

Perhaps the clearest view of the humeral joint is the frontal projection, also termed the *leading edge* or

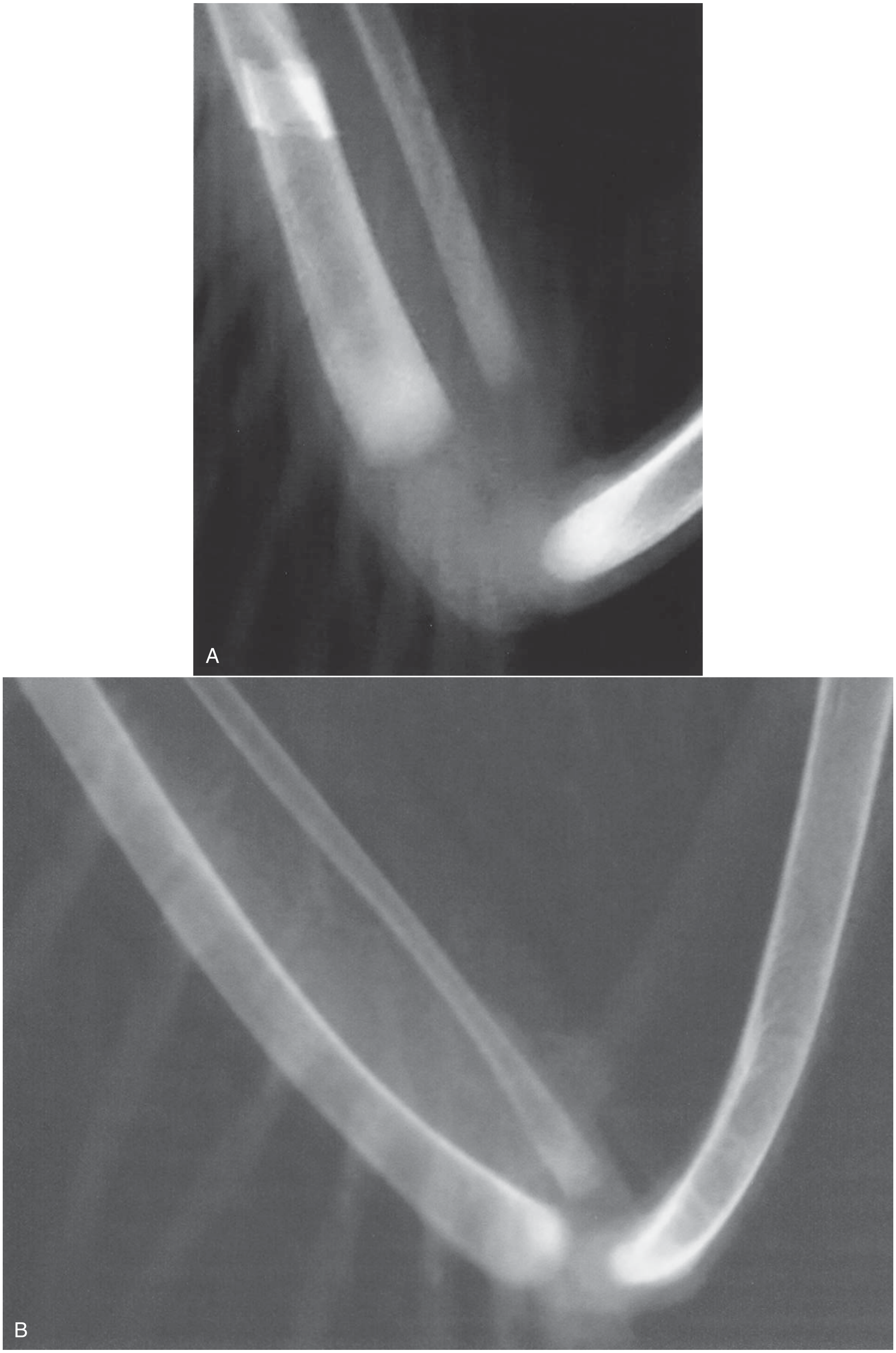

Figure 6-6 • A, Ultraclose view of the normal right cubital joint in a nestling owl faintly shows the circular cartilaginous epiphyses of the proximal ulna and distal humerus. **B,** As the epiphyses slowly ossify, they become more apparent, but the illusion of a widened joint persists.

Figure 6-7 • Ultraclose view of the normal right radiocarpal joint faintly shows incomplete ossification of the distal radius and ulna resembling septic arthritis in an adult bird but normal in a nestling.

Figure 6-8 • Ventrodorsal, spread-wing view of a normal adult sharp-shinned hawk shows fully ossified epiphyses and narrow cartilage spaces.

Figure 6-9 • Lateral, wings-up view of a normal adult sharp-shinned hawk shows fully ossified epiphyses and narrow cartilage spaces made indistinct (compared to the ventrodorsal projection) by superimposition.

Figure 6-10 • Close-up, ventrodorsal view of the shoulders of a healthy golden eagle shows the morphological details of the normal humeral joint.

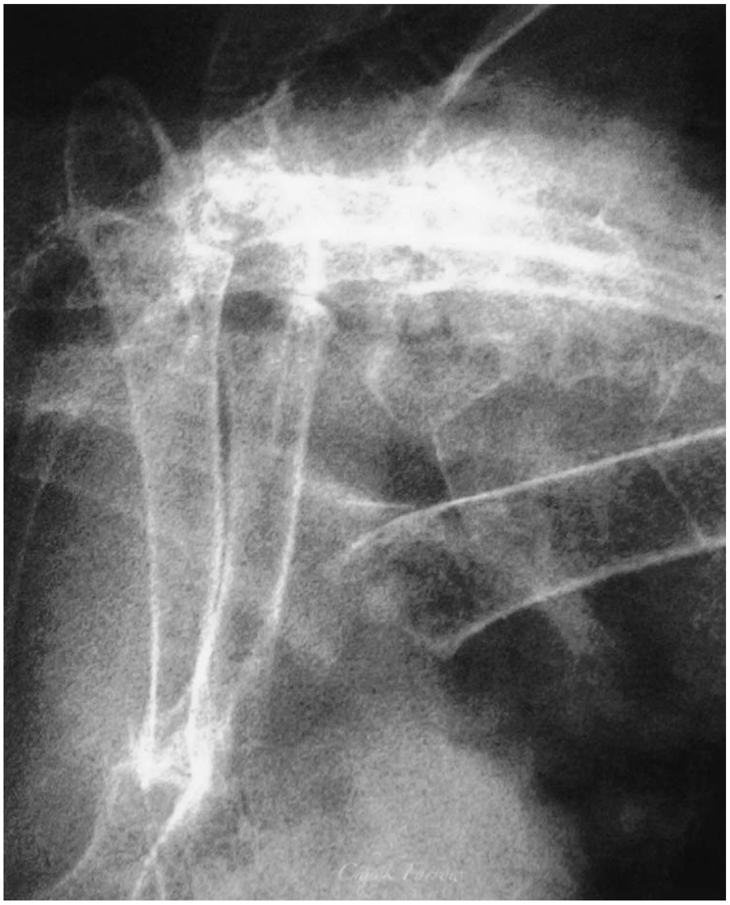

Figure 6-11 • Close-up, lateral view (wings-up) of a hawk with a shattered shoulder joint including a severely displaced proximal humeral fracture that wasn't visible in the ventrodorsal view because of superimposition.

hanging drop view, where the scapula, coracoid, and humerus can all be seen clearly with only minimal overlapping (Figure 6-12).

Humerus

The adult humerus, while clearly the stoutest and strongest of the avian wing bones, is not the longest; the adjacent radius and ulna are the longest avian wing bones (Figure 6-13). The proximal humerus is a distinctive bone that resembles the profile of an opening lily, which is the result in great part of the graceful arch of the humeral crest. The humeral shaft curves gently downward and then abruptly broadens into a wide condyle featuring a disproportionately large lateral element that articulates with the ulna and a comparatively small medial element that articulates with the radius.

Elbow

Just as with mammals, the avian elbow is capable of providing a variety of different looks when viewed ventrodorsally. These projectional differences are caused by rotation of the shoulder, which in turn leads to rotation of the elbow, thus accounting for a variety of possible oblique views. As the bird is being positioned for the VD view, one or both wings may be rolled unintentionally, causing the distal humeral metaphysis and associated condyle to appear abnormally wide when compared to a true lateral projection.

Perhaps the best indication of elbow obliquity is the defining of the lateral and medial halves of the distal humeral condyle, which are not normally appreciable in a true lateral projection because of superimposition. When oriented obliquely, the lateral half of the humeral condyle can appear even larger than it actually is when compared with its medially situated counterpart. But projectional illusion aside, the deliberate oblique position of the elbow typically provides the clearest view of the humeroulnar and humeroradial joints, a distinct diagnostic advantage when articular injury is suspected (Figure 6-14).

Radius and Ulna

There are two common projectional variants of the radius and ulna as seen in VD projections, both of which are related to obliquity at the shoulder. In one variation, both the radial and ulnar bodies appear bowed, while their distal counterparts appear relatively straight (Figure 6-15). In the second, featuring

Figure 6-12 • A, Orientation and close-up, leading edge **(B)** views of the wing of a healthy hawk. The latter shows the three articular components of the normal avian humeral joint: the scapula *(top right)*, coracoid *(bottom right)*, and humerus *(center)*.

Figure 6-13 • Ventrodorsal projection of the partially folded wings of a great blue heron shows the relative difference in length between the humerus and radius/ulna. Note the heron's long, narrow wing bones and laterally compressed torso compared to a raptor.

Figure 6-14 • Close-up, ventrodorsal view of the cubital joint of a Boreal owl. Unintended rotation of the humeral joint has resulted in some secondary obliquity of the elbow—a technique that can be used to deliberately separate the humeroulnar and humeroradial joints from one another to improve their visibility.

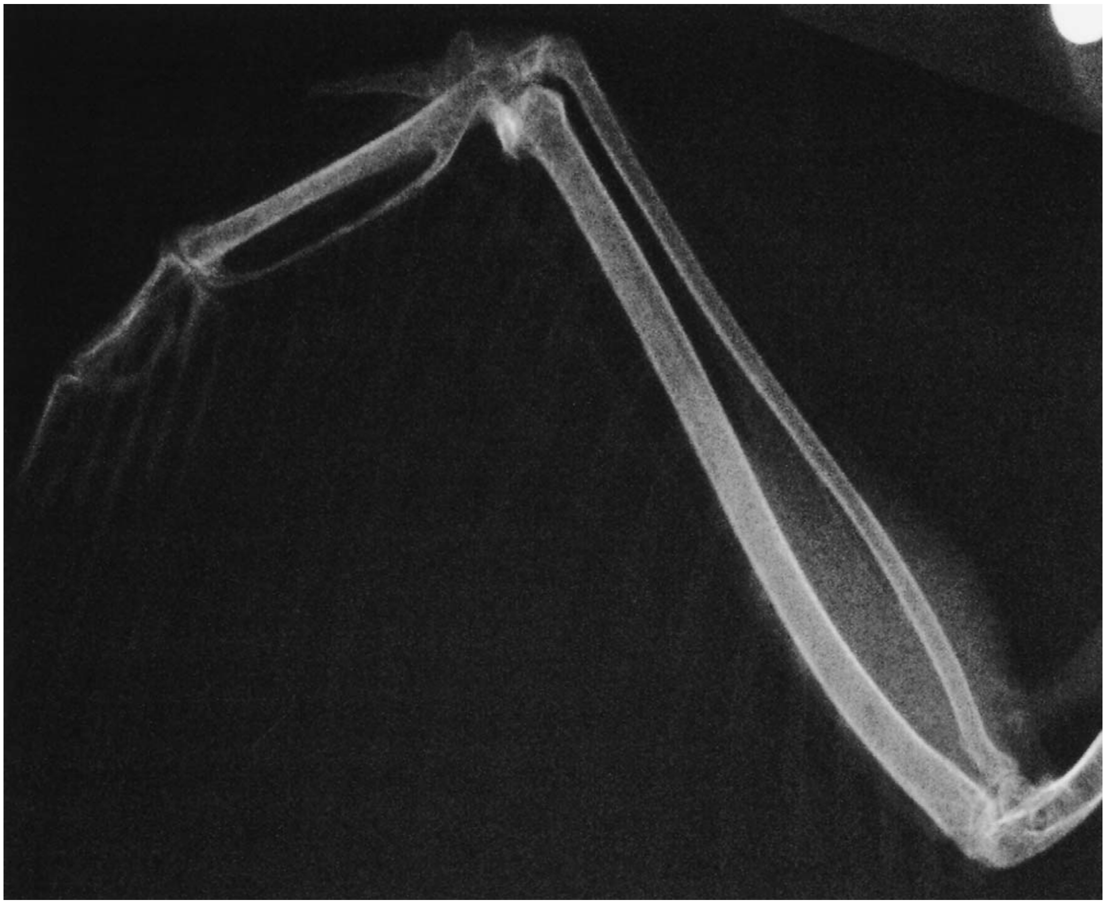

Figure 6-15 • Projectional variation. In this ventrodorsal projection of a hawk's wing, the proximal half of the radial and ulnar bodies appears bowed, while the distal diaphyses of both bones seem straight.

increased obliquity, the radius appears relatively straight, while the adjacent ulna looks bowed (Figure 6-16).

Radiocarpal and Ulnar Carpal Joints

The avian radiocarpal and ulnar carpal joints are simplified when compared with those of mammals. Two carpal bones, the radial and ulnar, directly connect the distal radius and ulna to the fused major and minor metacarpal bones and form a pair of hinge joints with little or no rotary capacity.

Carpus and Metacarpus (Carpometacarpus)

The carpometacarpus, which is the far side of the radiocarpal and ulnar carpal joints, comprises the radial and ulnar carpal bones proximally and the streamlined metacarpus distally. An abbreviated vestigial first digit protrudes from the leading edge of the large irregular tubercle located on the head of the major metacarpal bone (Figure 6-17).

Digits

A single digit (the second), formed by a pair of phalanges (first and second), emanates from the distal aspect of the metacarpus and forms the tip of the skeletal portion of the wing (Figure 6-18). Interestingly, the terminal second digit barely reaches the midway mark of the wing when the feathers are included. Another rudimentary digit, the third, originates from the trailing edge of the distal aspect of the minor metacarpal bone.

▮▮▮ NORMAL ANATOMICAL VARIATION

The skeletal anatomy of birds differs in both predictable and unpredictable ways. For example: the wing

Figure 6-16 • Projectional variation. Another ventrodorsal projection, with increased obliquity, makes the radius appear nearly straight and the ulna uniformly bowed.

Figure 6-17 • Lateral projection of the carpus and metacarpus (carpometacarpus) of an eagle shows (1) the distal radius and ulna on the right edge, (2) the superimposed radial and ulnar carpal bones in the upper right corner, (3) the greater and lesser metacarpal bones situated diagonally across the image, (4) the stubby first digit protruding from the proximal metacarpal tubercle at the top right center, and (5) the second and third digits in the lower left corner.

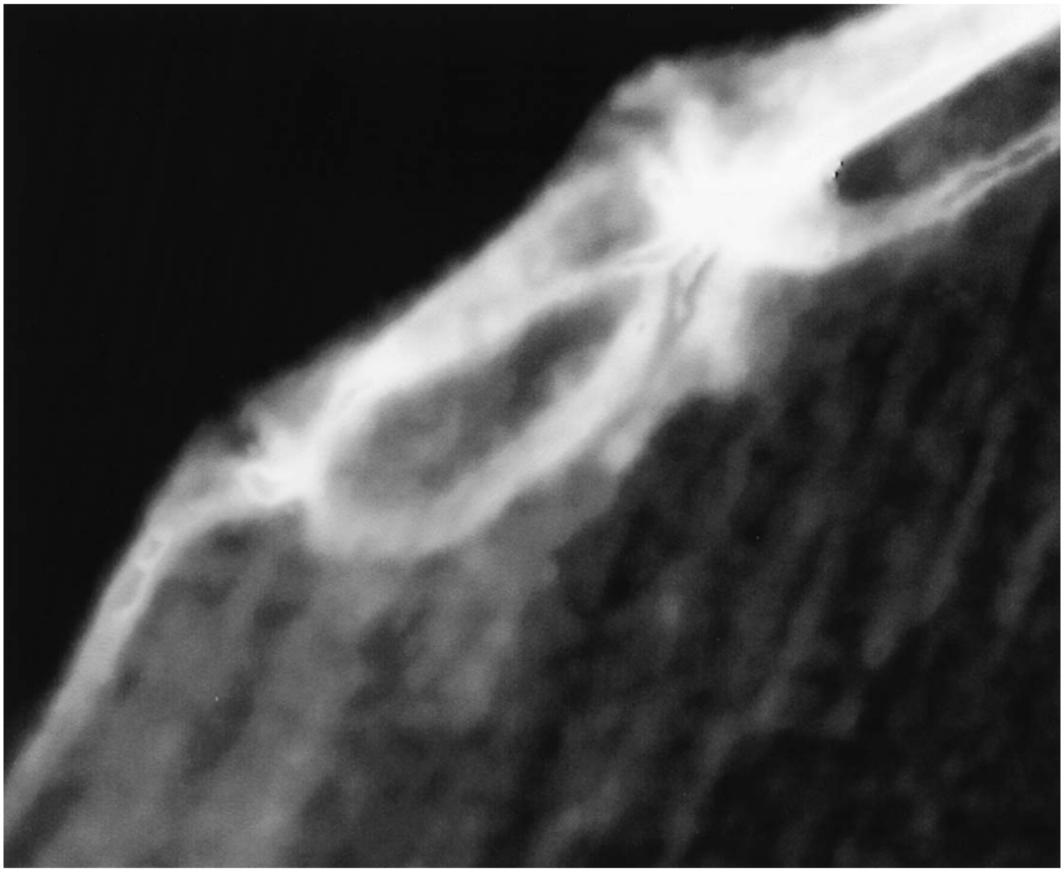

Figure 6-18 • Close-up, lateral view of the distal metacarpus and second and third digits of a hawk.

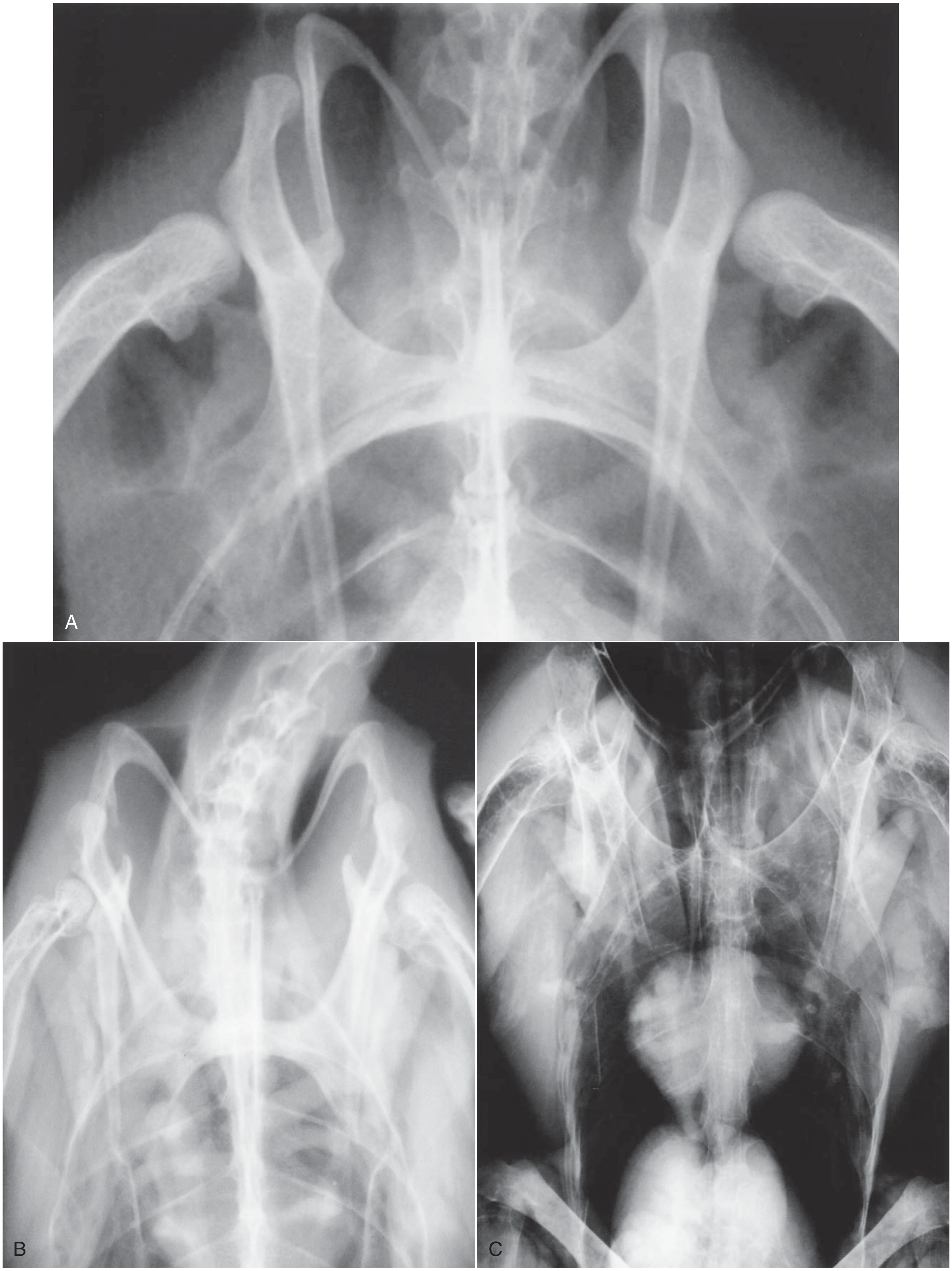

Figure 6-19 • Ventrodorsal views of the shoulder regions of three water birds—loon **(A),** cormorant **(B),** and pelican **(C)**—showing sometimes large and sometimes small differences in skeletal anatomy. In particular, note how the clavicles of the cormorant and loon arch far forward compared with that of the pelican.

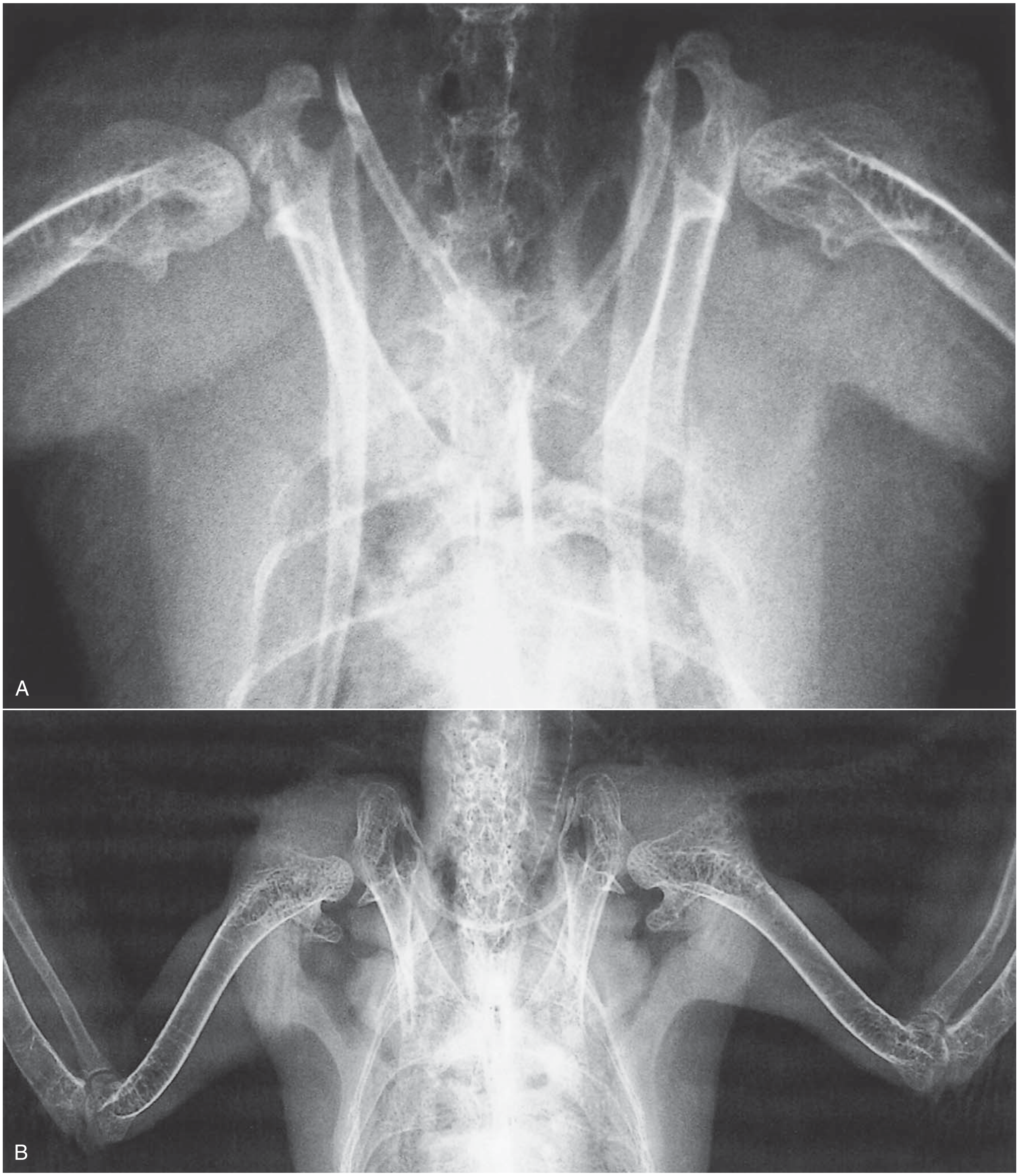

Figure 6-20 • Ventrodorsal views of the shoulder regions of a partridge **(A)** and an African Gray parrot **(B)** showing anatomical differences in the appearance of the shoulder joints.

bones of a great blue heron are proportionately longer than those of a hawk. This is a perfectly predictable difference provided one has observed both birds (see previous section). But who might predict the considerable anatomical differences that exist between the shoulders of water birds and raptors (Figure 6-19) or between parrots and partridges (Figure 6-20)? I dare say quite few.

Chapter 7

The Wing: Normal Computed Tomographic Anatomy

CONVENTIONAL CROSS-SECTIONAL COMPUTED TOMOGRAPHIC IMAGING

For most purposes, conventional biplanar radiography is quite suitable for routine avian imaging. However, there are instances where extensive hard or soft tissue overlap makes conclusive diagnosis difficult or impossible. Under such circumstances, cross-sectional imaging in the form of computed tomography (CT) or magnetic resonance imaging (MRI) warrants consideration. Using these imaging forms, it is possible to obtain very thin tissue slices, which by virtue of their diminutive slice thickness (2 mm or less, for example) largely or completely eliminate superimposition (Figures 7-1 to 7-3).

Using CT, it is also possible to obtain x-ray transmission values (Hounsfield units) that are characteristic of both normal and diseased tissues. These data can then be used to further refine or deny a particular diagnosis, as the case may be.

CT has been found to be most useful in the assessment of complex shoulder injuries in raptors, as well as in the assessment of some types of invasive abdominal tumors. I have yet to have the opportunity to perform magnetography on one of our injured birds, largely because of the high anesthesia risk related to the prolonged examination time required when using a **low field strength magnet.**

RECONSTRUCTED THREE-DIMENSIONAL COMPUTED TOMOGRAPHIC IMAGING

Three-dimensional reconstruction (*3-D recon*) created from multiple consecutive cross-sectional tissue slices realizes the full diagnostic potential of CT, particularly when combined with the ability to manipulate such images in three-dimensional space. These anatomical models may be created with either the dedicated software that accompanies most modern CT imagers or can be carried out with standardized digital communications (DICOM) software. The three-dimensionally reconstructed images of an owl's shoulder are provided as examples in Figures 7-4 and 7-5.

Figure 7-1 • An anesthetized great horned owl about to undergo CT is seen through the bore of the gantry.

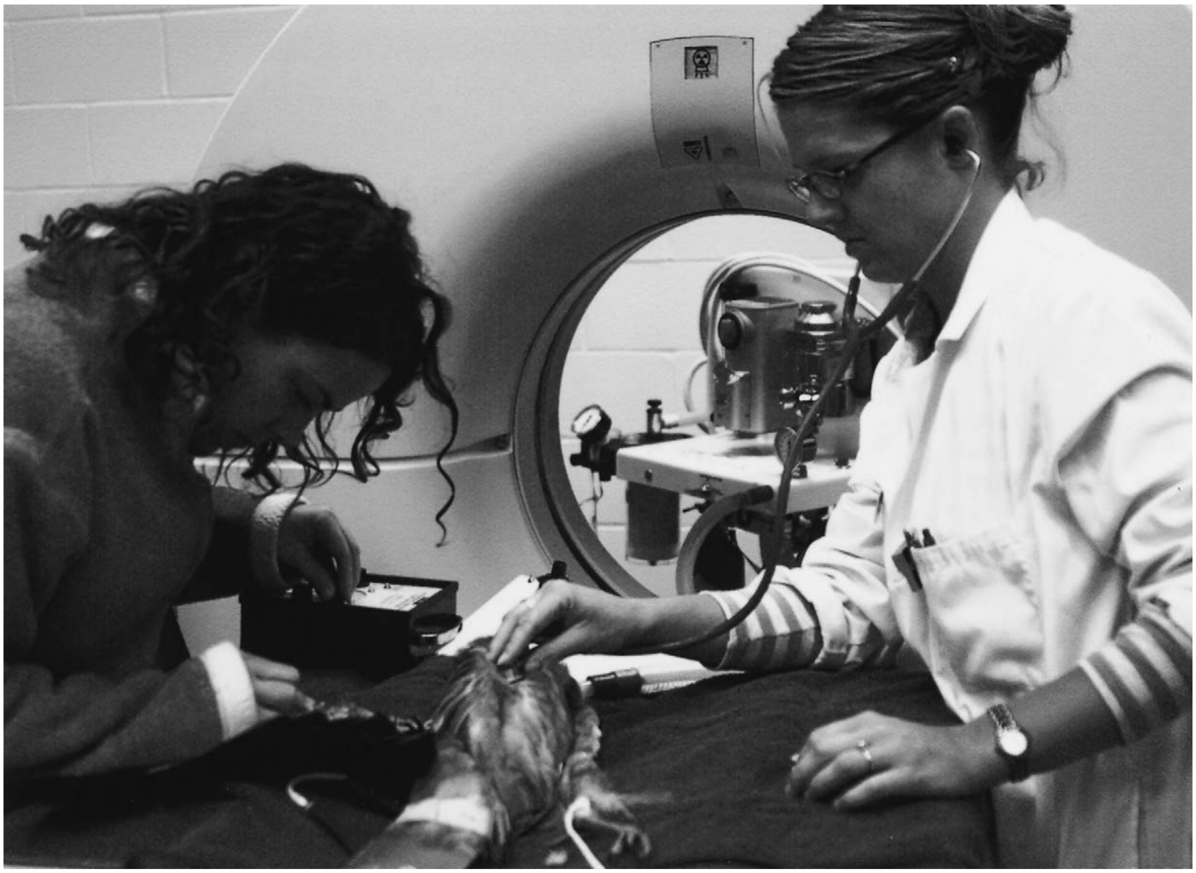

Figure 7-2 • A Harrier hawk being auscultated just before beginning a CT scan.

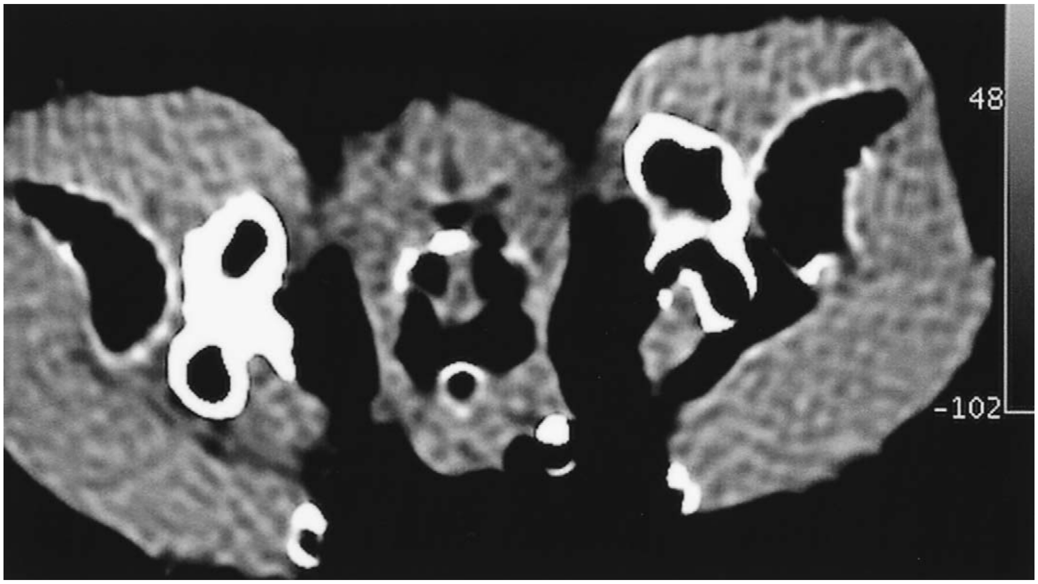

Figure 7-3 • Axial computed tomogram: single 2-mm slice taken through the shoulder region of a great horned owl.

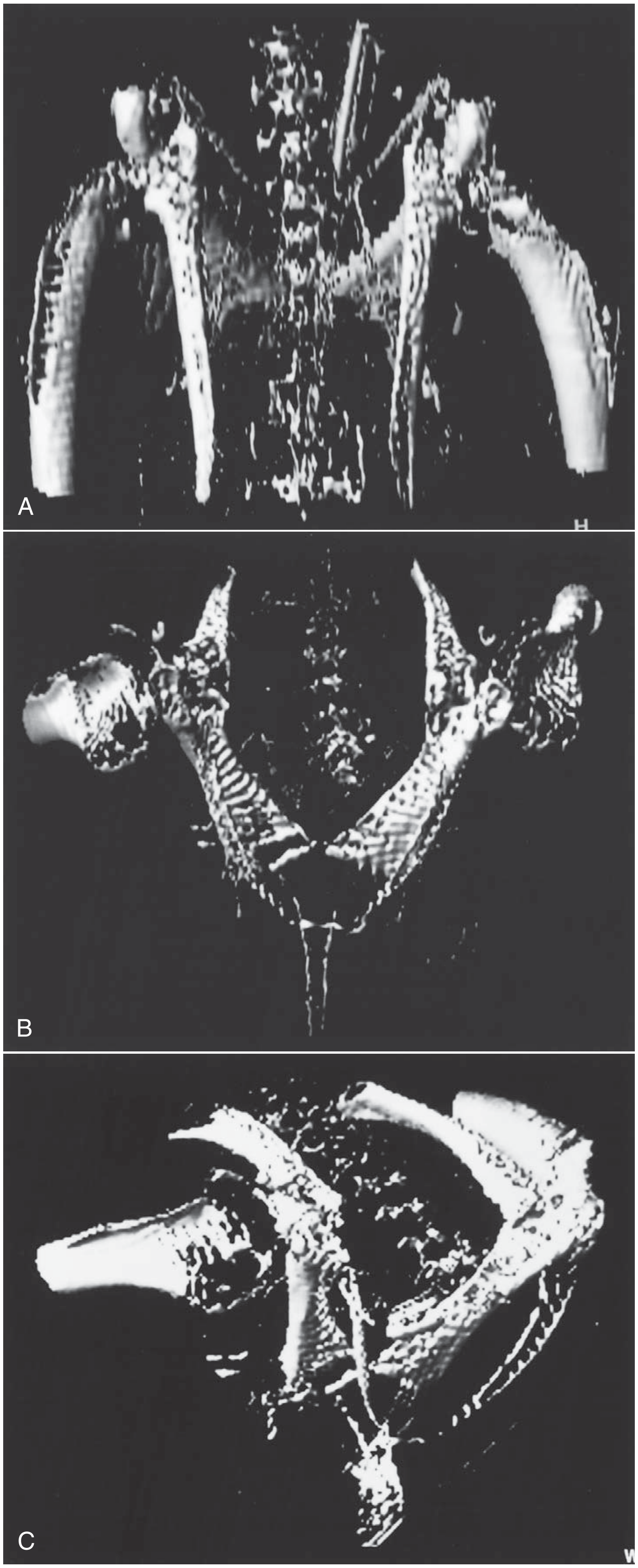

Figure 7-4 • 3-D reconstruction (surface rendering) of the shoulder region of a great horned owl as seen from dorsal **(A),** cranial **(B),** and lateral oblique **(C)** perspectives.

Figure 7-5 • 3-D reconstruction (volume rendering) of the shoulder region of a great horned owl as seen from the ventrodorsal perspective.

Chapter 8

The Wing: An Overview of Wing Injuries

FLIGHT FIRST

The first consideration when treating an injured wing is whether it can be made to fly again. If a damaged wing cannot be repaired, the bird is not fit to be released, although there may be a place for such disabled individuals in a game park or zoo. It must also be remembered that even minor hard or soft tissue wing injuries can adversely affect one or more control surfaces. Although not crippling, such injuries do require fine adjustments of the control surfaces on the opposite wing and sometimes of the tail as well. These adjustments require practice to perfect. Thus final release should be delayed until there has been an opportunity for a number of short, low-level test flights.

BONE, JOINT, AND LIGAMENT INJURY

Modern-day passenger aircraft configure their wings, or more specifically their control surfaces, to suit existing flight conditions such as takeoff, climbing, turning, descending, and landing. Some fighter aircraft can sweep their wings backward to reduce drag during supersonic flight and then spread them to land. Birds, too, can modify their wing configurations but to a much greater extent. Hawks, for example, can ride vertical air currents, called *thermals*, for minutes without ever flapping their wings. Taking flight control one step further, hummingbirds and terns are capable of hovering, either to feed in the former instance or to observe potential prey in the latter.

The source of this sophisticated flight lies in a bird's ability to use one or the other of its wings as control surfaces not just their trailing edges. Witness the controlled stall employed by a cormorant or Canadian goose moments before touchdown; this is achieved by the combined upward rotation and forward cupping of the wings, causing them to behave like air brakes.

Capsular tissues join the bone ends that form the joint cavity, and the interior synovial lining provides the specialized fluid that lubricates and nourishes the articular cartilage. Ligaments provide additional support but more importantly set the limits to joint motion. Thus it is highly improbable that any substantial dislocation can occur without an accompanying ligament injury (sprain).

Perhaps the best known wing sprain occurs to the *propatagial ligament*, which constitutes the leading edge of the wing fold situated between the shoulder and carpus, termed the *propatagium*.

MUSCLE AND TENDON INJURY

The most serious injuries (gunshot, laceration, puncture, and strain) are to the flight muscles, the pectorals and supracoracoideus. The *supracoracoideus tendon* is especially vulnerable to strain or blunt force trauma as it passes through the *triosseal canal*. Birds with serious supracoracoideus strains may be misdiagnosed with humeral joint fractures or a nonspecific nerve injury. Birds with fracture-dislocations usually have some degree of accompanying supracoracoideus injury.

VASCULAR AND NERVE INJURY

Although it is possible to radiographically diagnose avian vascular injuries, primarily thromboembolic disease and posttraumatic arteriovenous fistulas, the necessary catheterization skills needed to perform such a procedure require a great deal of practice, especially if the manipulated vasculature is to be preserved and not merely ligated. As far as I am aware, the radiographic diagnosis of nerve injury in the wings of birds has not been reported.

BROKEN OR MISSING FEATHERS

Broken or missing feathers are regularly seen in wild birds that prove fully flight capable, although a nonconforming feather or feathers will create drag, which will require some corrective measure in the opposite wing. It is safe to say that some feathers are more critical than others, at least as far as flight is concerned.

Chapter 9

The Wing: Fracture Types and Tendencies

ON BROKEN WINGS

First, a pair of important principles should be stated: (1) the wing is more susceptible to injury than any other part of a wild bird and (2) wing injuries, either directly or indirectly, often prove fatal.

The projectile nature of the wings makes them extremely vulnerable to in-flight injury, especially by man-made obstacles such as power lines, fences, wire, and the like. Although we occasionally encounter wild birds with one or more healed fractures, this is clearly the exception and most wild birds that break their wings do not survive long enough to heal, unless they are provided with nourishment and a protected environment in which to recover (treatment not withstanding).

FRACTURE TYPES

Articular Fractures

Articular fractures are among the most devastating of all wing injuries. Not only do they nearly always prevent future flight, but they also make it difficult or impossible for birds to feed adequately, causing them to weaken and eventually starve or fall prey to an opportunistic predator.

From a diagnostic perspective, shoulder fractures are the most difficult to diagnose because of the extensive superimposition of the four bones that comprise the humeral joint, or pectoral girdle, as it is also known. These bones include the humerus, coracoid, scapula, and clavicle. Although the fourth bone, the clavicle, is not strictly a part of the shoulder joint, it plays an integral role in flight mechanics.

Articular fractures of the cubital joint, or elbow, are diagnostically far less complex but can sometimes be difficult to identify when displacement is minimal and only one view is available. Unfortunately, elbow fractures in birds are frequently accompanied by dislocations (Figure 9-1).

Nowhere is an anatomical reduction more important than in the case of articular fractures. Even so, there is a high incidence of posttraumatic osteoarthritis that usually leads to some degree of disability. Extraarticular and periarticular bone deposits, termed *impingement exostoses*, may interfere with joint movement to the extent that normal flight proves impossible.

Simple Fractures

Simple, or two-piece, fractures occur most often in the shafts of long bones. Some breaks are barely perceptible, appearing as one or more fine cracks in the bone, and others are immediately evident, based on obvious discontinuity, misalignment, and override (Figure 9-2). Simple fractures are usually described according to orientation of the break relative to the long axis of the bone: transverse, short or long oblique, and longitudinal.

Simple transverse fractures reduced with a single intramedullary pin are prone to rotation and sheering unless counteracting stabilization techniques are used.

Comminuted Fractures

The comminuted fracture is usually heralded by its many pieces, which are typically clustered in the diaphyseal region of long bones such as the humerus (Figure 9-3), radius, and ulna. Three-piece comminuted fractures often feature a central, broad-based triangular fragment that resembles the silhouette of a butterfly, thus the term *butterfly fragment*.

Generally, comminuted fractures take longer to heal than simple fractures, are more inclined to delayed union because of related vascular disruption, and usually lead to some degree of malunion.

Figure 9-1 • Articular fracture. Close-up view of the right elbow of a kestrel shows a displaced, steep oblique fracture-dislocation of the cranial half of the radial head (emphasis zone).

Figure 9-2 • Displaced steep oblique fracture of the distal humeral body of an owl.

Figure 9-3 • Displaced, open, comminuted fracture of the left humeral midbody in an owl. **A,** Ventrodorsal view. **B,** Lateral, wings-up view.

Compound (Open) Fractures

The hallmark of the compound, or open, fracture is the presence of air in and around the injury site that often serves to outline or trace the ends of the fracture fragments (Figure 9-4). In instances of severe injury, for example, where one or more large bone fragments pierce the skin, atmospheric contamination may be quite extensive, with large quantities of gas accumulating beneath the skin, within deep fascial planes, and in between fracture fragments. Not unexpectedly, the incidence of osteomyelitis, implant dislodgement, and nonunion is highest in compound fractures.

Multiple Fractures

The presence of two or more unrelated breaks in a single bone is called a *multiple fracture* and is quite unusual. If these fractures are untreated, they have a higher malunion potential than single breaks, with all other medical factors being equal (Figure 9-5).

Gunshot Fractures

Gunshot fractures are fatal more often than not, either in their own right or because of injuries sustained in the ensuing fall. As mentioned previously, even if a wounded bird survives its initial gunshot injury and fall, it still must find food and water and avoid predators. High-speed bullets are particularly dangerous; even glancing blows may cause terrific injuries. BB and pellet guns can also prove lethal, especially to birds shot at close range (Figure 9-6).

▮▮▮ FRACTURE TENDENCIES

Shoulder

Humerus. Wild birds, as well as cage birds, rarely sustain proximal articular humeral fractures, with or without accompanying dislocation. The exception to this generalization is a gunshot injury, which may not only cause proximal humeral fracture but also may severely damage associated tissues, including nerves, muscles, tendons, and ligaments. Interarticular missile fragments may mechanically interfere with wing movement and thus prevent normal flight.

Coracoid. The coracoid is the most commonly fractured bone in the shoulder. Although appearing to be relatively invulnerable to injury because of its highly protected position beneath the pectorals, the coracoid is susceptible to fracture when a sudden downward force is exerted on the upper wing surface. Mechanically, the typical midbody coracoid fracture resulting

Figure 9-4 • Compound (open) fracture. Close-up ventrodorsal view of the shattered proximal humeral body of a great blue heron. This type of fracture is characterized by numerous gas pockets in and around the principal injury site and the telltale "tracing" of the disrupted cortical surfaces by air, which has entered the interior of the wing through multiple wounds.

Figure 9-5 • Close-up, ventrodorsal view of the distal radius and ulna shows multiple displaced ulnar fractures, in addition to a dislocated ulnar carpal bone and displaced fractures of both greater and lesser metacarpal bones. This is a probable flight-ending injury.

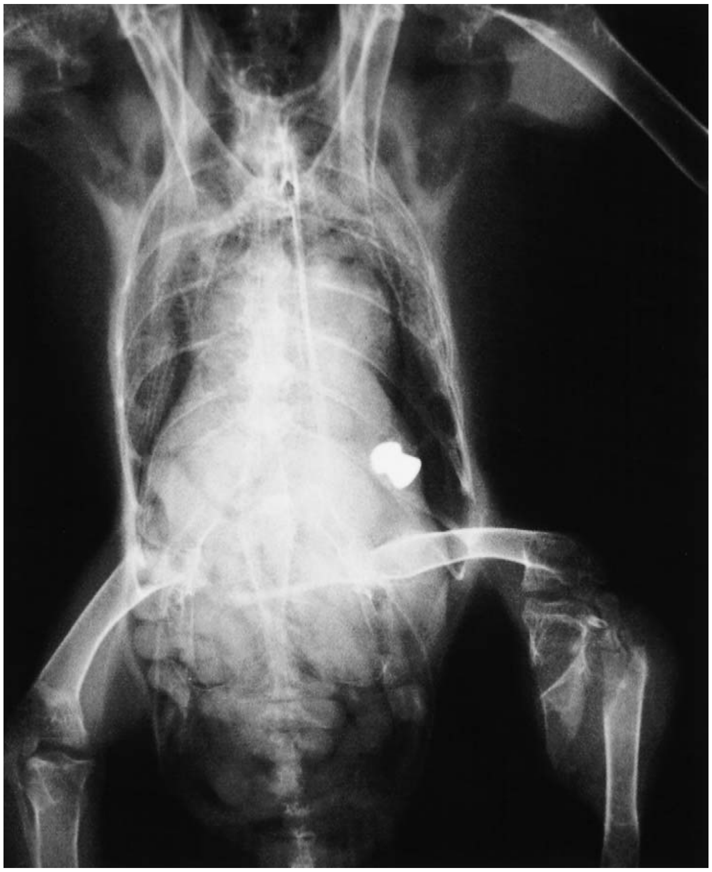

Figure 9-6 • Close-up, ventrodorsal view of a crow shot with an air gun. The pellet is lodged in the cranial aspect of the left kidney. As pointed out elsewhere in the text, the tibial fracture was sustained in the fall that occurred subsequent to being shot.

from a sudden collision with a motor vehicle, window, or power line can be likened to the snapping of a wing strut in a small aircraft after a flip on the tarmac.

Scapula. Like the humeral head, the scapula is rarely injured, but when it does fracture, it is usually in conjunction with the shoulder joint and in this respect constitutes a potential flight-ending injury.

Clavicle. The clavicle, or when fused with its opposite side counterpart, the furcula (wishbone), is not strictly a part of the shoulder joint because it has no articular component. Nevertheless, the clavicle possesses important design features. First, the clavicle functions as a secondary wing strut supporting the wing root (along with the coracoid) and dampening lateral compressive forces, which are exerted on the rib cage during flight by the downward sweep of the wing. A second important function of the clavicles is to indirectly connect the wing roots, thus assisting in the coordination of individual wing movements.

Triosseal Canal. The *triosseal canal* is an extraarticular channel formed by the confluence of the clavicle, scapula, and coracoid. This canal provides guidance, leverage, and protection to the critically important *supracoracoideus tendon*, which attaches to the dorsal humeral tubercle that elevates the wing during flight. Displaced fractures involving one or more bony elements of the triosseal canal suggest the possibility of concomitant supracoracoidial tendon injury. Compression fractures can lead to secondary tendonitis, and expression fractures or exuberant callus formation may result in impingement exostoses. Any alteration in the size or shape of the triosseal canal can potentially alter or interfere with the pull of the supracoracoideus muscle-tendon unit and accordingly alter the action of the associated wing.

HUMERAL BODY

The humerus is the largest, strongest bone in the wing, but it is not the longest. The distinction of longest bone goes to the radius and ulna, which are longer than the humerus by about 10%. Proximally, a large broad-based, reptilian-like ridge, the *pectoral crest*, dominates the bony landscape. Situated on the opposite side is a large angular bony outcropping, the *dorsal tubercle*, and in between lies the laterally compressed humeral head.

The humeral body is gently recurved and in places it is quite angular, especially when viewed in cross section. Just above the metaphysis, the humeral shaft flares laterally and medially, rounds up, and forms the lateral and medial humeral condyles, thus giving rise to the proximal aspect of the cubital or elbow joint.

Proximal humeral body fractures usually occur just below the pectoral crest and have a strong tendency to override, often quite badly, The consequences of override are twofold: first, the wing becomes shortened, sometimes by as much as 50%, and second, the humerus loses its proximal leverage and as a result, its power.

ELBOW

The elbow or cubital joint is dislocated more than any other, often in conjunction with at least one fracture. A fracture-dislocation of one or both components of the elbow is particularly onerous because it affects both the form and function of the joint.

RADIAL AND ULNAR BODIES

There is no particular pattern to radial and ulnar fractures. As with mammals, both bones are often fractured simultaneously. Displaced fractures occur more often than nondisplaced fractures. Multiple fractures occur occasionally. Open fractures occur regularly and are often associated with infection. Articular fractures may occur at either end of the antebrachium but in our practice are seen more often in the elbow and the same is true of dislocations.

CARPUS

Carpal bones are rarely fractured but are often dislocated as a result of serious distal radial and ulnar injuries.

METACARPUS AND DIGITS

The metacarpus is fractured occasionally, and as might be suspected, the smaller minor metacarpal bone is more susceptible to injury than its larger companion, the major metacarpal bone.

The first and third digits are susceptible to being torn away, especially the first digit, which is situated in a vulnerable position relative to frontal collisions. The second digit is most susceptible to traumatic amputation and dislocation of one or both of it phalanges.

Chapter 10

The Wing: Fracture Healing and Nonhealing

FRACTURE HEALING

What Does Healing Mean?

Healing refers to the return of most or all function, for example, a broken wing is healed sufficiently to enable a bird to fly (Figure 10-1) or a fractured leg is healed well enough to enable a bird to walk, or launch, or land. This healing is referred to as *functional healing*.

Another way to understand healing is in a *restorative* sense, for example, a previously broken bone has been restored to its preinjury appearance. Unfortunately, full restoration may require months or even years to come about (Figure 10-2), and thus the term becomes clinically impractical.

What Determines Healing Time?

It is impossible to predict a precise healing time for any given fracture—in a bird or any other creature for that matter—but it is reasonable to estimate a range of dates, or an approximation of dates, usually expressed in weeks, by which time most such fractures will have healed. For example, most simple nondisplaced, midshaft radial fractures will heal in 3 to 4 weeks provided that the associated ulna is intact. If the ulna is also fractured but not severely displaced, the injury will likely require an additional week or two to heal.

Severity of the Injury. The severity of an injury, in the case of a bone the number of fragments and their degree of displacement, is the principal determinant of healing time. To heal, the blood supply of a bone must be restored to the extent it was disrupted by the facture. Thus the greater the number of fracture fragments and the greater their separation, then the greater the damage to the associated circulation. *Proper healing requires a proper blood supply*.

Skill of the Surgeon. Operator skill, or in this instance, the ability of the surgeon to reduce and stabilize a fracture, is the sum of the surgeon's initial clinical training plus his or her subsequent experience (Figure 10-3). It becomes possible by this measure to predict the likelihood that a particular fracture is or is not likely to heal or achieve a positive outcome.

Complications. Orthopedic and other types of surgeries that do not go as planned are often attributed to *complications*, which is a rather imprecise pseudomedical term that can refer to a wide variety of unanticipated difficulties encountered during or after surgery. Such problems can range from trivial to disabling to life-threatening. For example, a small amount of bone cement may spill onto the surrounding muscle during the installation of a prosthetic hip, and this should not discernibly affect healing. On the other hand, a major artery may be inadvertently severed, leading to substantial blood loss, or a major nerve may be accidentally transected, causing paralysis.

Radiographic Features

Purposeful Versus Nonpurposeful Callus Formation. As pointed out previously, healing is such a highly variable process that depends on a number of different considerations. Thus there are no specific healing times, only prognostic estimates that are confirmed or modified according to subsequent progress examinations. *The single strongest radiographic indication of fracture healing is the development of a purposeful callus.*

A purposeful bony callus is one that forms in and around the fracture, serving first to unite and then to solidify the fragments. Early in its development a callus may be invisible because of an absence of mineral

Figure 10-1 • Dean Hamilton releases an owl after its complete recovery from a fractured wing.

salts. But later, the interfragmentary gap begins to cloud as mineralization occurs and new bone forms along the fragment edges. These events characterize the conversion of a soft to a hard callus (Figure 10-4).

With the further passage of time the callus becomes increasingly denser, reflecting its conversion to bone. Concurrently, the fracture line or lines become increasingly faint, eventually disappearing. On reaching maturity, a purposeful callus slowly begins to recede, eventually being fully or partially incorporated into the adjacent bone, and sometimes also disappears (Figure 10-5).

A nonpurposeful callus is one that develops at the ends of one or both fragments but fails to form in the interfragmentary gap. This type of ineffective callus is usually the result of fragment motion, which inhibits or disrupts the development of local vascularization. The presence of a nonpurposeful callus signals the potential for a delayed union, or worse, a nonunion (Figure 10-6).

Callus Size and Its Prognostic Significance. For various reasons, surgery is not always performed on many wing fractures. In such instances, callus formation often appears excessive. However, the presence of an exuberant callus in an unstabilized fracture is not a cause for concern because it is almost certainly the result of fragment motion and the additional bony response incurred.

Conversely, a fracture that has been anatomically reduced and stabilized often shows only minimal callus formation, especially in the first weeks after the surgery, which is mostly a result of a lack of fragment motion and is characteristic of plated fractures.

Given the influence of fragment motion (or lack thereof) on callus size, one should be suspicious of any nonreduced fracture that fails to readily form a callus. Likewise, one should also be concerned about a reduced fracture that forms an inappropriately large callus.

Delayed Fracture Healing. A delayed fracture is one that requires more time to heal than originally predicted. For example, a simple, minimally displaced fracture of the radial midshaft in an otherwise healthy raptor, treated by simple strapping, might be expected to heal in about a month. But if the bird repeatedly undoes its bandaging, necessitating capture, anesthesia, and rewrapping, the resultant callus disturbance will likely add an additional 1 or 2 weeks to the total healing time. Accordingly, the healing process will be prolonged.

Some fractures, for example, those involving the shoulder bones, especially the coracoid, routinely take longer to heal than other wing bones. Often, there is little or no evidence of healing for a month or more (Figure 10-7). Occasionally, new bone forms near but not actually in the fracture gap, making it seem that the fracture is healing in the ventrodorsal (VD) view. A lateral, wings-up projection will usually reveal the true status of the injury (Figure 10-8).

The Calculation of Predicted Healing Time

As indicated previously, the predicted healing time of a given fracture is first based on its severity and next

Text continued on p. 102.

Figure 10-2 • Full restoration can be a lengthy process. **A,** Orientation and close-up **(B)** ventrodorsal views of a middiaphyseal ulnar fracture 2 months after it was sustained show a small but effective callus that fully joins the currently malaligned fragments. **C,** A close-up, lateral view made 3 months after the injury shows near anatomical cortical realignment and a receding callus.

Figure 10-3 • Surgeon adjusts intramedullary pin in the wing of a hawk. A subsequent radiograph will confirm that the pin is in the desired location.

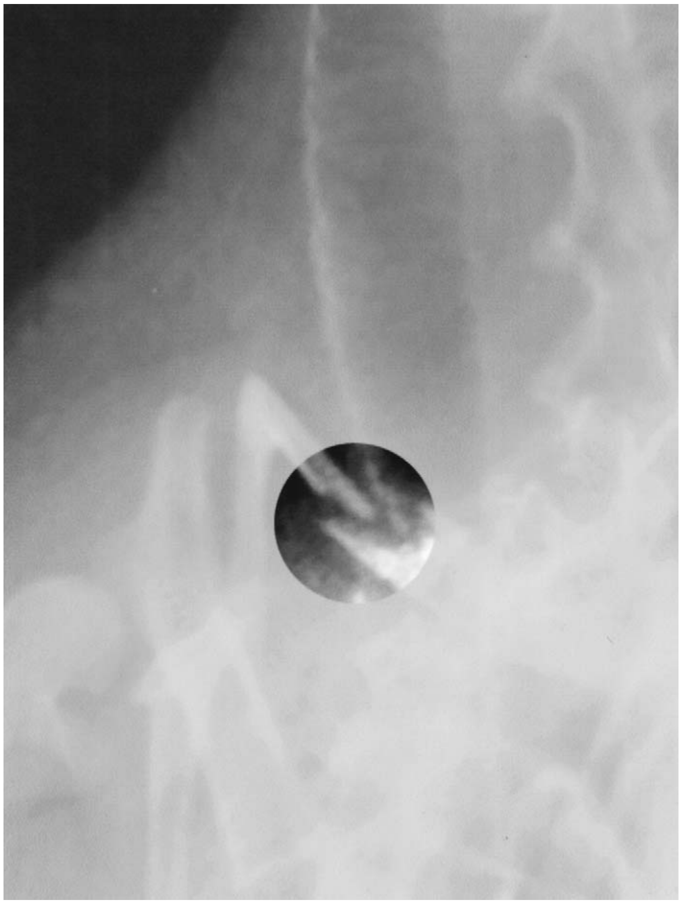

Figure 10-4 • Early interfragmentary callus formation: Ventrodorsal oblique view of a subacute displaced clavicular fracture (emphasis zone) in a redheaded duck shows (1) fragment displacement, (2) bone deposition along the edge of the distal fragment, and (3) clouding within the interfragmentary gap, which is an indication of early callus formation.

Figure 10-5 • A, Fresh, minimally displaced, comminuted midulnar fracture in a hawk. **B,** Four months later after repeated strapping. Note that although callus formation is advanced, the fracture fragments have shifted badly, typical of bandage fixation.

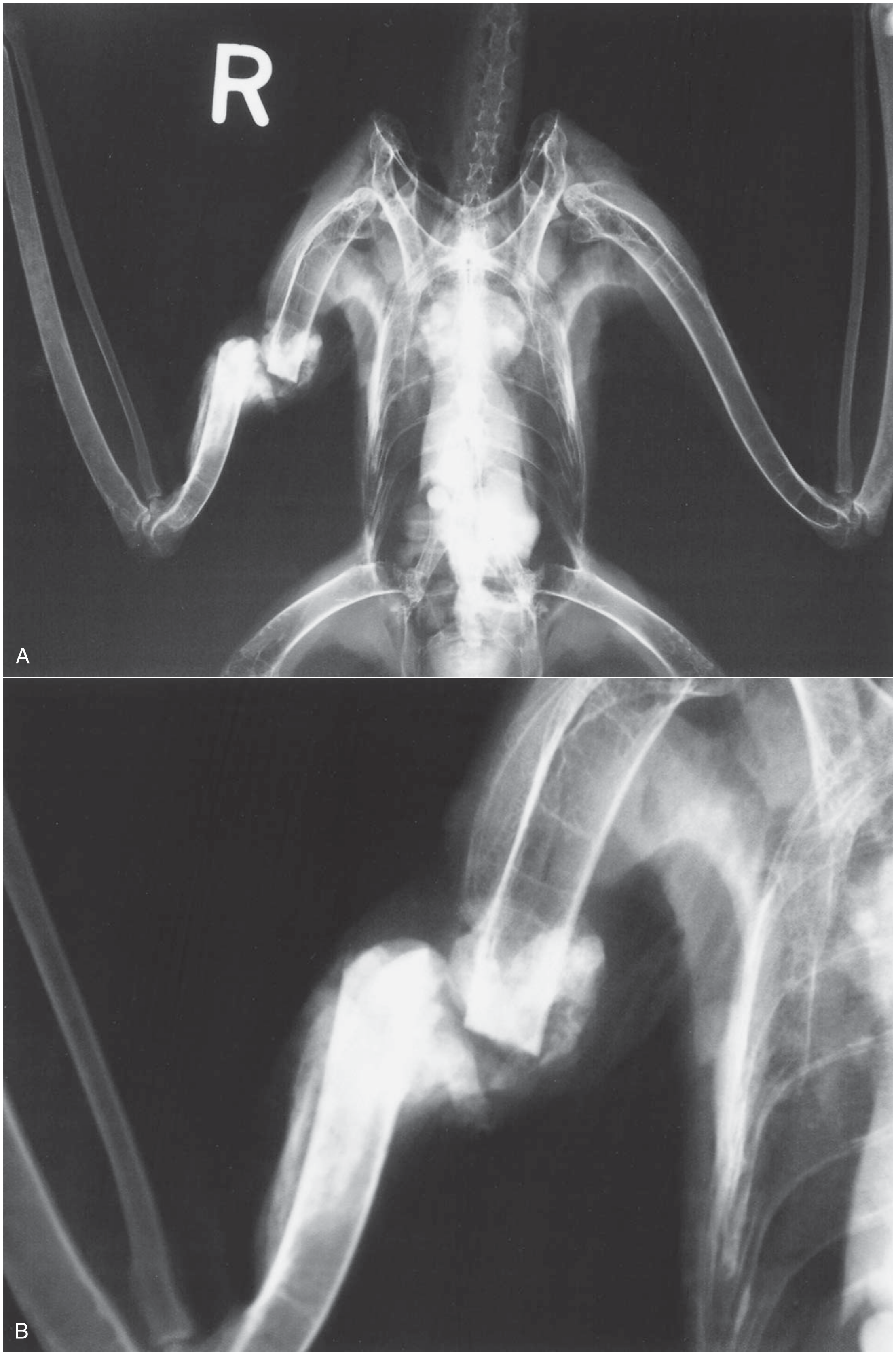

Figure 10-6 • A, Orientation, close **(B),** and ultraclose **(C)** ventrodorsal views of a nonunion fracture in the right humeral midshaft of a Swainson's hawk show a classical nonpurposeful callus, which has formed near the misaligned ends of both fragments but failed to bridge the fracture gap. **D,** A leading edge projection shows the development of a false joint situated between the rocker end of the proximal fragment and the new bone situated along the medial edge of the distal fragment.

Figure 10-6, cont'd • For legend see opposite page.

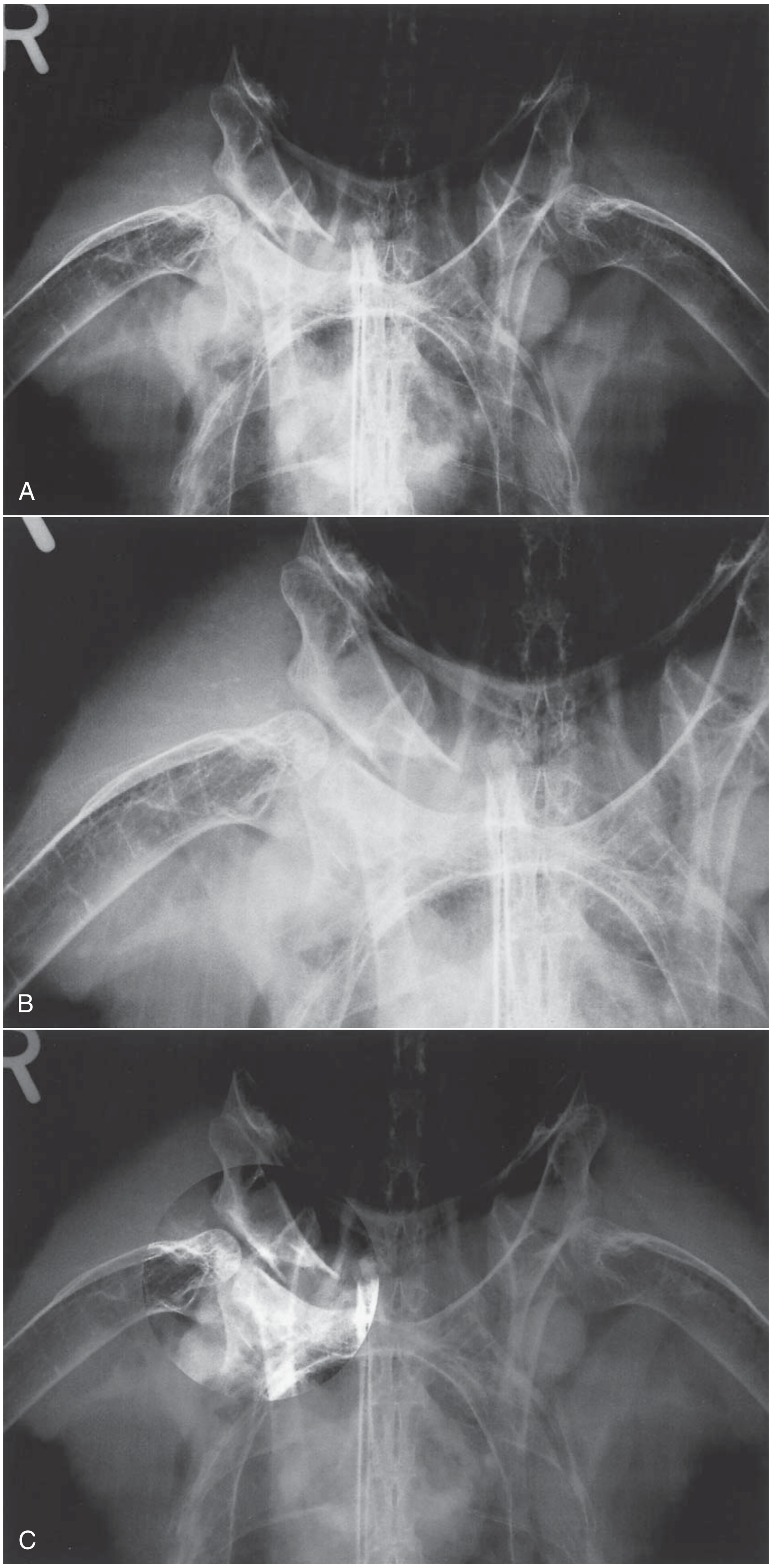

Figure 10-7 • Delayed union. **A** and **B,** Plain and emphasized **(C)** ventrodorsal views of a 1-month old displaced right coracoid fracture in a bald eagle. To date there has been no radiographic indication that the fracture is healing, thus it is considered a delayed union with the potential for nonunion.

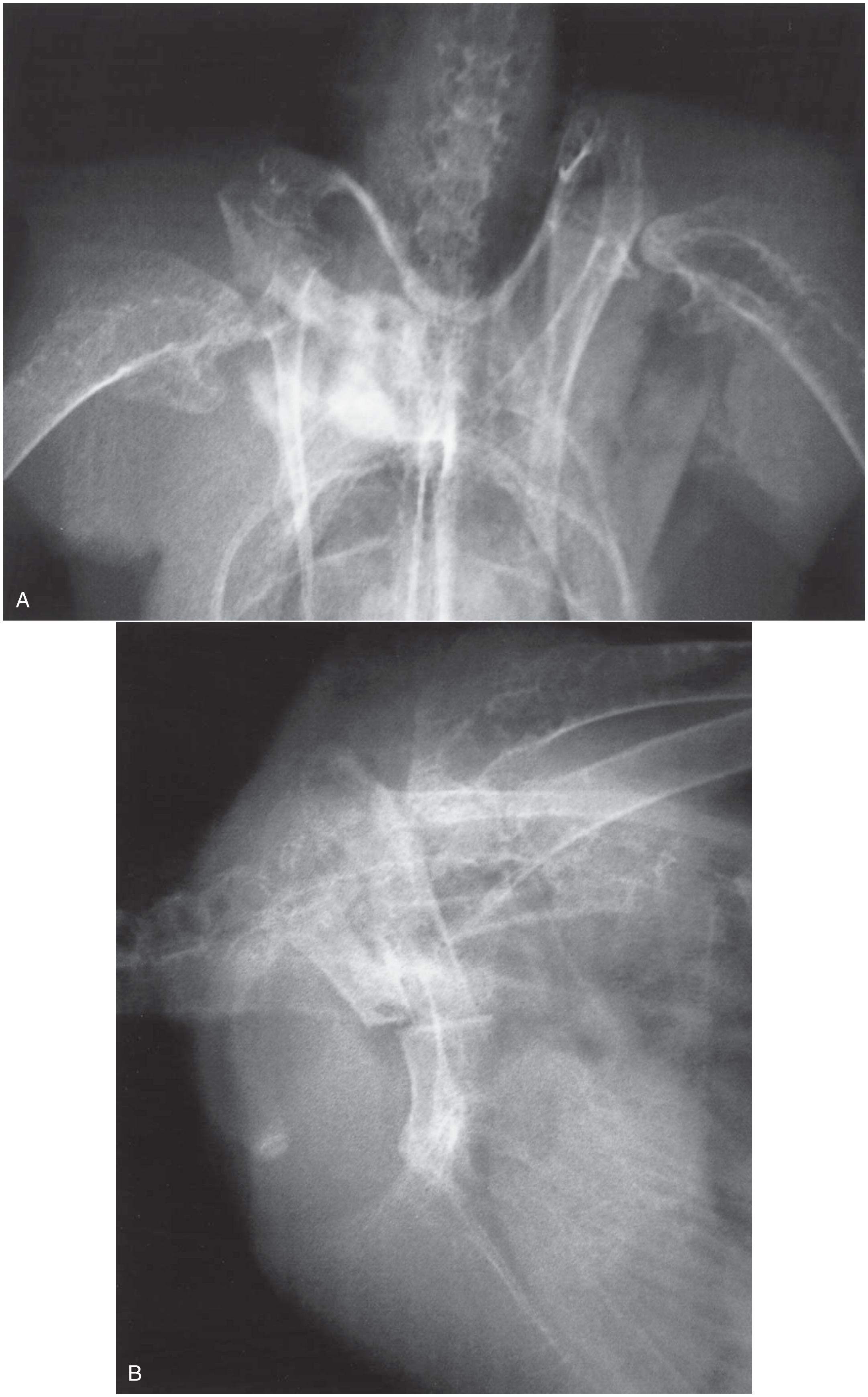

Figure 10-8 • A, Close-up, ventrodorsal and lateral, wings-up **(B)** views of a hawk with a 2-month-old, nonhealed right coracoid fracture. Note that in the ventrodorsal projection there appears to be ample callus, but in the lateral projection the fraud is revealed: There is no purposeful callus. All of the new bone has been formed away from the fracture where it will do nothing to solidify the break.

based on the skill and experience of the operator. Additional factors include the condition of the patient, especially the presence of any other serious injuries. Once these matters are considered, comparable cases should be reviewed and a prognosis formulated, and one should remember that healing time is first and foremost a *prediction*, which can and must be modified according to what is observed in subsequent progress films.

Immediate Postoperative Films. After surgery, immediate postoperative radiographs must be made for the purpose of technical evaluation. If the occasion arises, these radiographs can be proof that the surgery was performed as agreed on (Figure 10-9). The importance of making a complete set of postoperative radiographs once the surgery has been completed cannot be stressed enough. If for any reason immediate postoperative films cannot be made, for example, if the power goes out or there is an equipment failure, then the medical record should be so annotated and the responsible party notified.

Progress Films. As the name implies, progress films are made to monitor, as well as predict, fracture healing. Because no two fractures heal in exactly the same manner or at the same rate, each injury must be assessed in its own right, according to the following criteria:

- The severity of the original injury, especially the degree of comminution, and whether it is open (potentially infected)
- The effectiveness of the surgery, particularly with respect to the apposition and alignment of fracture fragments
- The maintenance of fragment position
- The maintenance of implant position
- The maintenance of implant integrity
- The relative appearance of the fracture compared with all previous radiographic examinations
- The physical appearance of the fractured part and the degree to which it has regained function
- The overall health and condition of the bird during the time it is being monitored

These data may then be used to derive a current status report. For example, an initial 1 month progress report might read: "Early healing as indicated by new bone formation in and around fracture site; fragment and implant positions have been well maintained" (Figure 10-10). The same data can also be employed in a predictive fashion, for example, "Anticipate callus should be strong enough in another 2 weeks to allow removal of support wrap. Recommend wing be radiographed again in 1 month's time."

Alternatively, a progress report might read: "Currently, there is no evidence of callus formation, although the bone appears healthy and the fracture fragments and implants stationary. Based on its current appear-

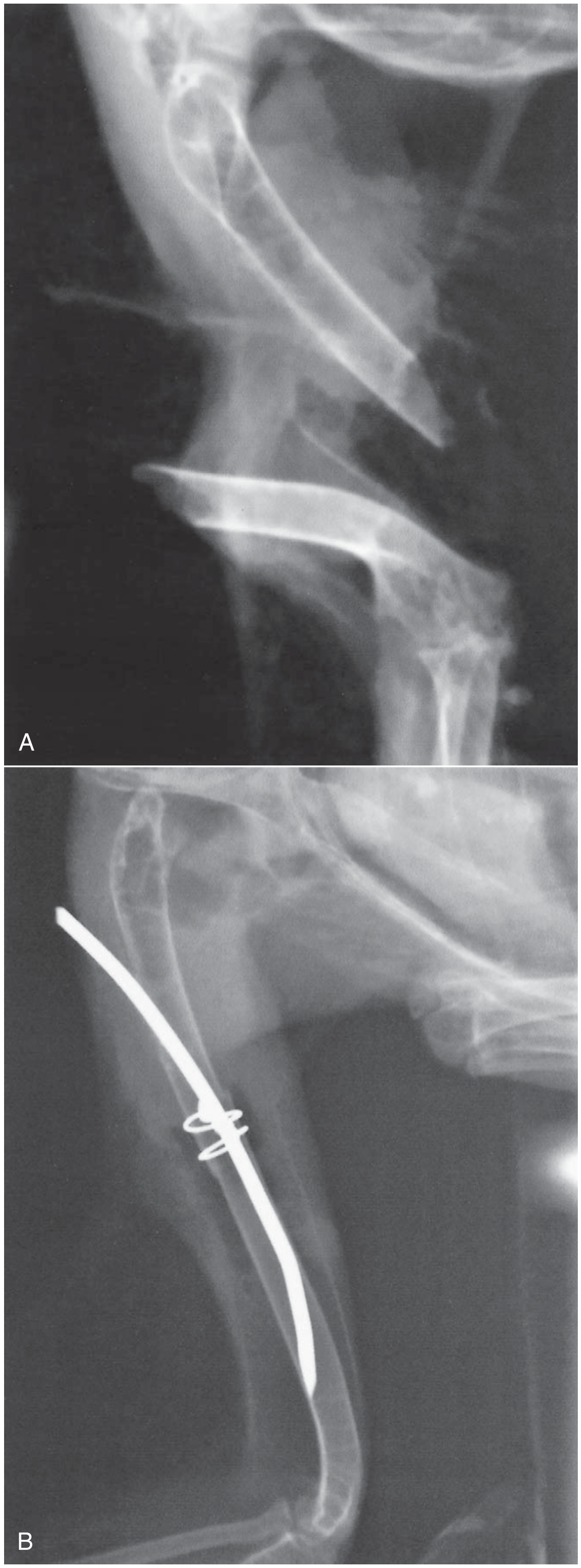

Figure 10-9 • A, Close-up, ventrodorsal view of a badly displaced, compound, midshaft humeral fracture. The bones are actually poking out of the skin in two places. **B,** An immediate postoperative film made the next day showing anatomical reduction.

Figure 10-10 • A, One-month progress ventrodorsal and leading edge **(B)** views of the left wing of a great gray owl, which shattered its shoulder against a power line. In this type of external fixation, the transdermal pins are fixed to the bone internally and to bone cement externally. Although the fractured proximal humerus has partially healed, it remains subluxated, while the glenoid has become arthritic.

ance, delayed union should be anticipated. Recommend 3-week progress check."

FRACTURE HEALING THAT RESEMBLES INFECTION

Certain types of callus can resemble infection. This is especially true of long minimally displaced spiral fractures where the callus resembles an infective *involucrum* (Figure 10-11). Alternatively, some fractures may not only fail to form a callus, but may instead lose density. This latter appearance is usually due to either *avascular necrosis* or *posttraumatic osteoporosis* (see Figure 10-11).

NONRESTORATIVE BONE HEALING: THE MALUNION FRACTURE

Most authorities exercise some discretion when using the term malunion, generally reserving it for moderate to severe deformities that might lead to some degree of disability (Figures 10-12 and 10-13). In my experience, malunions are a potentially greater concern in the wings of birds than in the limbs of mammals.

Does Malunion Equal Dysfunction?

There is nothing inherently dysfunctional in a malunion fracture. Rather, malunion is a radiographic designation, or categorization, that indicates only that a fractured bone has failed to be fully restored, with or without treatment.

Time and Gradual Adaptation

Generally, severe malunions can be accommodated provided there is sufficient time to make and practice the necessary compensatory adjustments to the control surfaces of the affected wing. The principal purpose of raptor recovery facilities is to provide time for gradual adaptation.

THE NONUNION FRACTURE

Radiographic Determination

A nonunion fracture is a fracture that fails to heal. Classically, a clinical nonunion is defined by three things: lameness, palpable pain, and fragment movement. Radiographically, the two types of nonunions are *hypertrophic* and *avascular*; the latter is also termed *atrophic* or *unreactive*.

Implant Failure and Dislocation

Implants do not fail, people do. Surgeons may use the wrong implants for a particular repair or apply an implant incorrectly. Alternatively, owners may fail to restrict their pet's activities in the critical period before recently repaired bone fragments have had sufficient time to solidify and are subject to dislocation.

Hypertrophic Nonunions

Not surprisingly, hypertrophic nonunions are most likely found in the wing, where regular movement at the fracture site impedes interfragmentary vascularization and discourages purposeful callus formation. Instead, new bone deposition is confined to the ends of the fracture, making the bone appear overly dense, flared, and often blunted, which is an appearance sometimes referred to as an *elephant's foot*. Over time, humeral and radioulnar nonunions can become encased in a thick cuff of connective tissue, which is sometimes referred to as a *false joint*. Figures 10-14 and 10-15 include examples of nonunions.

Avascular Nonunions

Fractures that have lost their blood supply are incapable of healing and eventually go on to become avascular nonunions. Unlike hypertrophic nonunions that deposit nonpurposeful callus around the bone ends (but not in between fracture fragments), avascular nonunions deposit little or no new bone (Figure 10-16). Instead, avascular nonunions result in a depletion of the mineral salts from the original bone, causing it to become dark and ill-defined compared with healthy bone. In some instances, the bone adjacent to the fracture appears to disintegrate or disappear altogether, thus the term *atrophic nonunion* is used (Figure 10-17).

Another type of nonunion is the unreactive, or nonreactive, nonunion in which the injured bone fails to change in any identifiable way, merely remaining quiescent over time. Surgical revisions often behave in this manner.

When to Make the Radiographic "Call"

As I proposed nearly 2 decades ago and based on a similar proposal by Heppenstall, a fracture should be declared a nonunion if it fails to show signs of healing in two consecutive radiographic examinations made at least *3 months* apart. Obviously, if a fracture is palpably unstable, then its fragments are clearly ununited.

SUMMARIZING CASE EXAMPLE

In this extraordinary example, the proximal radius and ulna of a snowy owl are first subjected to the grillwork of a northern logging truck and subsequently to three

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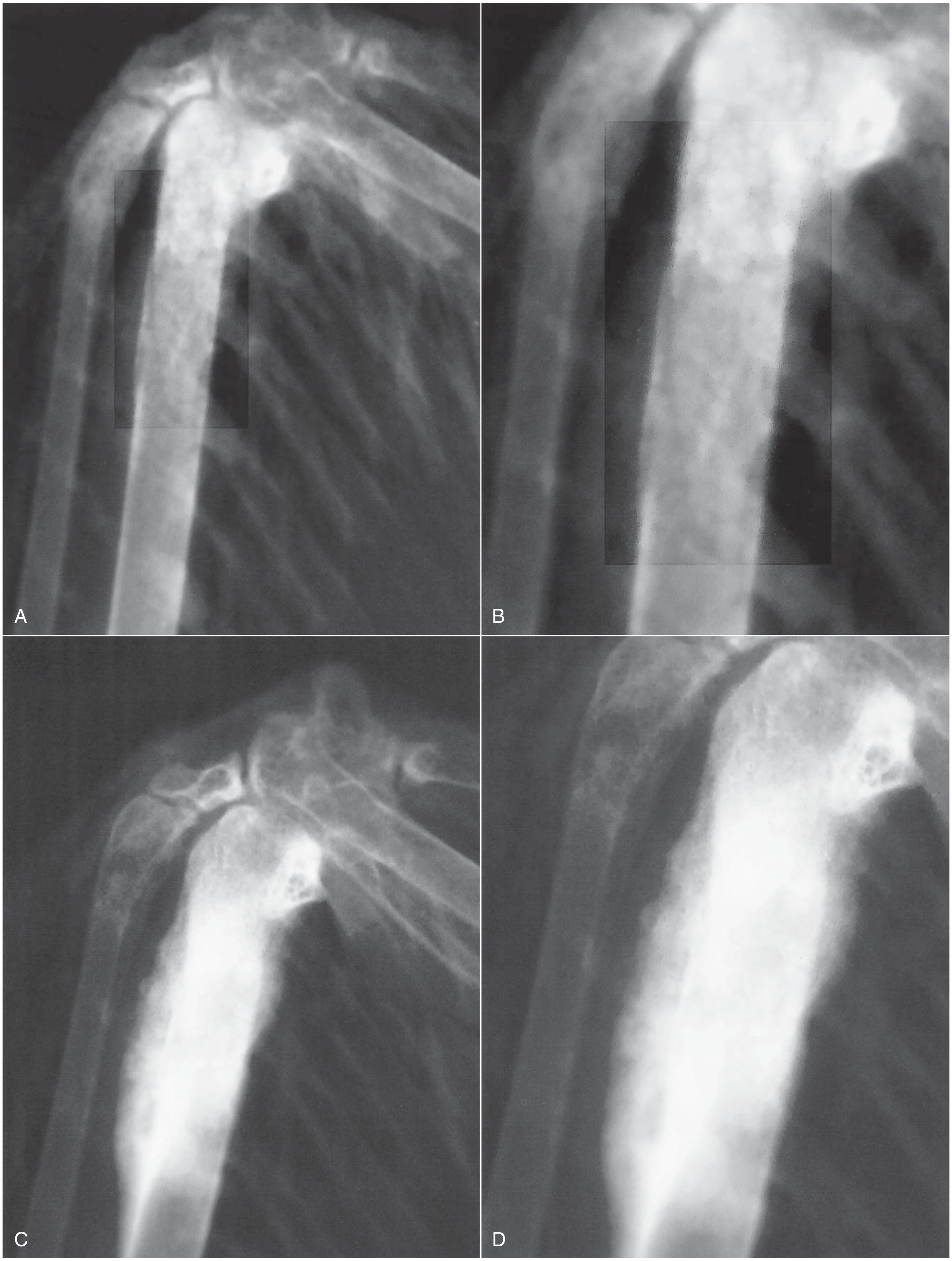

Figure 10-11 • A, Close and ultraclose **(B)** emphasized ventrodorsal views of subacute, minimally displaced fractures of the distal radial metaphysis and associated ulnar body. The radial break is partially folded on itself, resulting in an abnormally angular appearance, and the faint ulnar fracture spirals upwardly from the distal metaphysis to the central third of the diaphysis. One-month progress examination shows close **(C)** and ultraclose **(D)** ventrodorsal views of the same area of the wing and the ulnar fracture heavily encased in a lengthy bony callus and somewhat resembling osteomyelitis. The radial fracture shows no signs of healing; instead, it appears extensively lysed, presumably a result of a combination of avascular necrosis and posttraumatic osteoporosis.

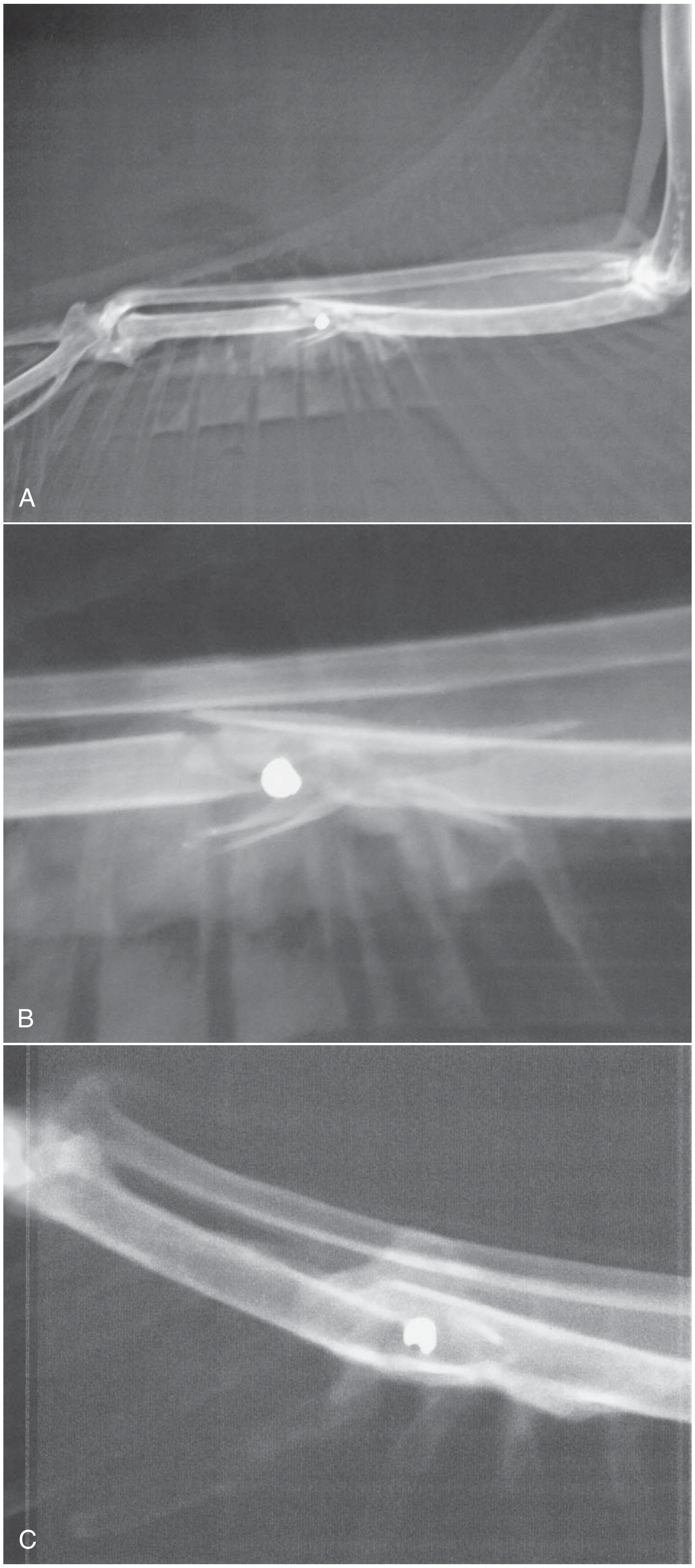

Figure 10-12 • Multiple fractures, one of which becomes a malunion. **A,** Orientation view of the right wing of a snowy owl shows an overridden articular fracture of the radial head and a comminuted gunshot fracture of the ulnar midshaft. Both fractures are also shown close-up **(B** and **C).** The injuries were treated with a body wrap and radiographed again 2 months later, at which time the ulnar fracture was deemed healed, albeit as a malunion **(C).** Healing of the radial fracture was delayed but eventually healed as well.

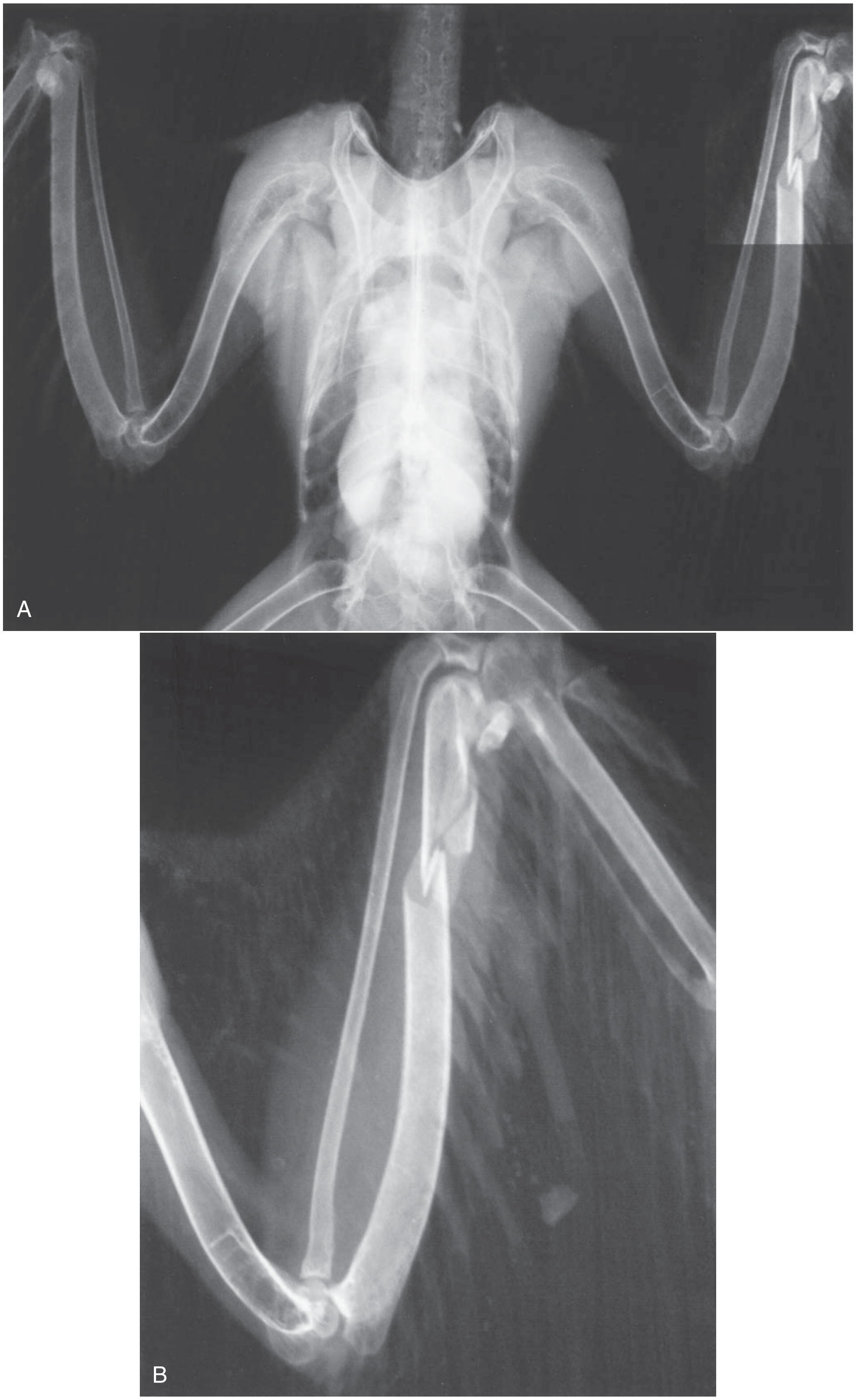

Figure 10-13 • A, Ventrodorsal orientation and close-up **(B)** views of a hawk with a displaced, comminuted, distal left ulnar body fracture and multiple broken feathers. One month progress recheck shows close-up **(C)** and oblique **(D)** ventrodorsal views, and the fracture has healed as a side-to-side malunion, typical of nonreduced fractures of this type, but with preservation of the nearby ulnar-carpal joint.

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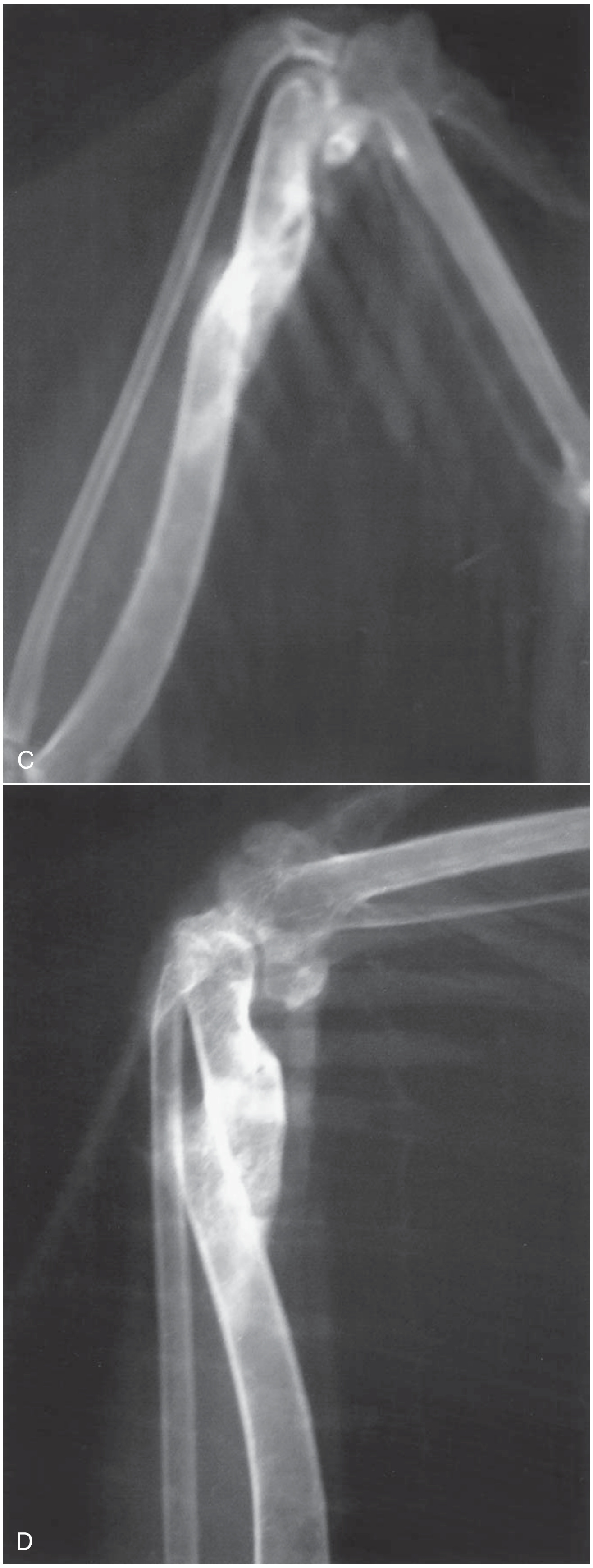

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Figure 10-14 • Close-up, ventrodorsal view of a hypertrophic nonunion in the distal radial body of a bald eagle.

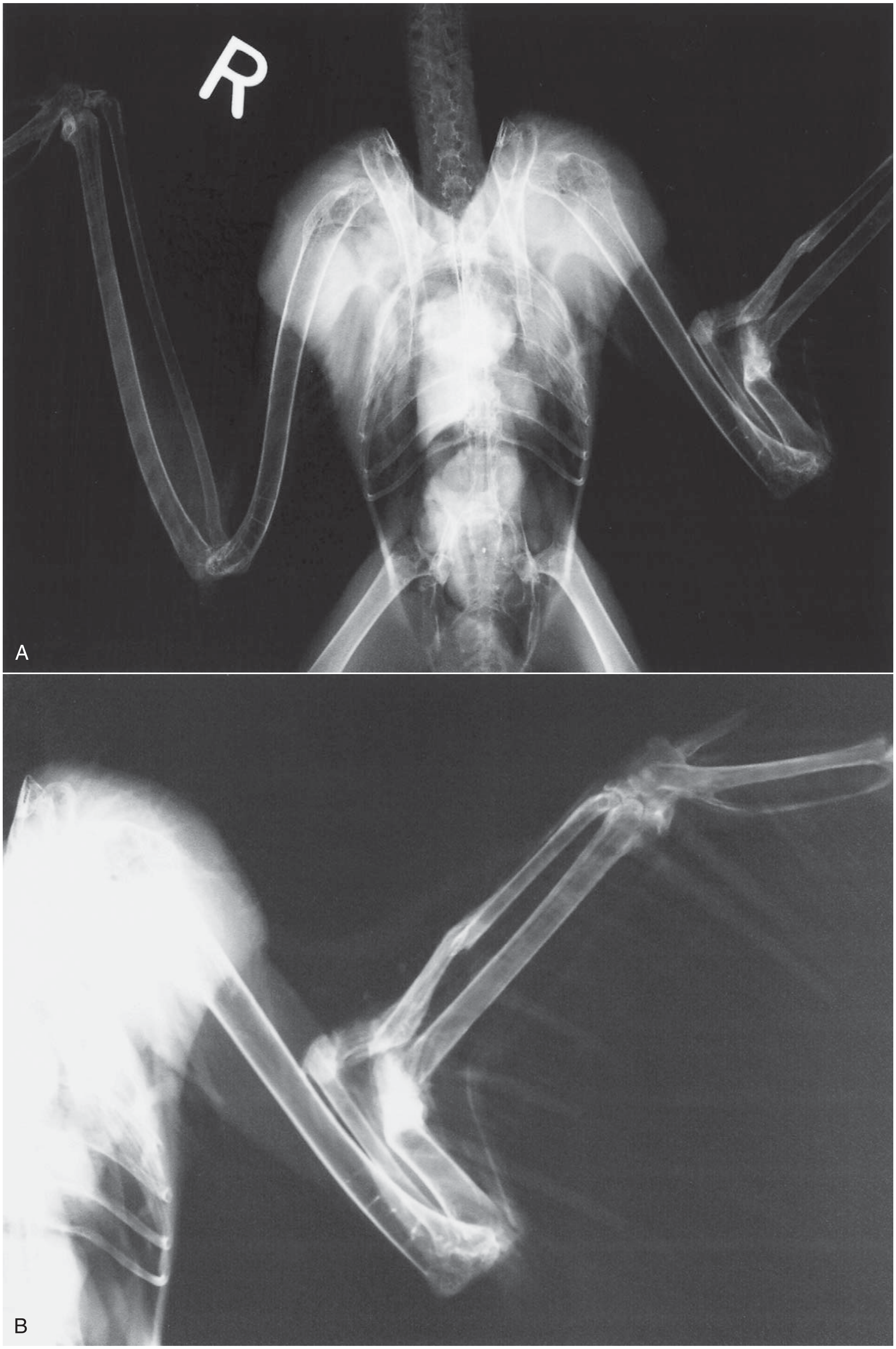

Figure 10-15 • A, Ventrodorsal orientation and close-up **(B)** views of the right wing of a hawk, which fractured its proximal radius and ulna approximately 10 weeks earlier. Lateral, wings-up orientation **(C)** and close-up **(D)** views are also provided, along with leading-edge orientation **(E),** close **(F),** and ultraclose **(G)** views. These images reveal a complex injury, which is currently characterized by nonunion, malunion, deformity, and dysfunction. Specifically, the radius has broken into four pieces, one of which now articulates with the proximal ulnar fragment, courtesy of a false joint. The distal ulnar fragment has followed suit by forming a pseudoarthrosis with its proximal counterpart that in turn articulates with the newly formed radioulnar joint, thereby creating a super joint. Note that both elbow joints appear narrow as a result of a temporary volume loss in the articular cartilage.

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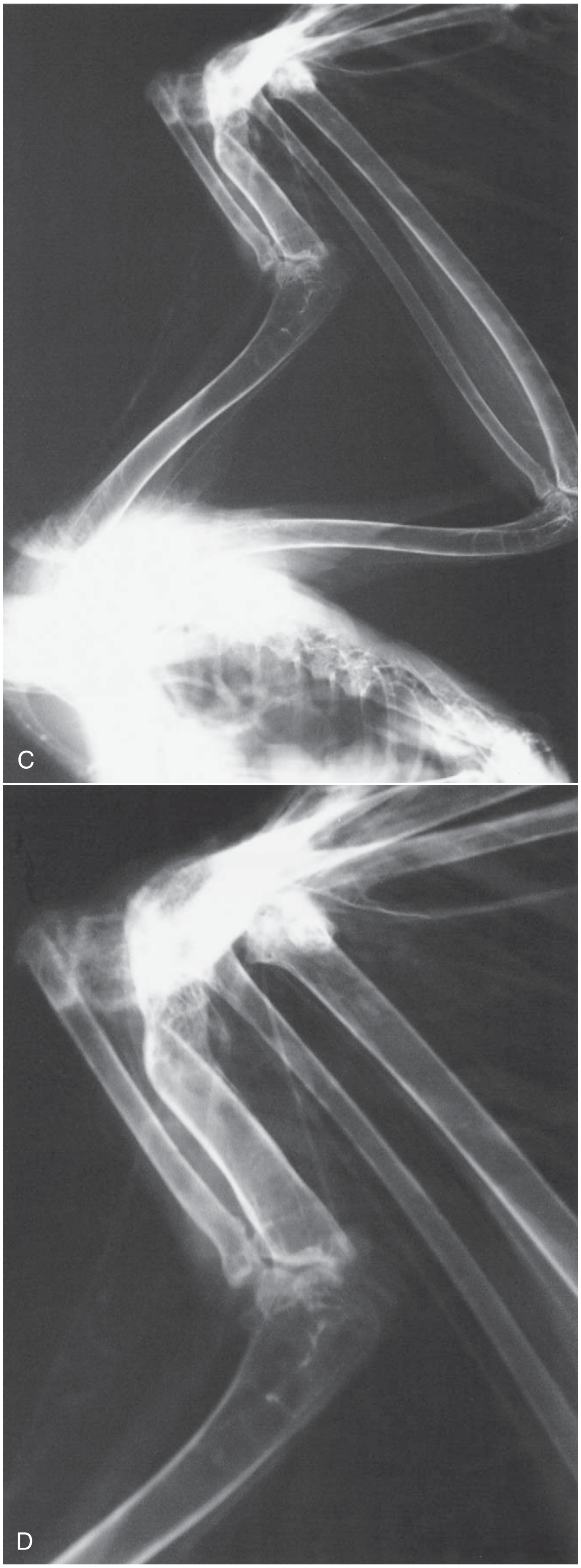

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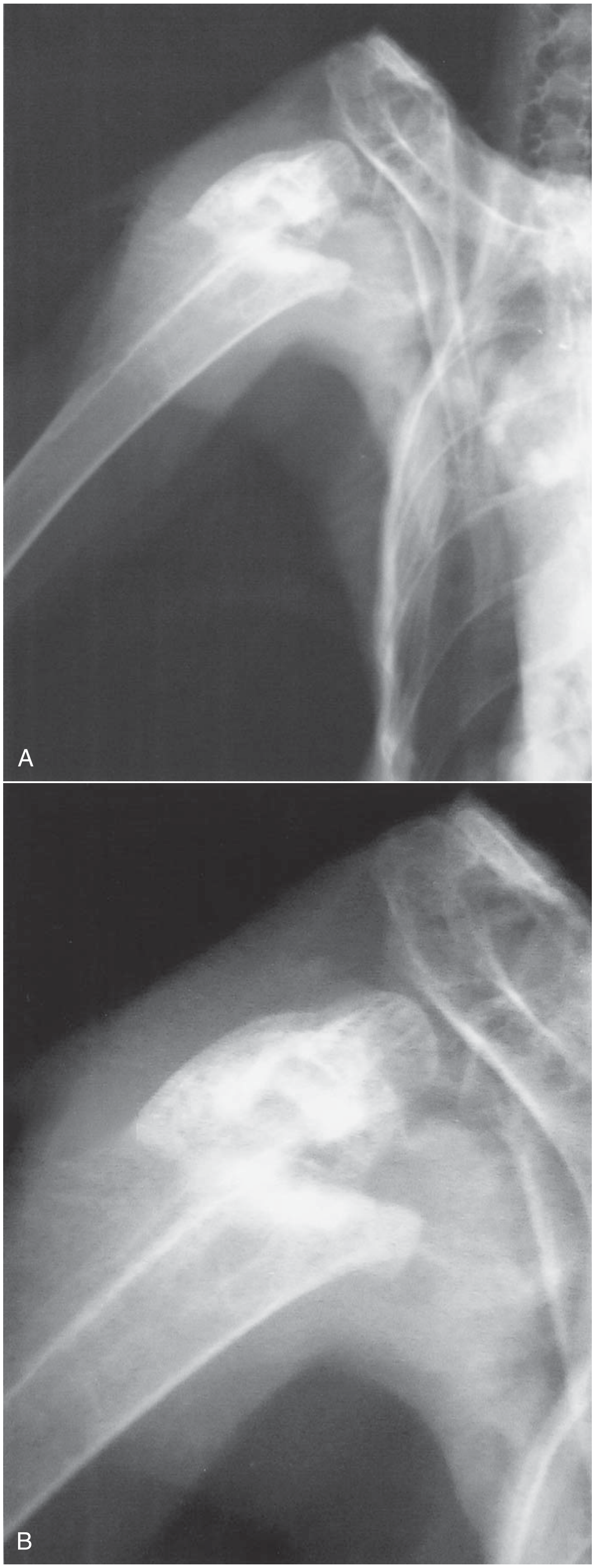

Figure 10-16 • A, Close and ultraclose **(B)** ventrodorsal views of a proximal humeral atrophic nonunion in a bald eagle. There is no purposeful callus, only some bony consolidation of the fragment ends.

Figure 10-17 • Flicker with a shattered shoulder resulting in multiple atrophic nonunions. **A,** Orientation, close-up **(B),** and close-up, negative **(C)** ventrodorsal views, plus right **(D),** and left **(E)** ventrodorsal oblique close-ups. There are nonunion fractures of the right clavicle and coracoid and a fracture-dislocation of the associated scapula. The result is that the entire right humeral joint has been partially collapsed, and in the process, shifted caudally so that it no longer aligns with the uninjured left shoulder.

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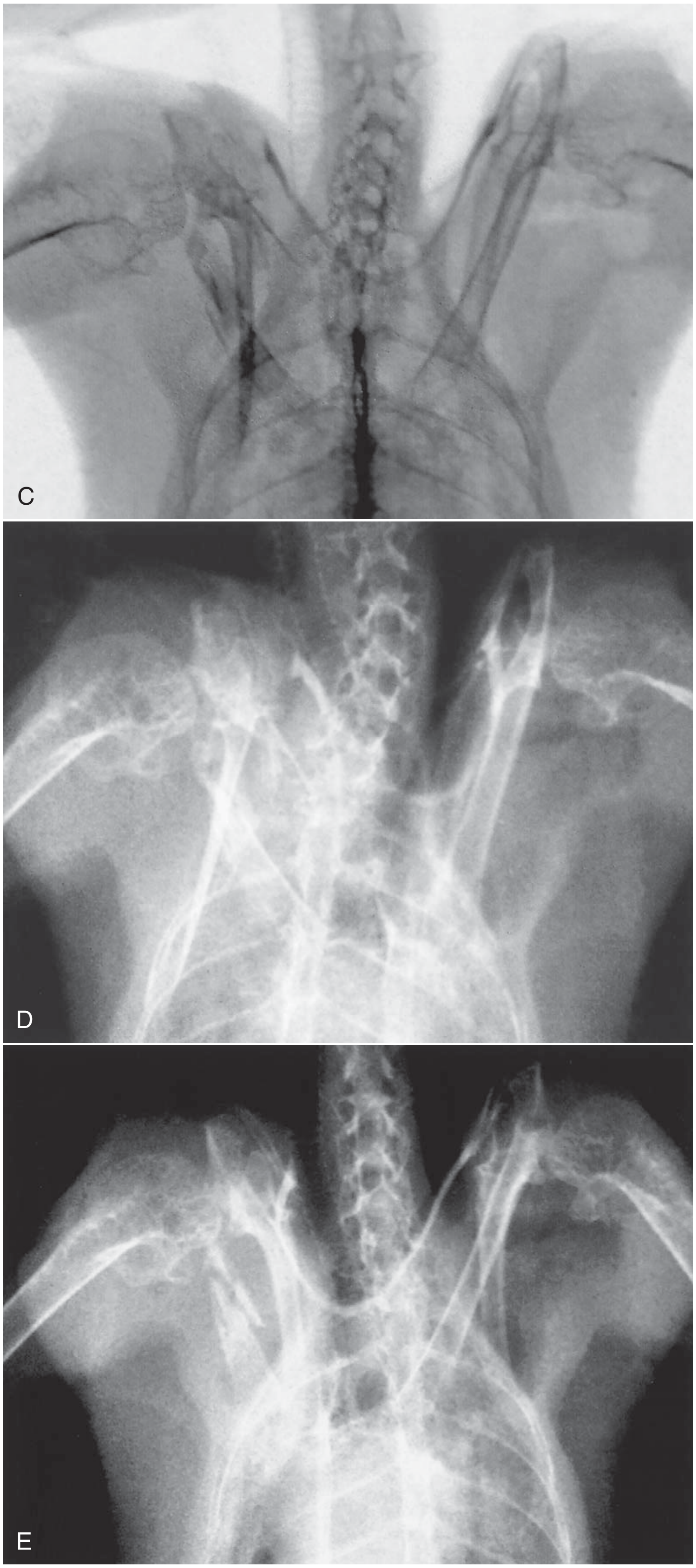

Figure 10-17, cont'd • For legend see p. 113.

Figure 10-18 • A, Orientation and close-up **(B)** ventrodorsal views of the right elbow of a snowy owl hit by a logging truck shows badly displaced fractures of the proximal radius and ulna, which approach but do not enter the cubital joints. **C,** The uninjured left elbow is provided for comparison.

operations. The period of clinical observation is approximately 14 months. During this time, the injured bones exhibited a wide variety of radiographic appearances, including delayed union, avascular necrosis, nonpurposeful bone deposition, infection, nonunion, and ultimately malunion. These images convey many valuable lessons, not the least of which is the toll extracted from the regional circulation and how this adversely affects fracture healing (Figures 10-18 to 10-23).

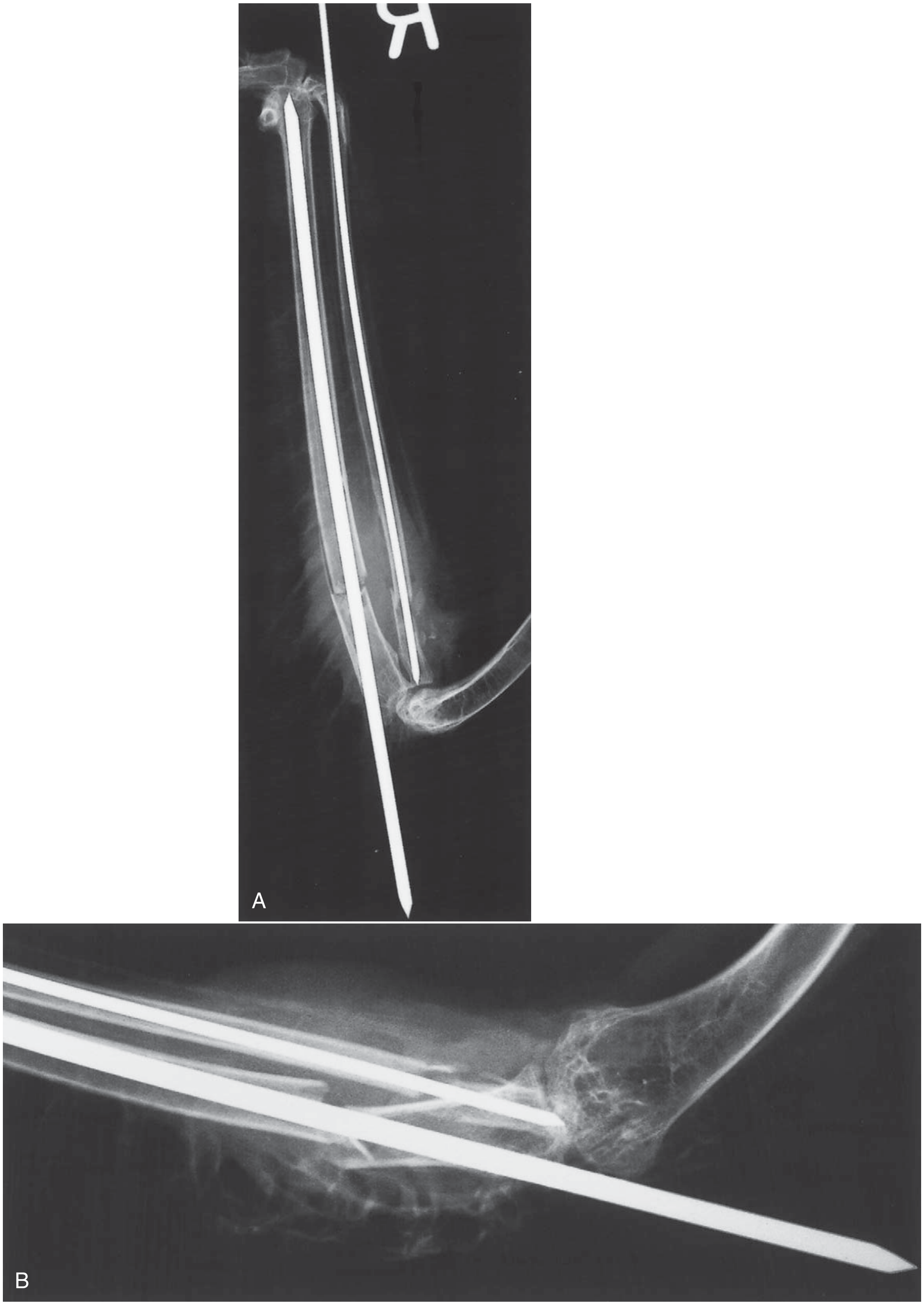

Figure 10-19 • A, Immediate postoperative ventrodorsal view shows what appears to be near anatomical reductions of both the radial and ulnar fractures, but a leading edge projection **(B)** reveals otherwise: The proximal end of the radial pin has missed its mark, impaling the radial head directly rather than first entering the proximal radial diaphysis.

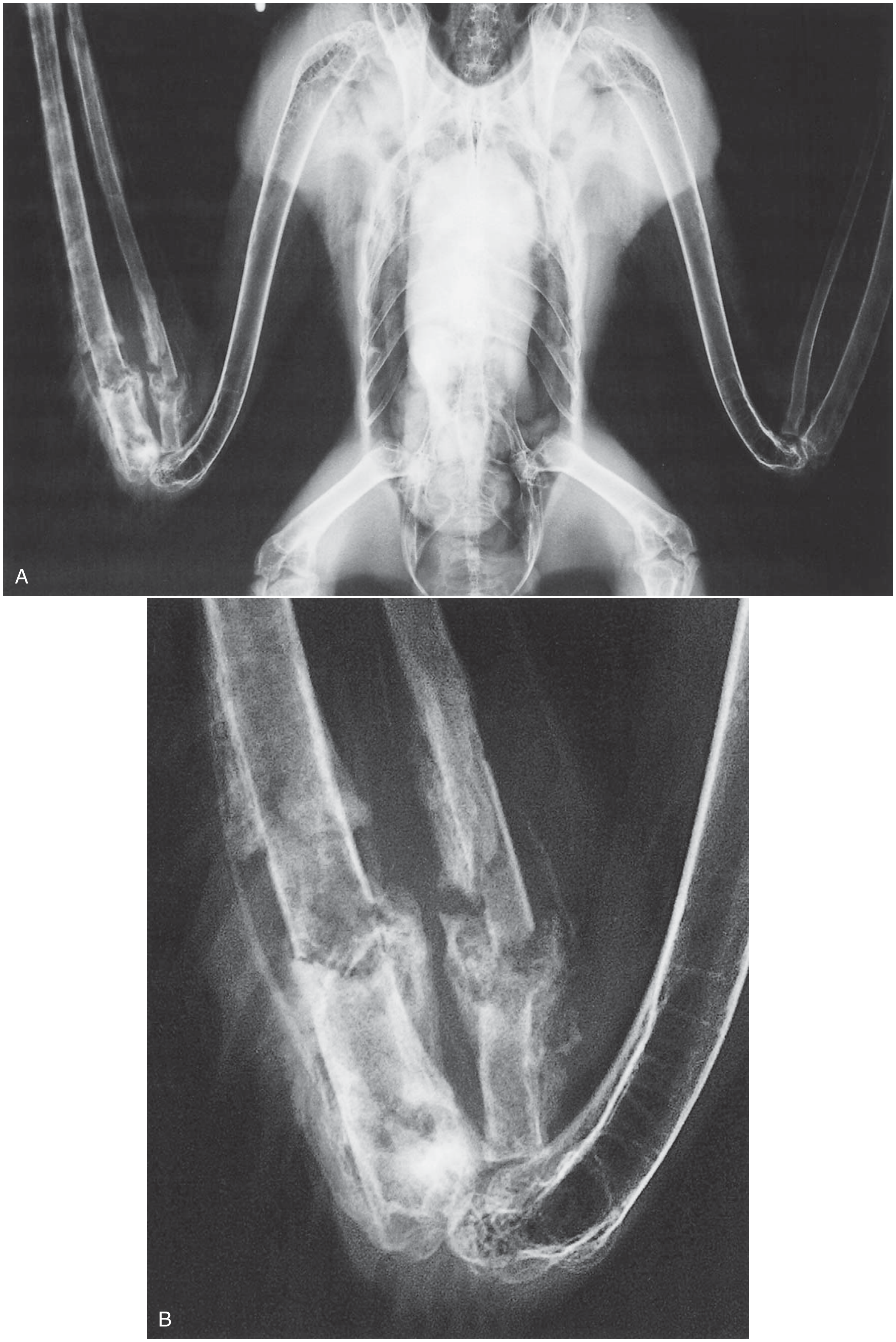

Figure 10-20 • The pins were left as is, but the bones failed to heal because of regional devascularization brought about by a combination of fragment instability and infection. **A,** Orientation and close-up **(B)** ventrodorsal views made immediately after the ineffective implants were removed illustrate most of the features of nonhealing fractures of whatever cause, including (1) persistence and widening of fracture lines, (2) absence of fracture-bridging calluses, (3) extensive bone deposition well away from the fracture sites, and (4) the presence of posttraumatic osteoporosis, especially pronounced in the radial midshaft. Also, note that there is now an additional radial fracture just below the original break. Presumably, this is an *insufficiency fracture*, an injury incurred when a structurally weakened bone is subjected to what would otherwise be considered routine bending forces.

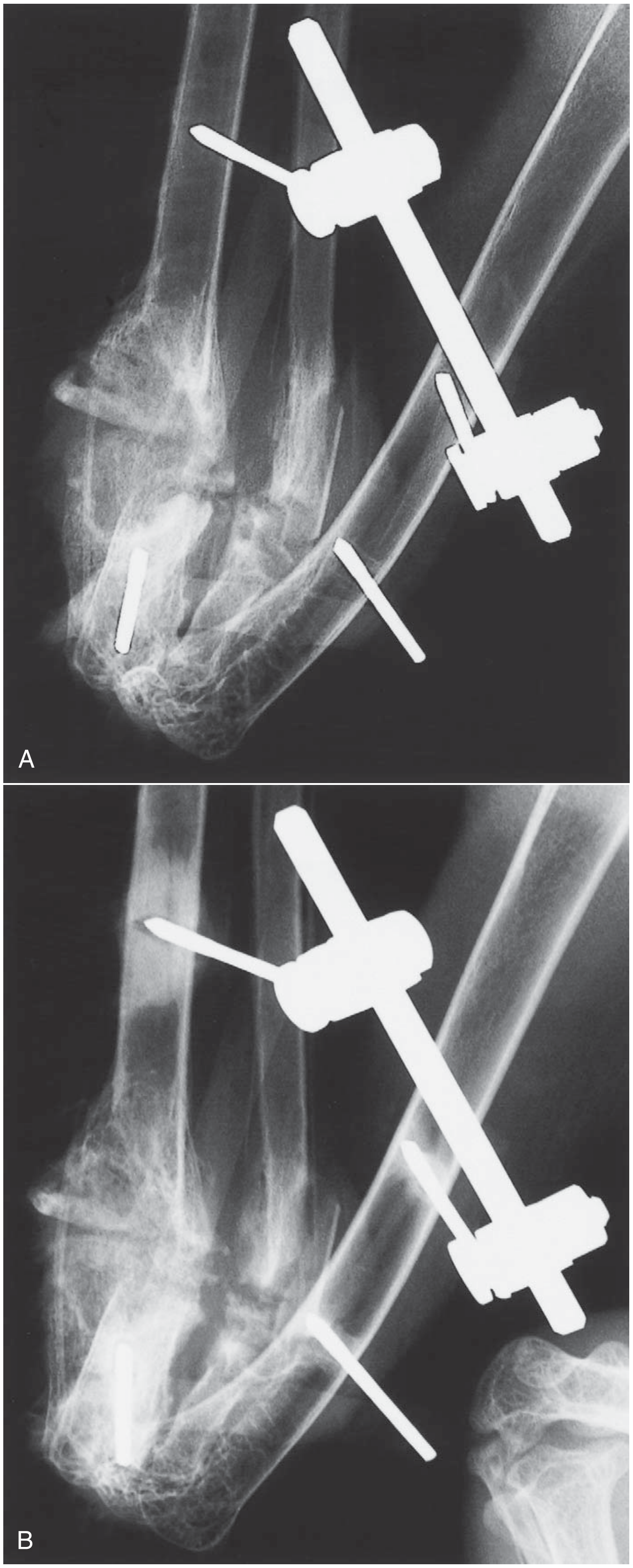

Figure 10-21 • A, Immediate postoperative ventrodorsal close-up view of the owl's second wing operation reveals a new strategy, one that unfortunately will prove no more successful than the first. Here the objective is to immobilize the fractures by placing pins into the ulna and nearby humerus, with the wing in maximal flexion, and then securing the implants to an exterior bar. **B,** A similar follow-up view made 1 month later shows localized medullary clouding, a phenomenon peculiar to birds in which new bone deposition is largely or exclusively confined to the endosteum rather than the periosteum. It is important to recognize that these sorts of bone deposits may occur as a result of a variety of stimuli and are nonspecific.

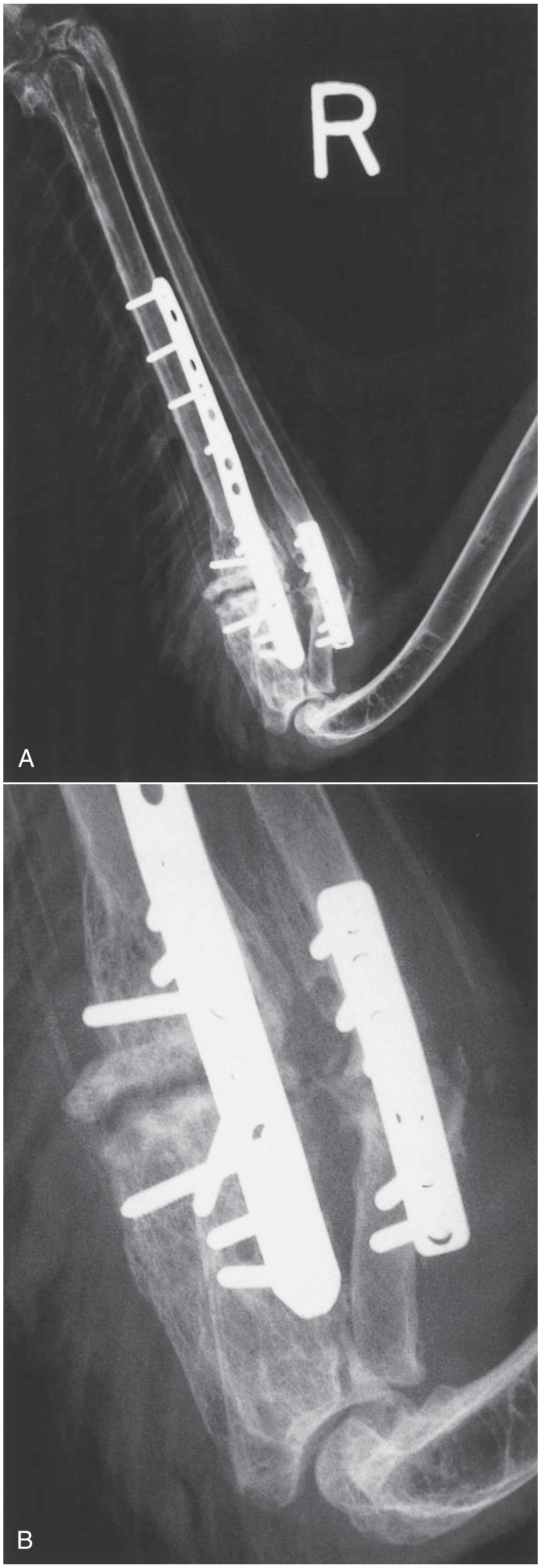

Figure 10-22 • The owl's third operation, performed in an effort to correct nonunions in both the radius and ulna, consisted of plating both fractures as seen in orientation **(A)** and close-up **(B)** ventrodorsal projections. Note the "open-lips" sign associated with the radial fracture, a characteristic radiographic feature of many avian nonunions.

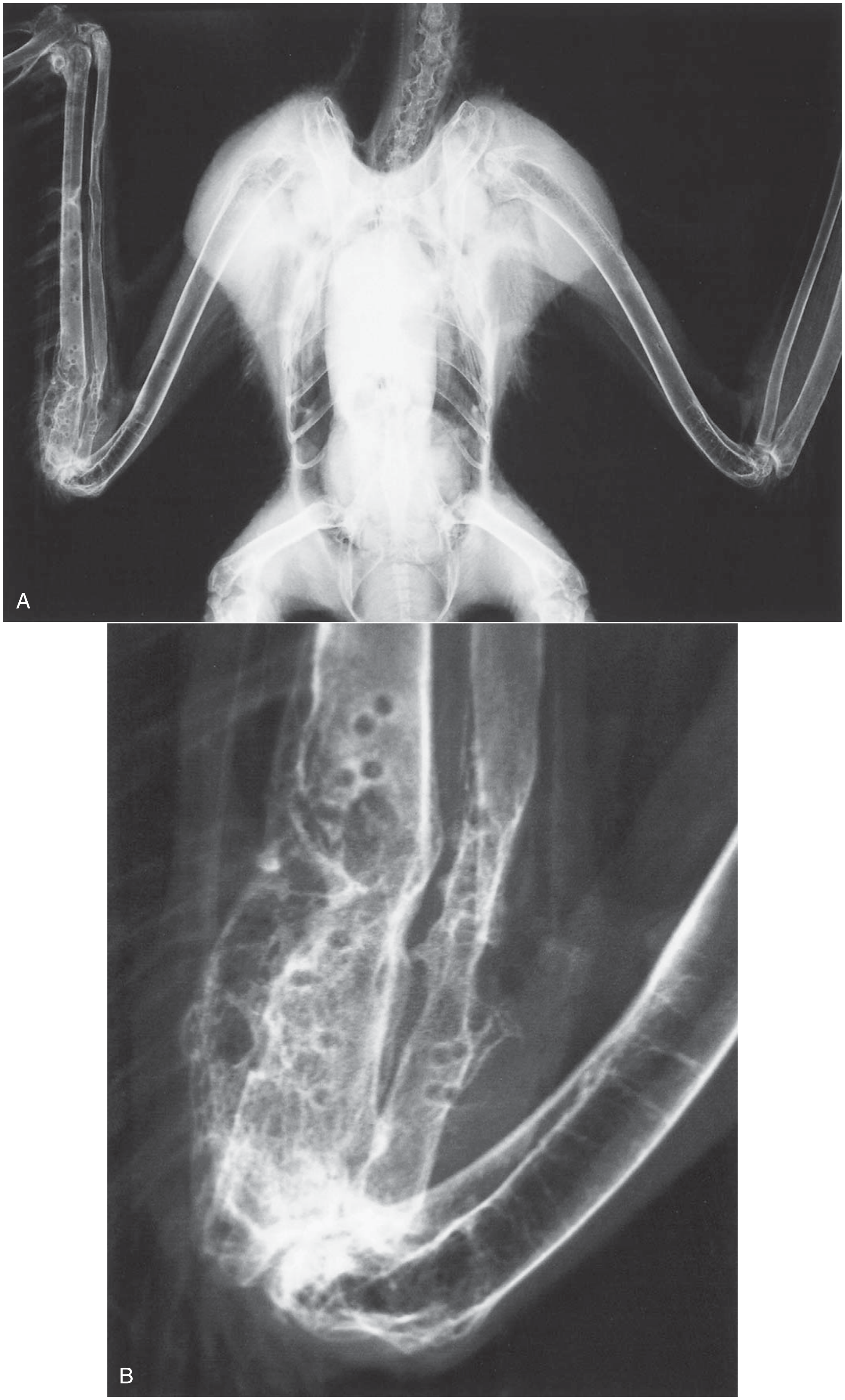

Figure 10-23 • Finally, over a year later, the ulnar fragments appear joined, although the bone is radically remodeled as seen in these orientation **(A)** and close-up **(B)** ventrodorsal projections made just after the plates were removed. The overlapped radial fragments have yet to solidify.

Chapter 11

The Wing: Soft Tissue Injuries

BRUISES, PUNCTURES, AND LACERATIONS

Bruises occur as the result of collisions with automobiles, trucks, and power lines, and they generally accompany falls after a bird has been shot. Punctures and lacerations can occur from flying into barbed wire (Figure 11-1) or from being attacked by a dog, cat, or wild animal. Some of these wounds can be difficult to detect because they are hidden beneath layers of feathers and have not bled a great deal.

STRAINS

Among the most serious wing strains are those occurring to the body or tendon of the primary flight muscles, the pectoralis or supracoracoideus. Complete severance, rupture, or avulsion of either the origin or insertion of these flight-critical muscles constitutes an even more serious injury.

SPRAINS

Propatagial Ligament

The *propatagial ligament,* a large, cordlike ligament strung from the shoulder to the carpus, provides the principal leading-edge support for the skin and feathers covering the proximal half of the wing. Additionally, the propatagiale ligament assumes some of the load placed on the wing when in flight and functions as a stabilizer to counteract the buffeting force of the wind. Damage to this critical part of the wing may secondarily result in a defective or deformed wing surface, for which a bird may or may not be able to compensate by adjusting its various control surfaces (Figure 11-2).

Dislocations

Although radiographically invisible, serious sprains can be inferred from dislocations (luxations, subluxations). For example, a complete dislocation of the elbow must at the very least stretch (and in many instances tear) one or both collateral ligaments. Accordingly, such injuries must be promptly relocated and immobilized long enough for the ligament to heal. If not, the joint will become arthritic.

POSTTRAUMATIC MUSCLE ATROPHY AND LOSS OF TENDON ELASTICITY

Although not an actual injury, posttraumatic muscle atrophy, with a concomitant loss in tendon elasticity, poses a serious threat to normal flight. The only practical way for a bird to regain muscle mass and flexibility is to use its injured wing—a process that initially can be quite slow. Thus the necessity for controlled rehabilitation, especially in the case of raptors.

Figure 11-1 • Close-up ventrodorsal view of the right wing of a great horned owl recently trapped in a barbed-wire fence shows a number of abnormalities, including (1) a deep gas pocket lying against the distal humerus, (2) disruption of the muscle contours of the forewing, (3) a hematoma in the central portion of the propatagiale ligament, and (4) numerous broken feathers.

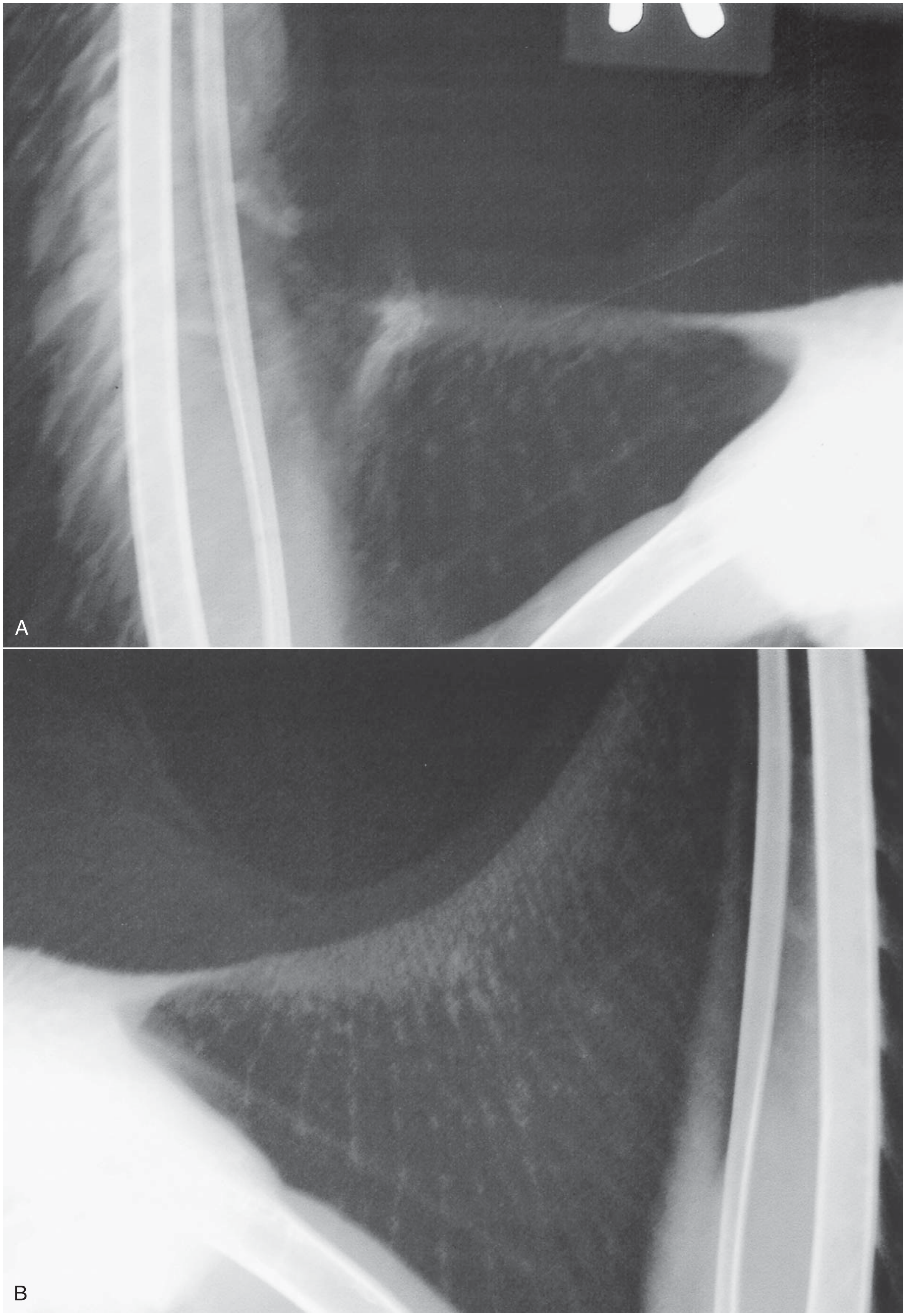

Figure 11-2 • A, Close-up view of a severely torn and detached right propatagiale ligament in a hawk. **B,** The uninjured left propatagiale ligament is provided for comparison.

Chapter 12

The Wing: Dislocation, Fracture-Dislocation, and Traumatic Amputation and Avulsion

DISLOCATION

Pure dislocations of the humeral, cubital, radiocarpal, or ulna carpal joints of birds are not nearly as frequent as combined fracture-dislocations. The elbow is dislocated most often (Figure 12-1), followed by the shoulder.

FRACTURE-DISLOCATION

Fracture-dislocations occur most commonly in the elbow joints of birds. As with all dislocations, the associated ligaments are stretched, torn, or avulsed and termed *first-, second-, and third-degree sprains*. Typically, both the humeroulnar and humeroradial joints are dislocated and/or fractured (Figure 12-2). Less frequently, one or both cubital joints are dislocated secondary to an articular fracture of the distal humerus (Figure 12-3). Most shoulder dislocations are associated with a displaced coracoid fracture, with scapular or clavicular injury (Figure 12-4).

TRAUMATIC AMPUTATION AND AVULSION

Traumatic amputations occur most often in the distal portion of the wing at the level of the midmetacarpus or distal metacarpus, typically removing the distal half of the wing in the process (Figures 12-5 through 12-7). Less often, the second digit is simply ripped free of its attachment to the metacarpus, taking the distal part of the wing along with it (Figure 12-8). Such injuries effectively pinion the bird, making flight impossible.

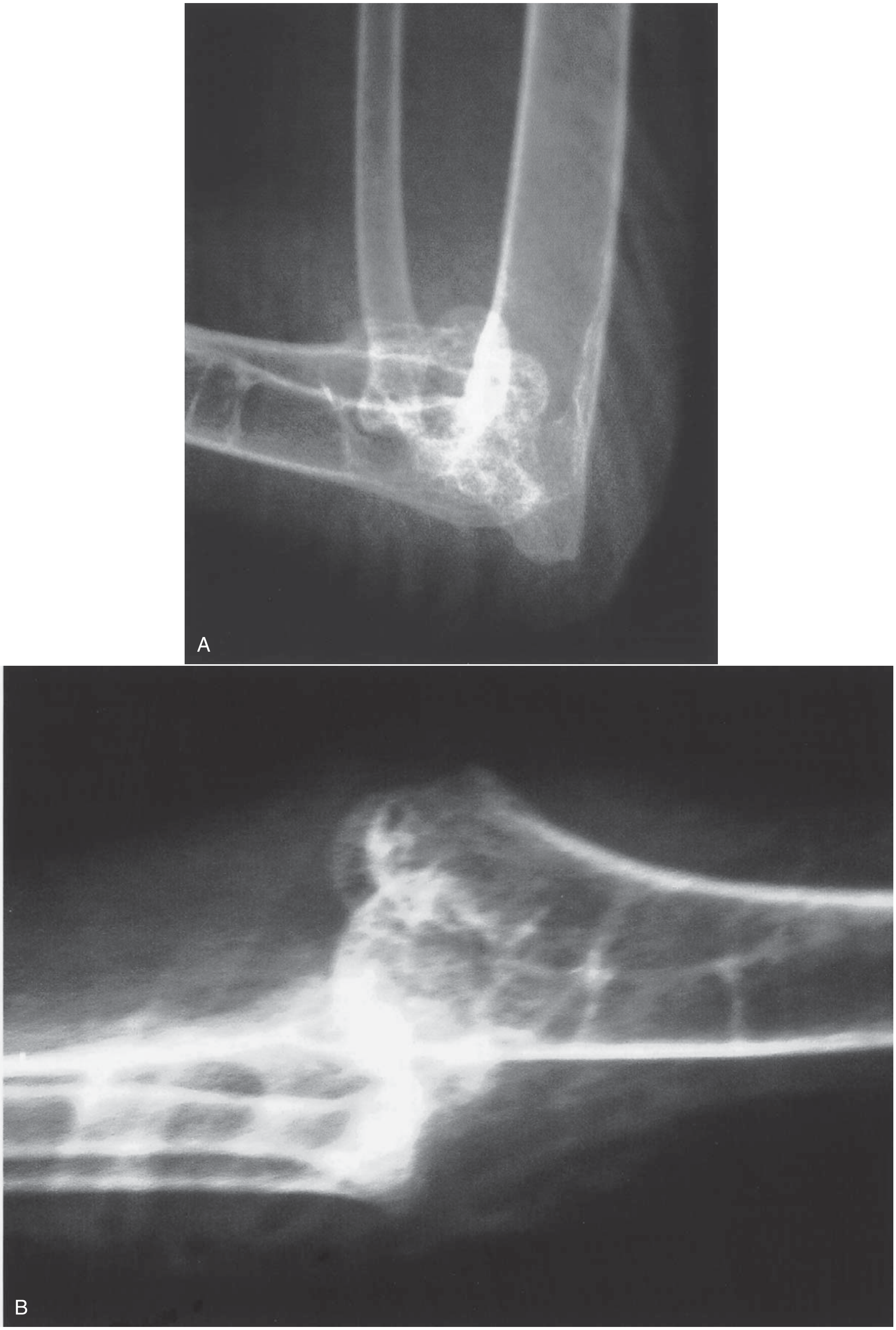

Figure 12-1 • Dislocated elbow in a hawk. **A,** Close-up ventrodorsal and **(B)** leading edge projections show that the injury is not fresh, as indicated by periarticular and extraarticular new bone deposition on the proximal radius. Marked regional swelling is the result of scarring.

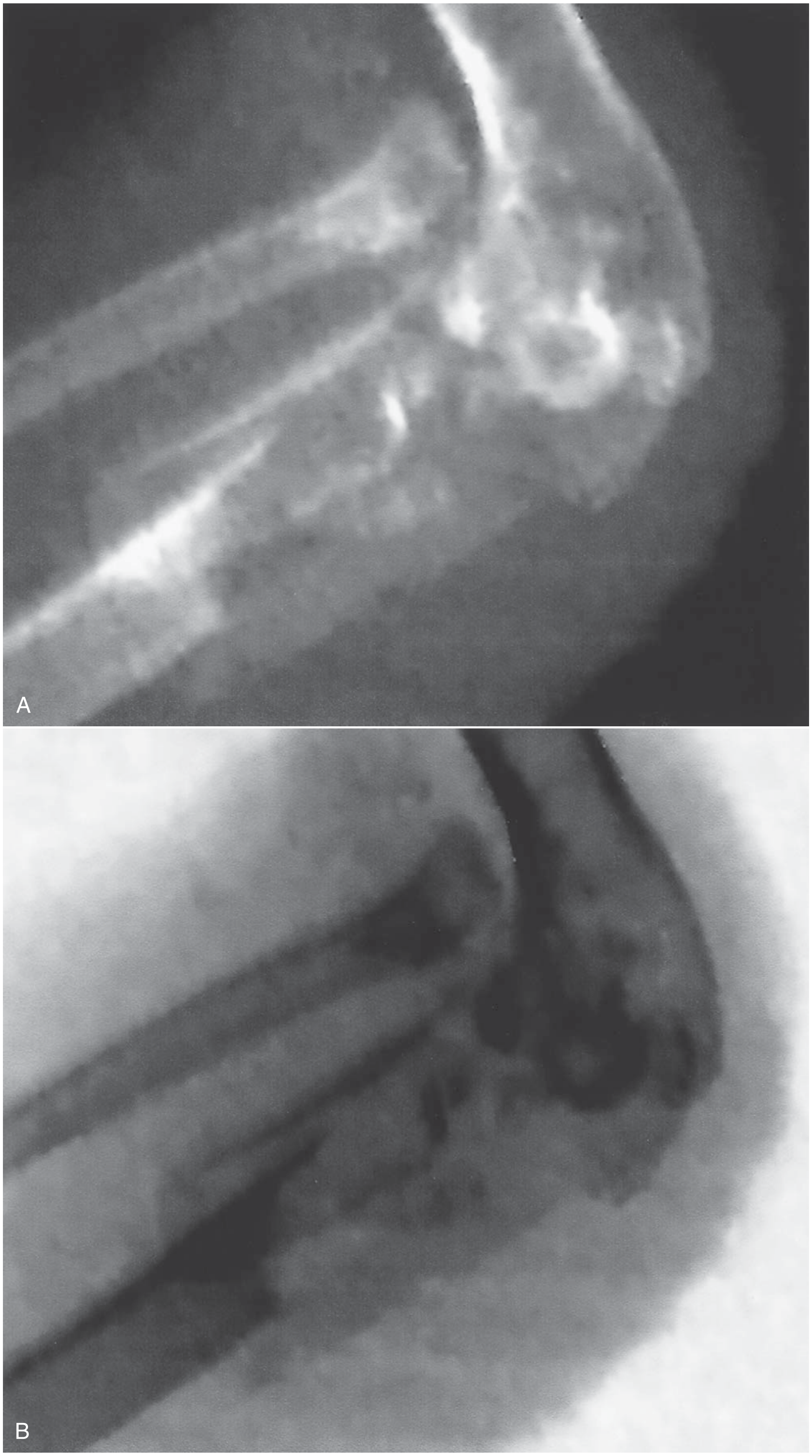

Figure 12-2 • Subacute fracture-dislocation in an owl. **A,** Ventrodorsal close-up shows a fully dislocated proximal radius and a badly comminuted, partially dislocated proximal ulna. The pronounced density loss in the ulna is due to avascular necrosis. **B,** A negative image accentuates the described ulnar bone loss, as well as the subcapital radial fracture, which appears as a dark overlap band.

Figure 12-3 • Fracture-dislocation in a robin. **A,** Orientation, close-up **(B),** and ultraclose **(C)** ventrodorsal views of the right wing and elbow show detachment and splitting of the distal humeral condyle with dislocation of both cubital joints. **D,** A leading edge projection reveals the full extent of the dislocation. *Continued*

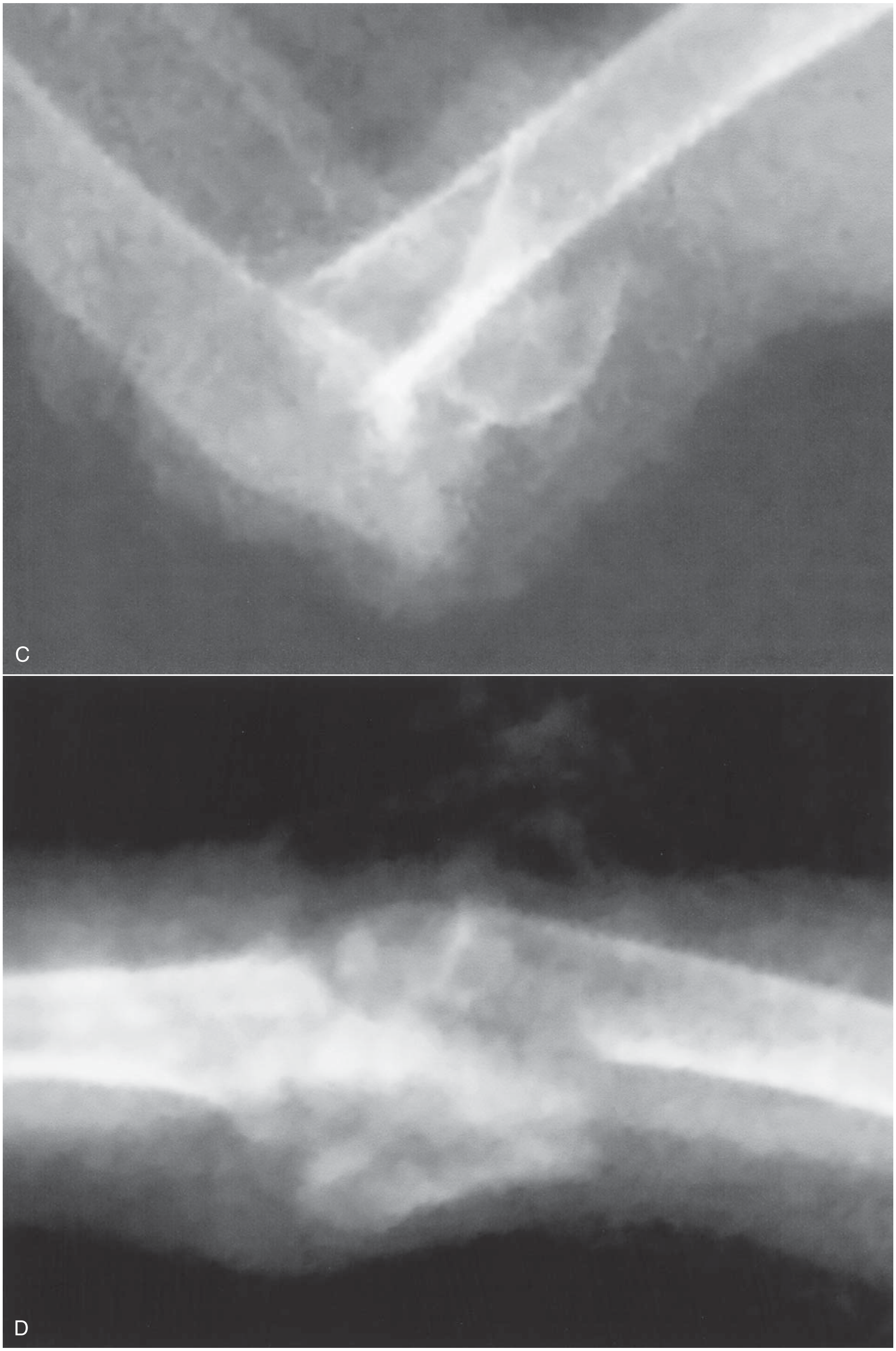

Figure 12-3, cont'd • For legend see p. 127.

Figure 12-4 • Dislocated left shoulder in a hawk. Close-up ventrodorsal view of the shoulder region shows luxation of the left humeral joint in conjunction with displaced fractures of the left central coracoid and proximal scapula. This pattern of injury is regularly seen in raptors.

Figure 12-5 • Traumatic amputation in a mountain bluebird. Ventrodorsal projection of the wings and shoulder region shows absence of right distal metacarpus and digits.

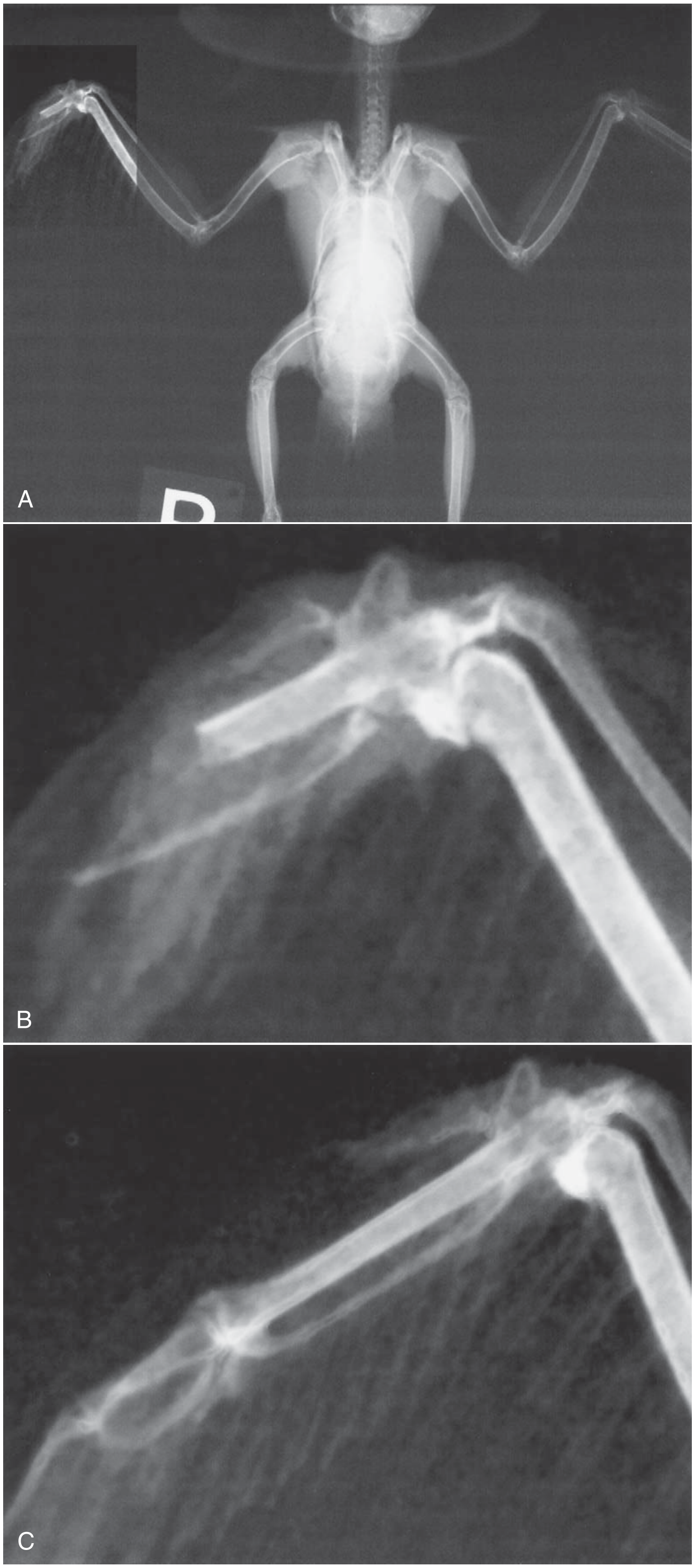

Figure 12-6 • Traumatic amputation in a kestrel. **A,** Orientation and close-up ventrodorsal views of right skeletal wingtip **(B)** show absence of distal half of the major metacarpal and distal minor metacarpal bones and the associated digits. **C,** The normal left wingtip is provided for comparison.

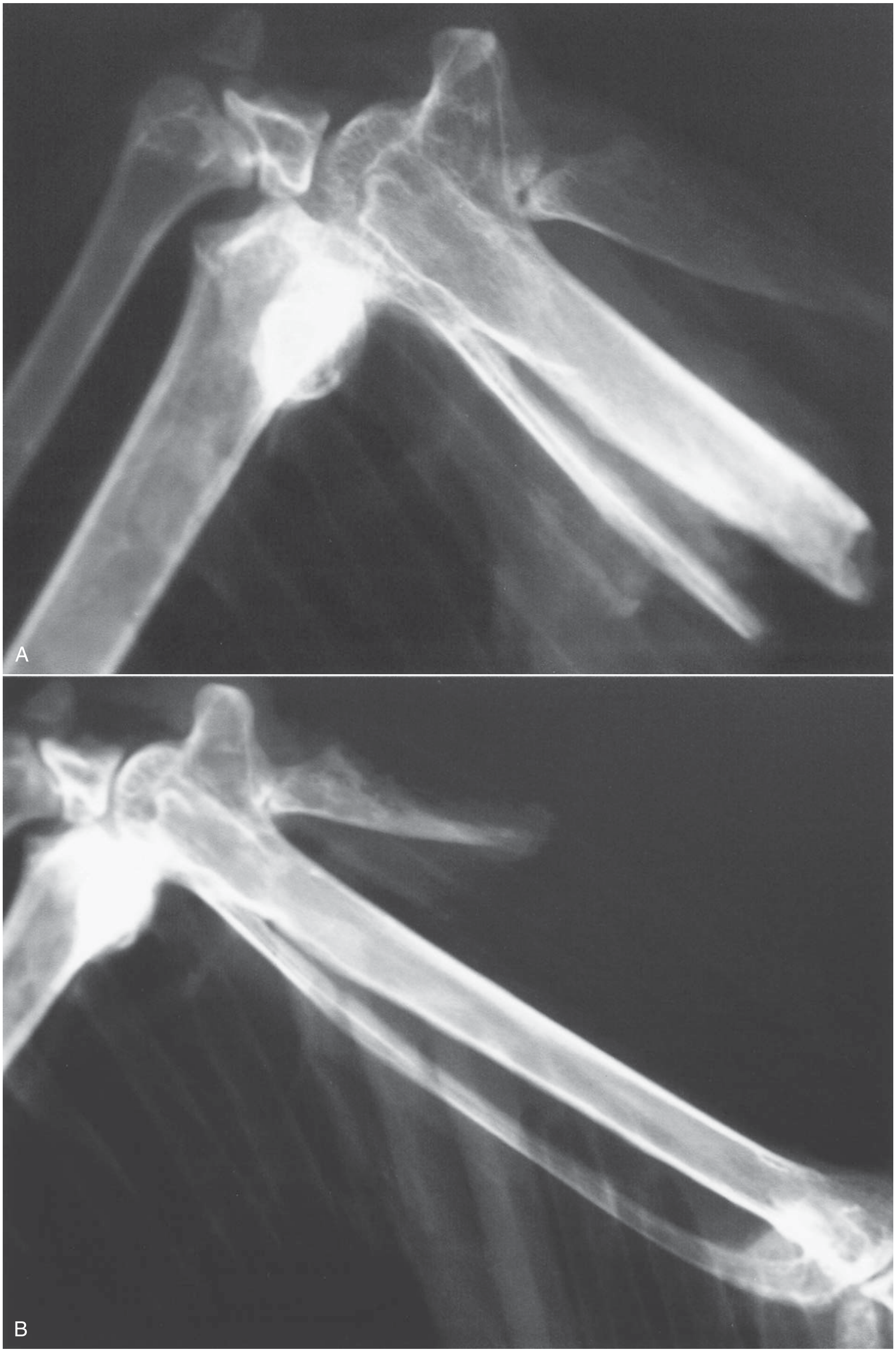

Figure 12-7 • Traumatic amputation in an eagle. **A,** Close-up ventrodorsal view of the distal aspect of the right wing shows nothing beyond the severed midmetacarpus. **B,** The normal left wingtip is provided for comparison.

Figure 12-8 • Traumatic avulsion in an eagle. The first and second phalanges of the second digit have been torn from the distal metacarpus (and each other) as seen in this ventrodorsal close-up view.

Chapter 13

The Wing: Gunshots

ON SHOOTING BIRDS

Birds are shot for a variety of reasons, some more legitimate than others: Hunters shoot birds for sport, ranchers dispose of pests, and others simply seek a target of convenience. Some shoot birds to have them mounted, preferring to view them over mantelpieces rather than in the wild. But whatever the reason, people shoot birds, sometimes killing them, sometimes not.

When a bird is shot, it may be killed outright or it may be incapacitated, falling to the earth where it may sustain further injuries, which may or may not be fatal in their own right. Ironically, an injured water bird may drown before it can reach shore.

Once it finds itself earth bound, an injured bird will usually take refuge in the nearest cover, where it will remain until it feels compelled to leave in search of food and water. It is in this later circumstance where it must potentially contend with its most formidable danger, predators.

Shotgun Wounds

Radiographically, shotgun wounds appear as one or more spherical metallic densities, some of which may be deformed as a result of striking bone. Fractures may result from shotgun wounds.

Air Gun Pellet Wounds

Air gun pellets have a distinctive appearance that resembles a symmetrically crimped bullet. Although capable of causing fatal injury, especially at short range, most air gun pellets lodge beneath the skin or in the superficial soft tissue and usually do not cause fractures. Projectile deformity is exceptional.

Occasionally, air gun pellets become lodged in or against complex joints, such as the shoulder, causing debilitating pain or mechanical interference (Figure 13-1). Pellets may also interfere with the opening or closing of hinge or rotary joints, such as the elbow, carpometacarpus, or metacarpophalangeal articulations (Figure 13-2), as well as secondarily impeding the action of tendons that regulate the critical control surfaces of the wing.

BB Gun Wounds

BB gun wounds rarely result in fractures but these ubiquitous projectiles are capable of deeply penetrating the wing and may even enter a joint. BBs, unlike lead or alloy shot, are quite hard and rarely become deformed. BBs are inert under most circumstances, are disinclined to migrate, and in my experience do not lead to abscesses.

Low-Velocity Gunshot Wounds

The most common low-velocity gunshot wounds sustained by birds are from 22 caliber rifles. Head, neck, and torso wounds are often fatal. Direct midextremital and upper extremital hits can result in fracture, especially if the bird is small and shot at short range. More distally situated wounds usually damage feathers and imbed beneath the skin.

High-Velocity Gunshot Wounds

High-velocity gunshot wounds are more often than not fatal. Distal extremital wounds can be survived, especially if the bird is not seriously injured in the subsequent fall. Grazing wounds to the midextremity and upper extremity often cause substantial wing damage but lack the knockdown power of a direct hit. Some wounded birds are capable of making a crash landing of sorts, somewhat resembling that of a partially disabled helicopter.

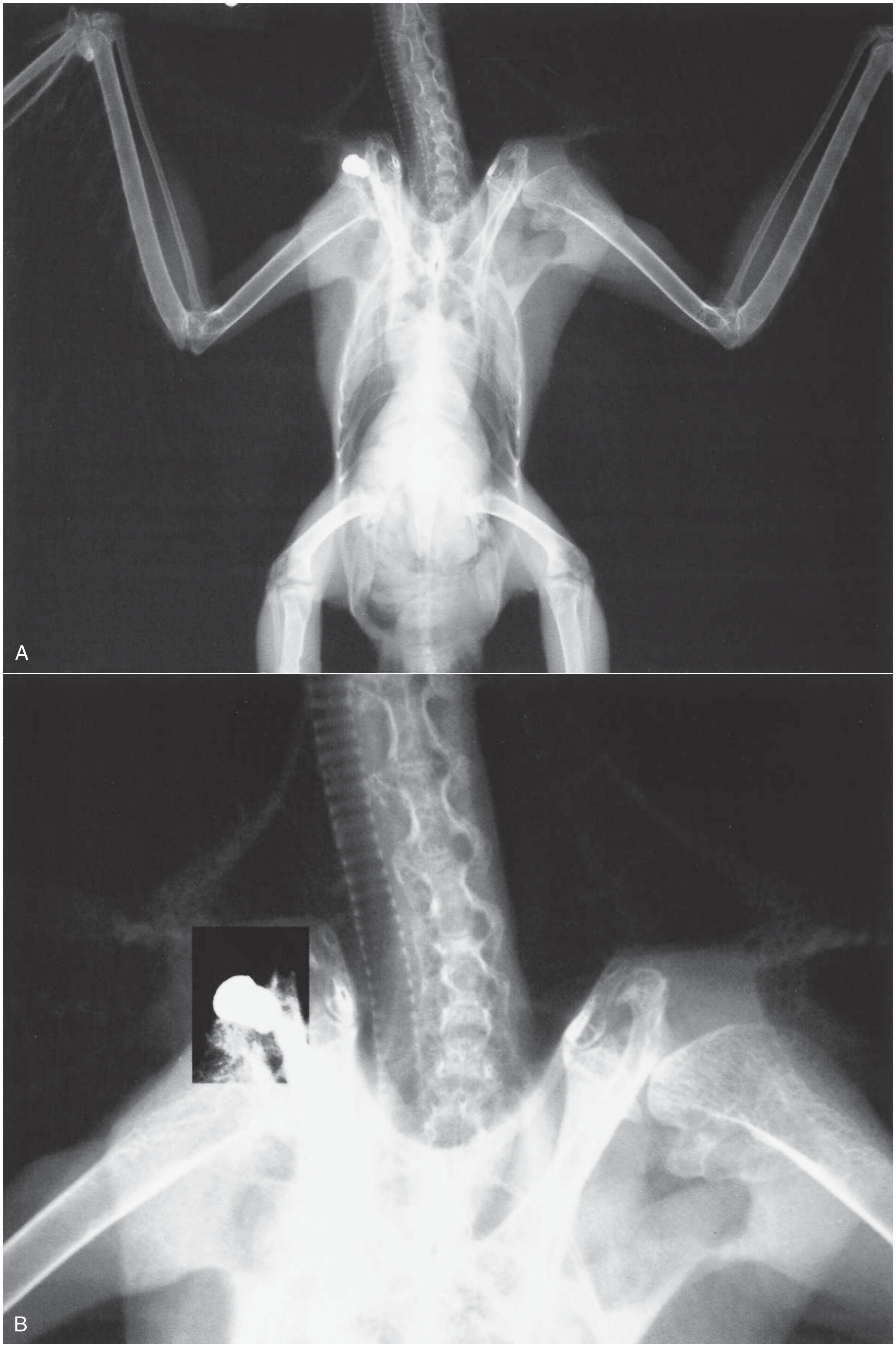

Figure 13-1 • A, Orientation, enhanced ventrodorsal close-up **(B),** wings-up lateral **(C),** and leading edge **(D)** views. Only **D** clearly shows that the pellet lies outside the humeral joint.

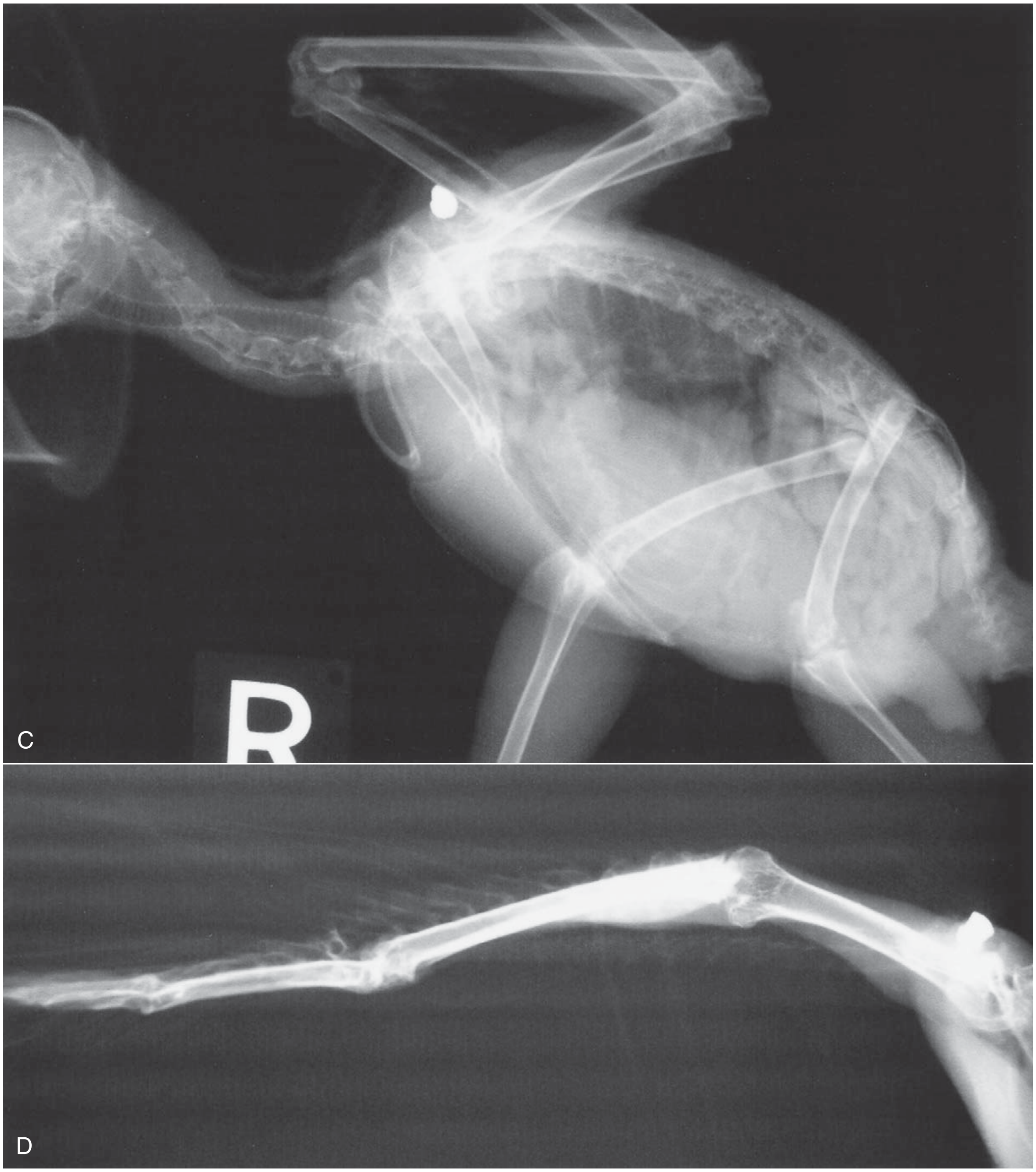

Figure 13-1, cont'd • For legend see opposite page.

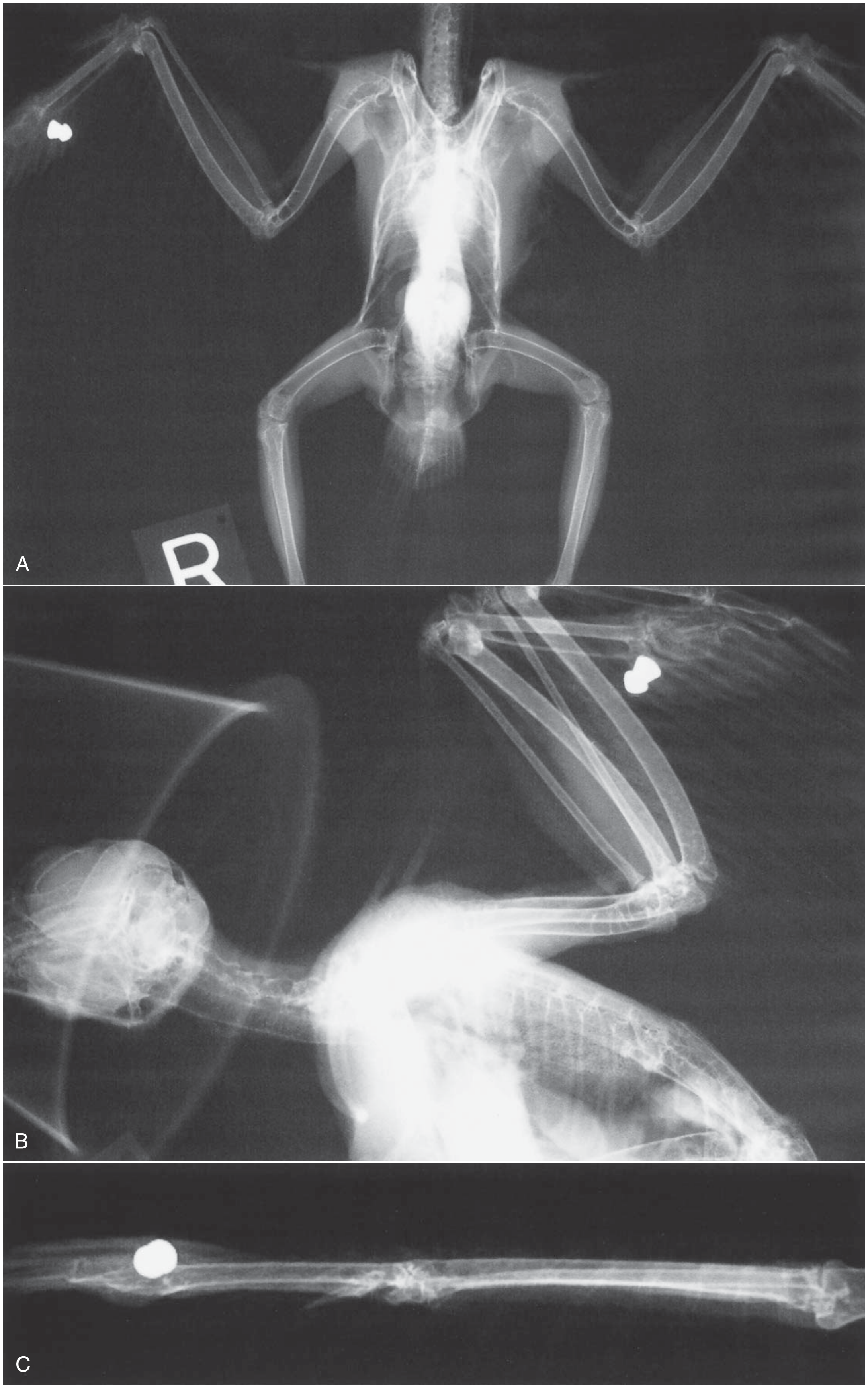

Figure 13-2 • As in Figure 13-1, the extended ventrodorsal **(A)** and lateral **(B)** views of the right wing of a recently shot Merlin suggest the pellet lies against the metacarpophalangeal joint, a suspicion that is subsequently confirmed by the accompanying leading edge projection **(C)**.

Figure 13-3 • A, Orientation and close-up **(B)** ventrodorsal oblique projections of an owl shot in the left shoulder by a high-velocity bullet reveal a shattered humeral joint in which the proximal scapula, coracoid, and humerus have all been fractured and, to various extents, dislocated. All that remains of the bullet are a few flecks of metal in and around the shoulder joint **(B).** The needlelike object in the left tibia is an intramedullary catheter **(C)** used to administer injectables.

Continued

Generally, the bulk of a rifle bullet passes completely through a bird, leaving only a series of small fragments in its wake, especially in and around fractured bone (Figure 13-3). The enormous kinetic energy that builds up in high-velocity bullets typically causes the bone to shatter on impact, which is particularly devastating when it occurs in or around a joint (Figure 13-4).

Other Missile-Related Fractures

Occasionally, we tend to birds that have sustained a fracture as a result of being hit by a rock as reported by an eyewitness. Based on such accounts and somewhat surprisingly, an adult is just as likely to have inflicted the injury as a juvenile. In the example provided, an immature seagull, part of a large flock resting on a sandbar, was hit in the right shoulder by a rock thrown from the shore (Figure 13-5).

Homemade or commercial slingshots, loaded either with small rocks, ball bearings, or purpose-built ammunition, are capable of causing serious injury, with headshots often proving fatal.

Wound Debris

Raptors hunting the northern logging roads are subject to being struck by vehicles and, in the process, hurled to the densely packed gravel surfaces where their wounds become readily contaminated. When radiographed, embedded gravel may be confused with fracture fragments, and for this reason it is best to remove as much of the road debris as practical before radiographing the bird (Figure 13-6).

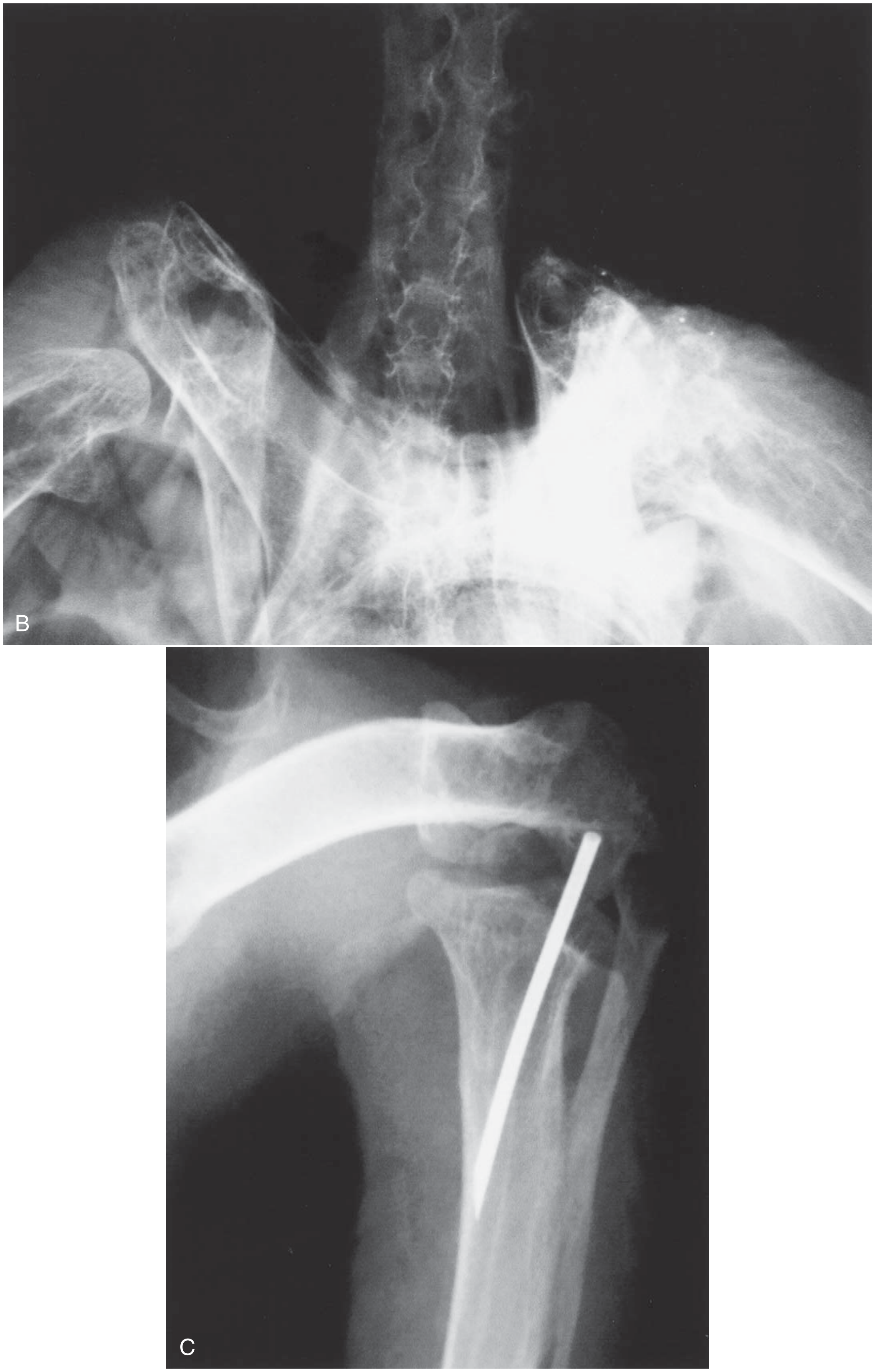

Figure 13-3, cont'd • For legend see p. 137.

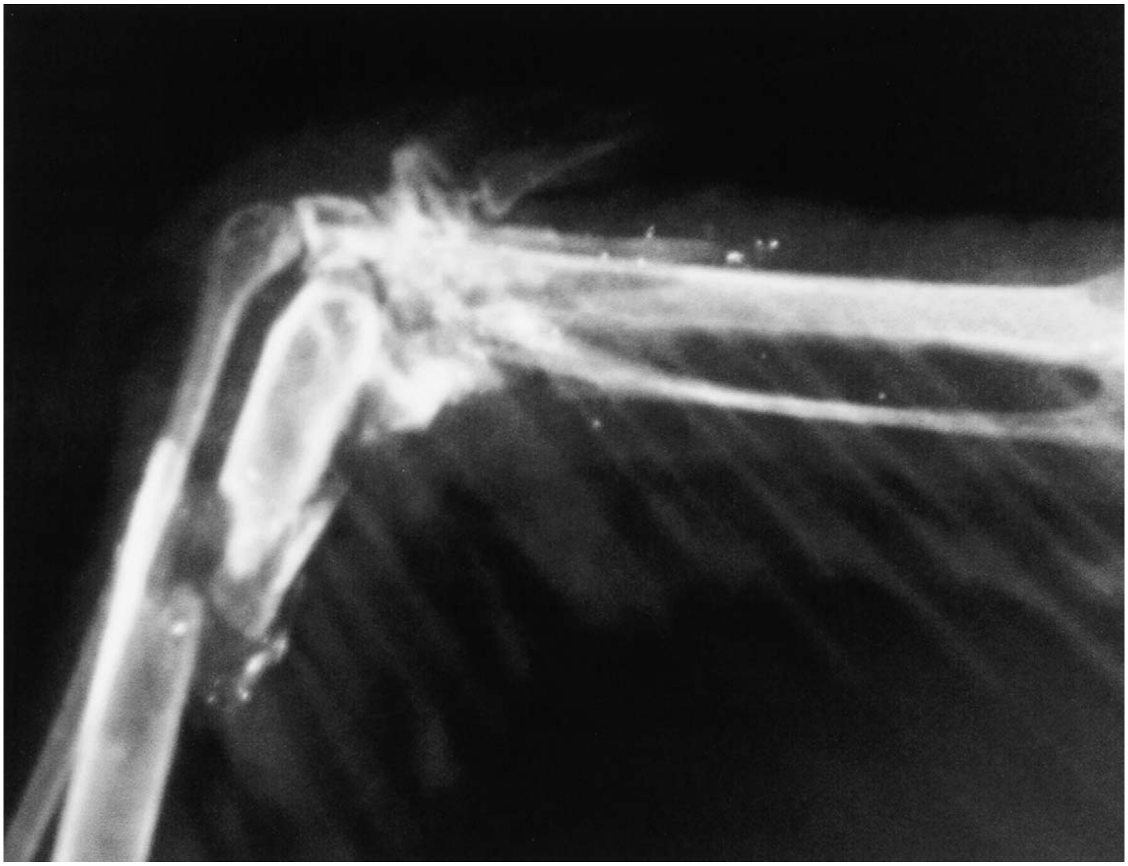

Figure 13-4 • Close-up ventrodorsal view of the carpal region of a snowy owl shot by a high-velocity bullet shows displaced comminuted fractures of the distal ulnar body and proximal major metacarpal bone, which severely disrupt the carpometacarpal joint. It appears that the ulnar carpal bone has been fractured and dislocated and is now in the process of being bound to the fractured metacarpus by callus.

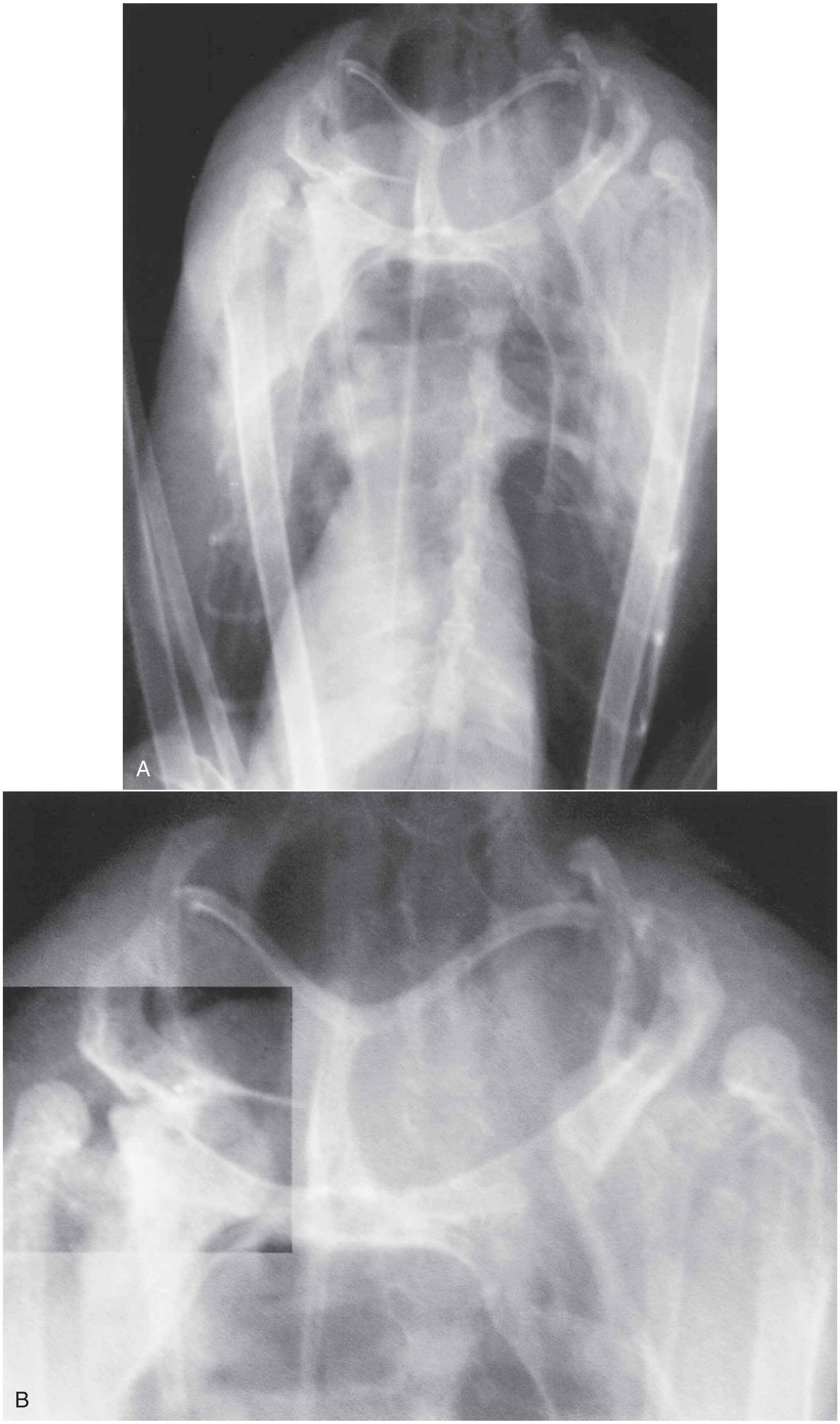

Figure 13-5 • A, Orientation and close-up **(B)** flexed ventrodorsal oblique views of a immature gull recently hit in the right shoulder by a rock show a badly displaced right coracoid fracture and separated humeral joint (emphasis zone in **B**).

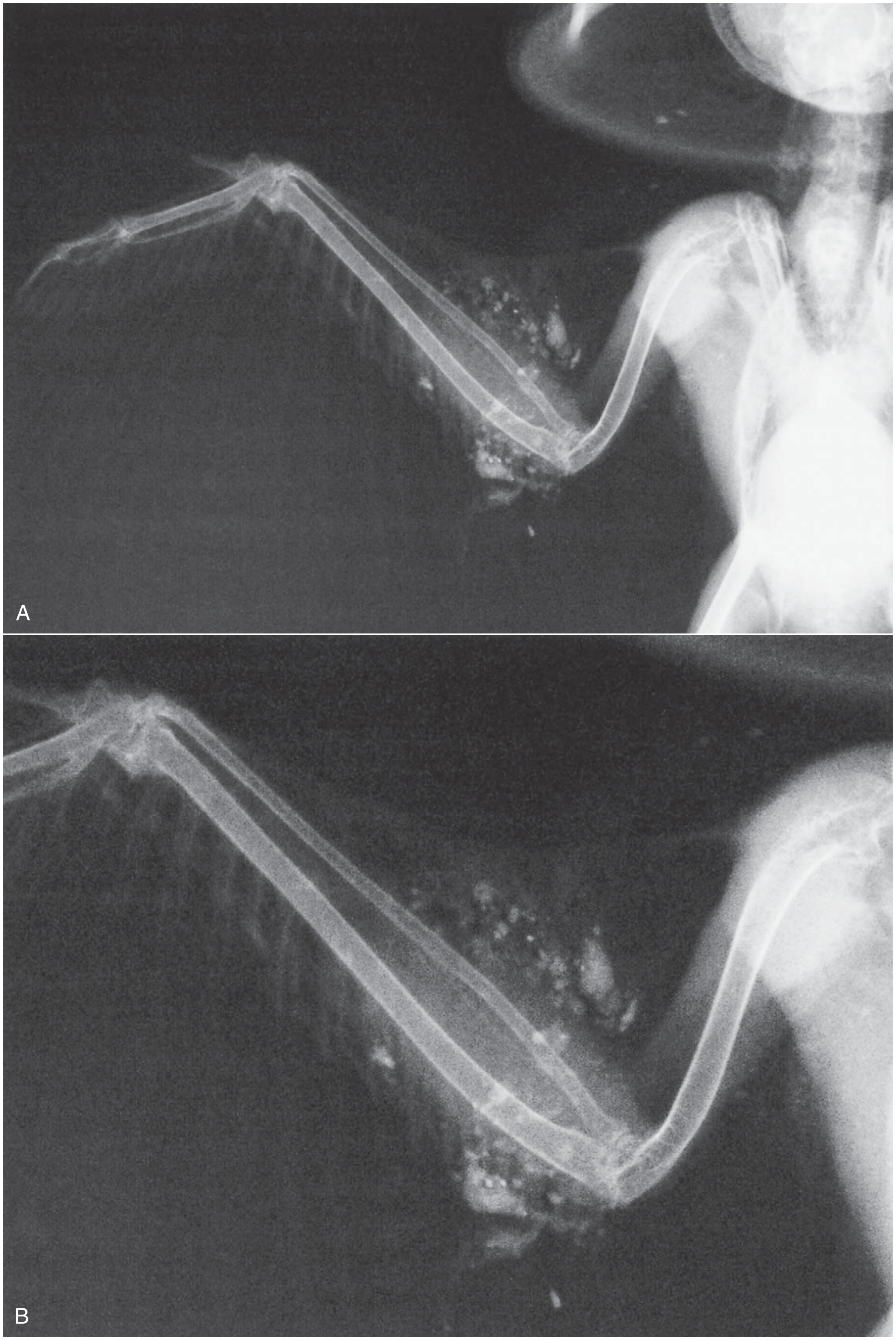

Figure 13-6 • A, Orientation and close-up **(B)** ventrodorsal views of a Merlin found unable to fly along the shoulder of a northern grid road. On first impression the proximal ulnar and radial bodies appear shattered, but closer inspection reveals no fractures, only extensive gravel embedded in the surrounding soft tissue.

Chapter 14

The Wing: Infections

SURGICAL INFECTIONS

Surgical infections are most often associated with attempted fracture repair, including revisions. The damaging effects to the avian bone, as seen radiographically, closely resemble those reported in mammals: cortical and medullary destruction, sequestration, inappropriate new bone deposition, plus or minus the formation of a nonpurposeful callus (Figures 14-1 and 14-2). These features may be accompanied by implant dislocation.

OPEN FRACTURE INFECTIONS

Open fractures are considered by many authorities to be already infected at the time they are initially seen, which is a reasonable assumption given the high incidence of failed repair in such birds (Figures 14-3 and 14-4).

SYSTEMIC INFECTIONS

Systemic infections in birds are often characterized radiographically by multiple localized lesions, which may assume a variety of forms. Most appear first as medullary clouding, and later, a surface reaction often becomes apparent. In unchecked infection, cortical sequestra may develop, sometimes enveloped by well-defined involucra. I see such lesions only rarely, although they are reported.

BONE DESTRUCTION VERSUS BONE REDUCTION

Localized bone loss, especially when identified in conjunction with the surgical reduction of a fracture, is often mistakenly attributed to infection. Although this might be an accurate interpretation, it also may be incorrect. Other possible explanations for bone reduction in a postoperative context include: (1) fragment movement, (2) small-scale implant movement (cyclic movement), or (3) full-fledged dislocation (sometimes termed *migration*).

Localized Infection

Open fractures in and around joints, particularly those associated with puncture wounds, can lead to quite localized infections, which are occasionally associated with abscess. Unlike the more usual type of infection, which often ranges up and down the shaft of the infected bone, this localized form of osteomyelitis typically is confined to the joint and immediately surrounding areas, slowing dissolving the bony tissue, behaving in this respect much as a malignant synovioma. For this reason, these kinds of infection are often termed *low grade* or *smoldering* (Figures 14-5 and 14-6).

Figure 14-1 • Close-up view of the distal ulna of a crow after repair of a closed comminuted fracture shows a severe surgical infection that resulted in the devitalization of much of the distal ulna, including the lateral half of the condyle, which has become detached. There is almost no purposeful callus formation, that is, there is no new bone crossing the now widely separated fracture fragments. A large amount of inappropriate new bone, which provides no fragment stabilization, has been lain down along the originally unaffected portion of the ulna, nearly reaching the elbow joint. A faint cloak of new bone has also developed around the distal radial shaft, signaling the further spread of the infection. The fracture fragments have moved away from the pin rather than the other way around, which is typical of fractures reduced with a snugly fitted intramedullary pin that subsequently become infected,

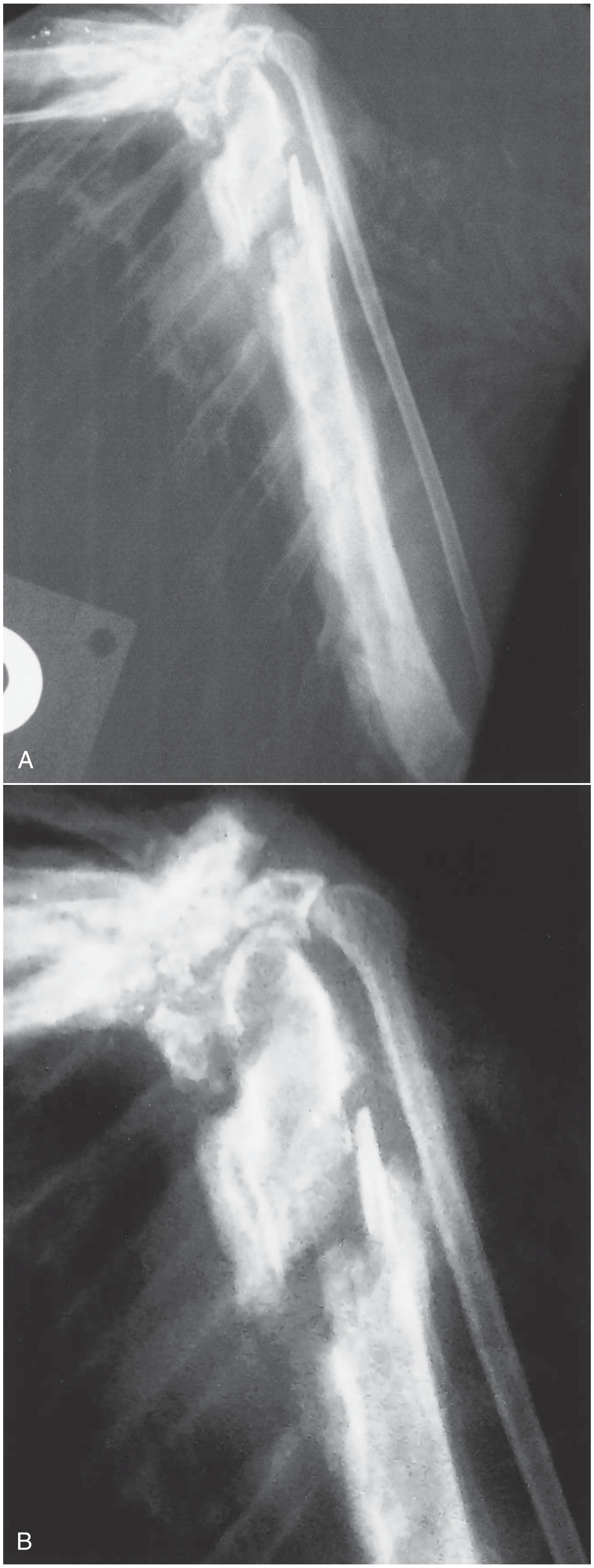

Figure 14-2 • A, Orientation and close-up **(B)** ventrodorsal views made after pin removal show that much of the new bone elicited by the infection through the combined processes of ischemia, thrombosis, devascularization, and necrosis has developed in the diaphyseal interior rather than on the exterior as it did initially.

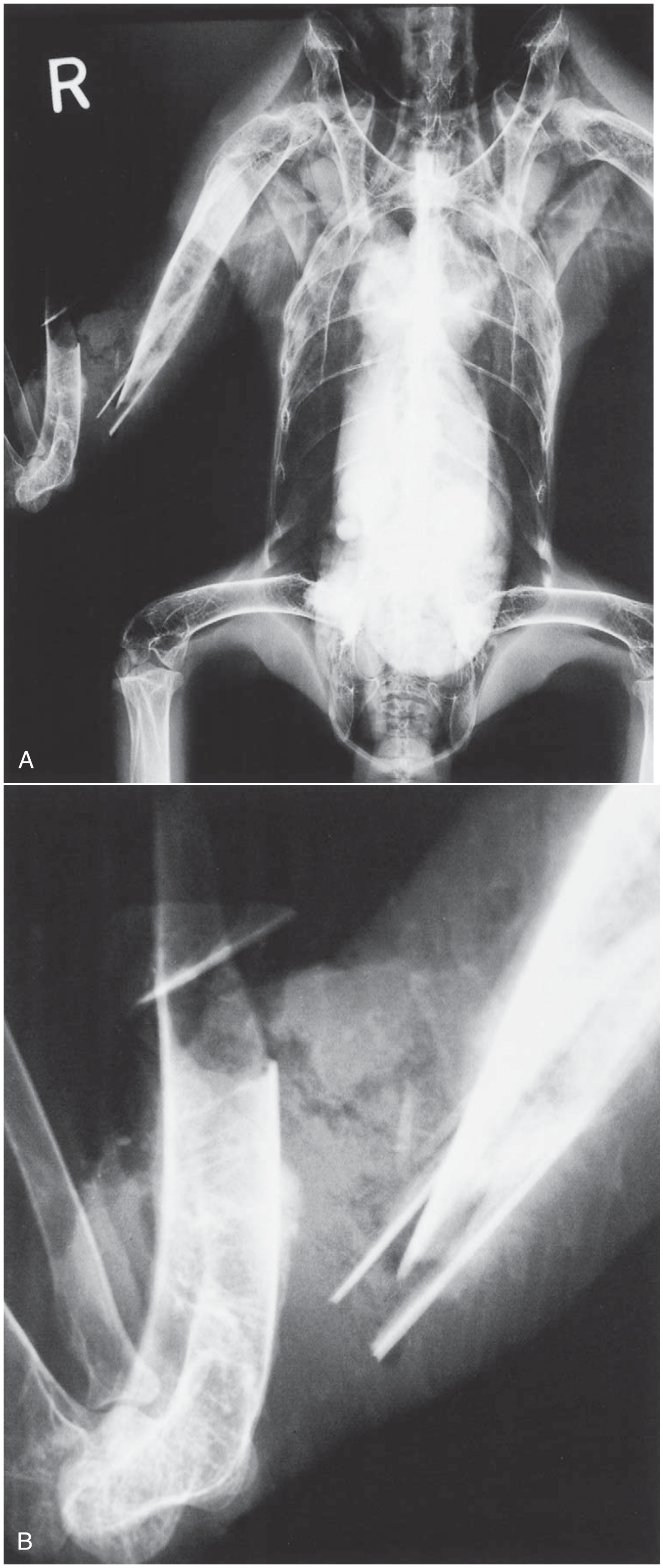

Figure 14-3 • A, Orientation and close-up **(B)** projections of an open, badly displaced, distal humeral body fracture in a bald eagle. The new bone deposits on the surfaces of the fragments attest to the subacute nature of the injury.

Figure 14-4 • Close-up view of an open humeral fracture in a hawk. The wound is nearly invisible among the damaged flight and insulation feathers.

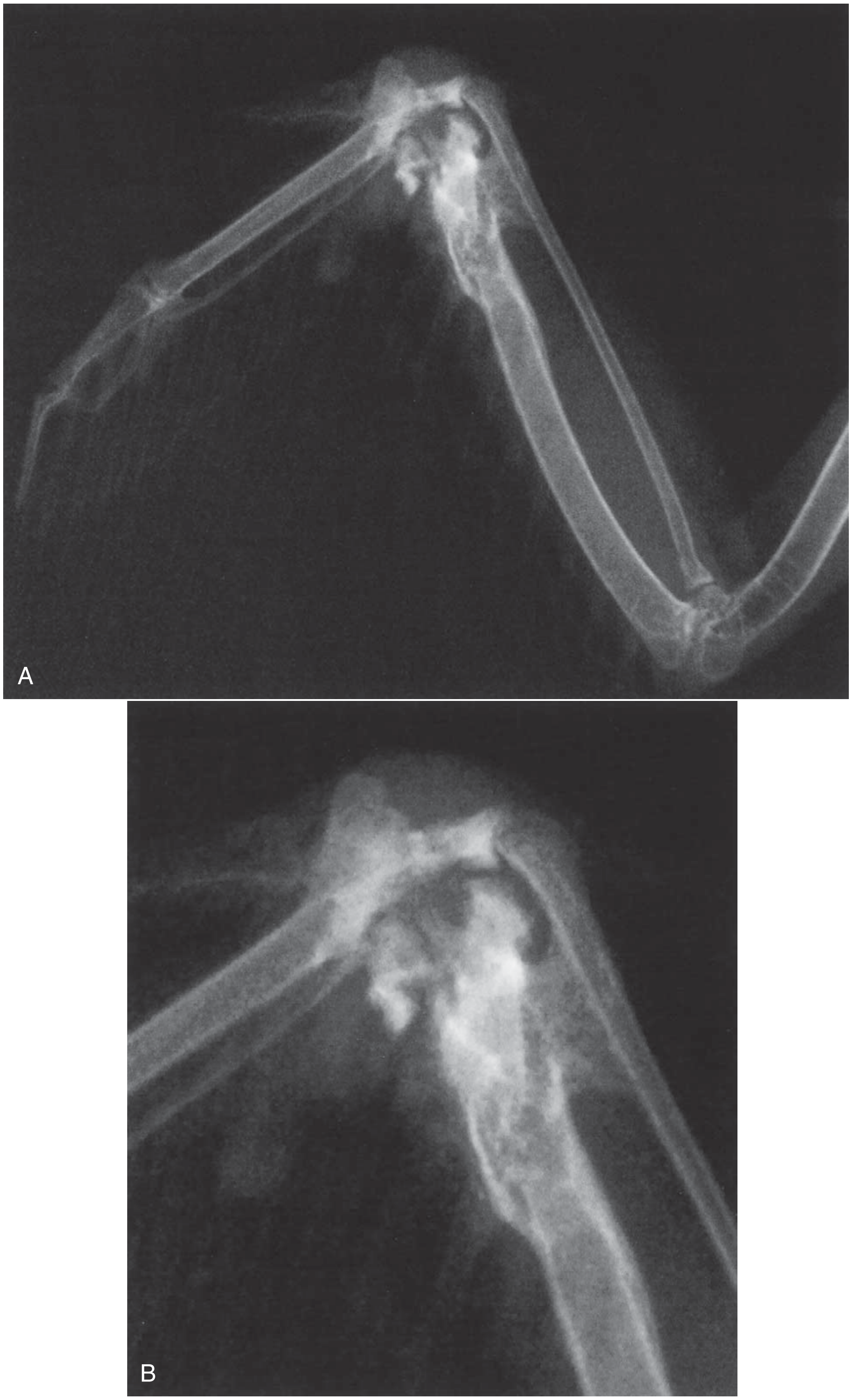

Figure 14-5 • A, Orientation and close-up **(B)** ventrodorsal projections of a chronically infected right carpometacarpal joint in a hawk. The distal ulna was fractured 3 months earlier, presumably the result of flying into a power line. Attempts to eradicate the associated infection failed. The distal ulna, including its fractured articular subsurface, has partially disappeared, creating the impression of a widened cartilage space. This illusion is further enhanced by carpal and proximal metacarpal bone loss.

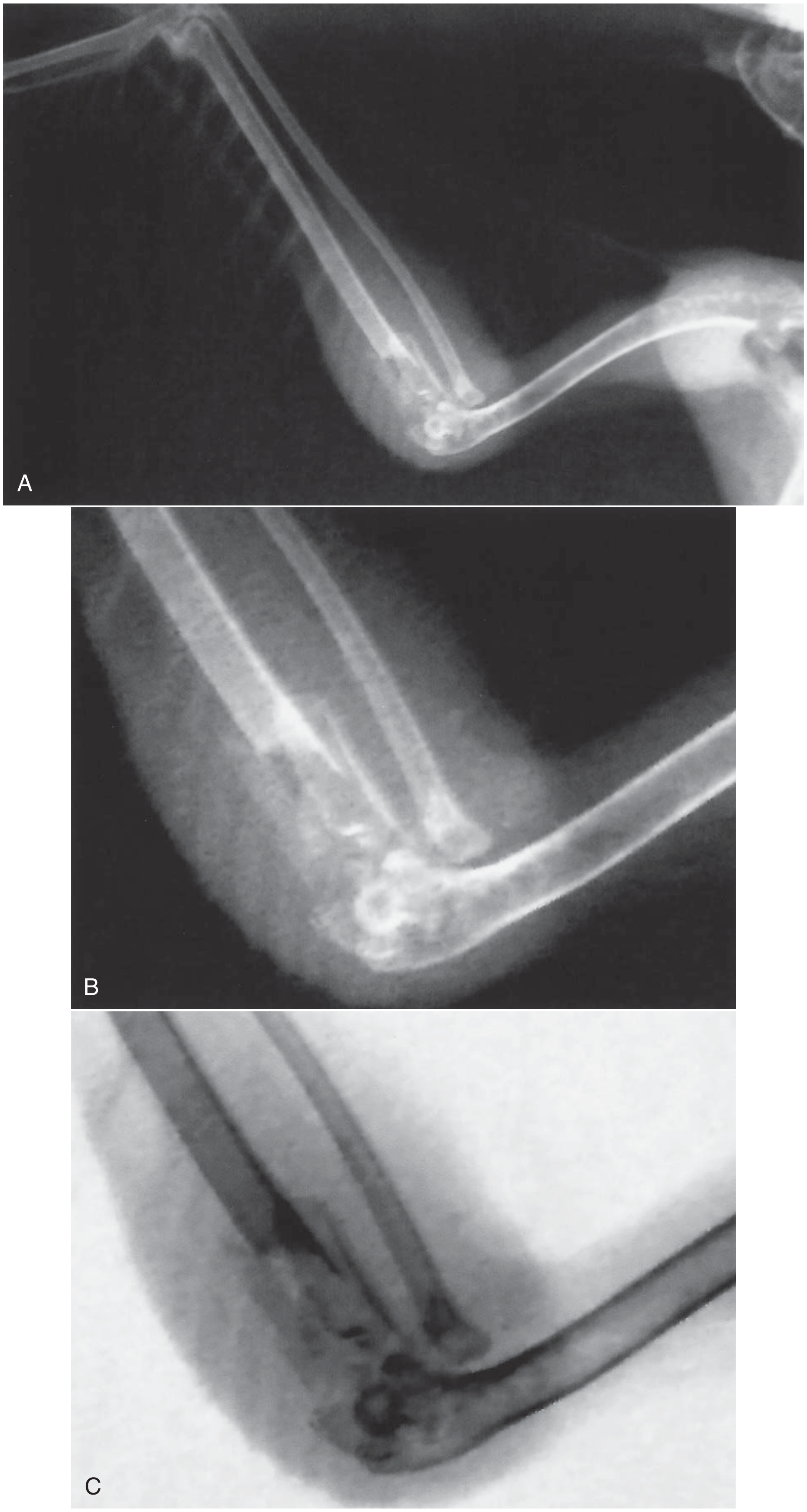

Figure 14-6 • A, Orientation and close-up **(B)** views of the right elbow region of a hawk show a severely infected, comminuted articular fracture of the proximal ulna and cranial dislocation of the radius. Ulna lysis has become so severe that it is nearly impossible to identify the articular surface of the bone, even with the aid of a negative image **(C).** Note the marked regional soft tissue swelling.

Chapter 15

The Wing: Posttraumatic Osteoarthritis

INCONGRUITY AND DESTABILIZATION: FORMULAS FOR OSTEOARTHRITIS

Posttraumatic osteoarthritis is caused by joint *incongruity*, which most often occurs as the direct result of an articular fracture, fracture-dislocation, or simple dislocation. Severe sprains (third degree) may also eventually lead to osteoarthritis by allowing one or more articular elements to exceed their normal range of motion. Infectious arthritis may lead to osteoarthritis either by destroying a portion of the joint and thus rendering it incongruent or alternatively by damaging a periarticular or intraarticular ligament, causing excessive motion. A severe capsular injury can have a similar destabilizing effect.

Sprains that are aggravated before fully healing may eventually lead to elongation of one or more of the damaged ligaments, which can produce instability and later osteoarthritis. This *destabilization* is always a concern when migratory wild birds must be released prematurely.

Figures 15-1 through 15-3 illustrate some of the effects of posttraumatic osteoarthritis.

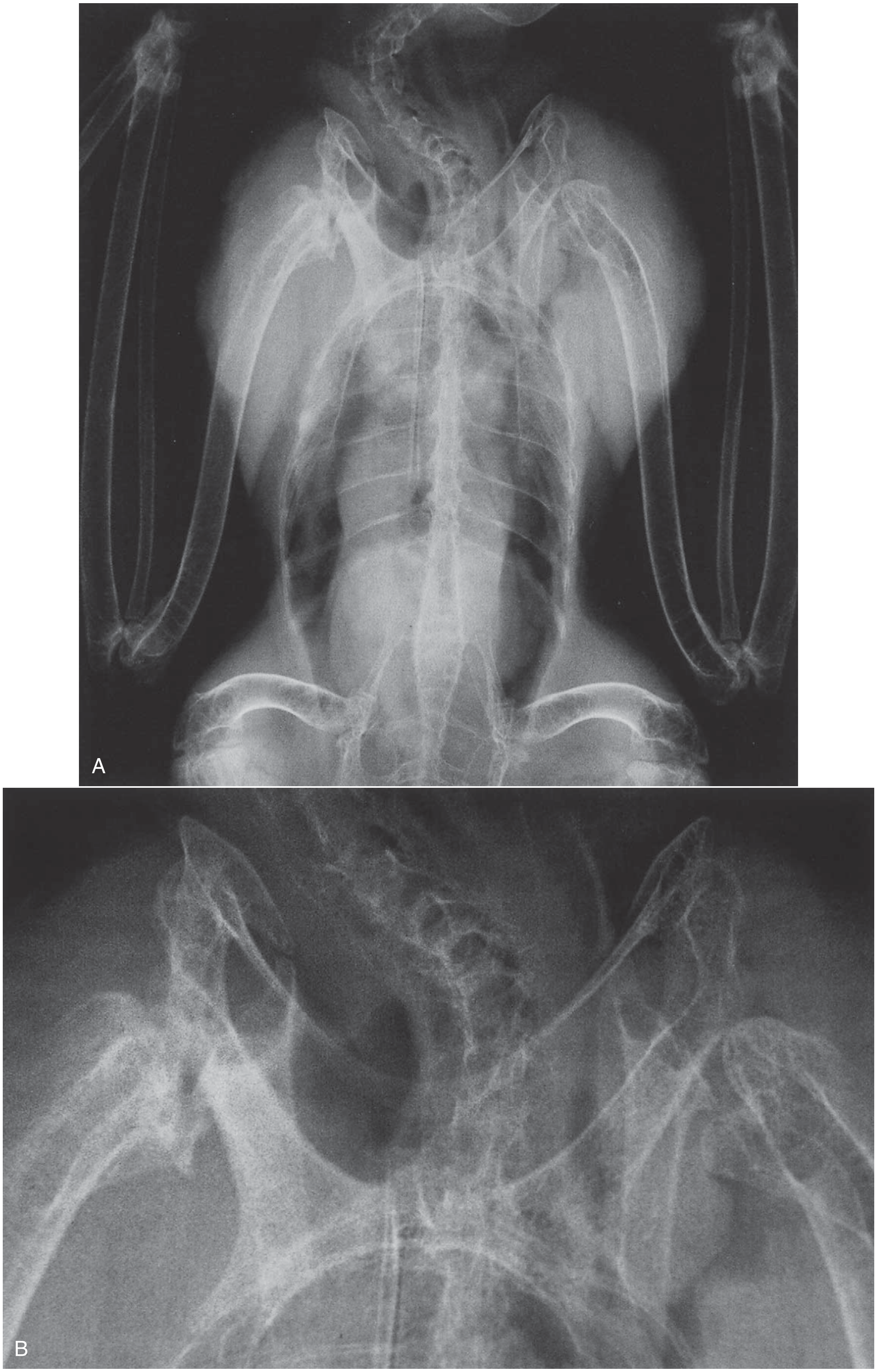

Figure 15-1 • A, Orientation and close-up **(B)** ventrodorsal views of the right humeral joint of a hawk that suffered a fracture-dislocation 3 months earlier and as a result has developed osteoarthritis.

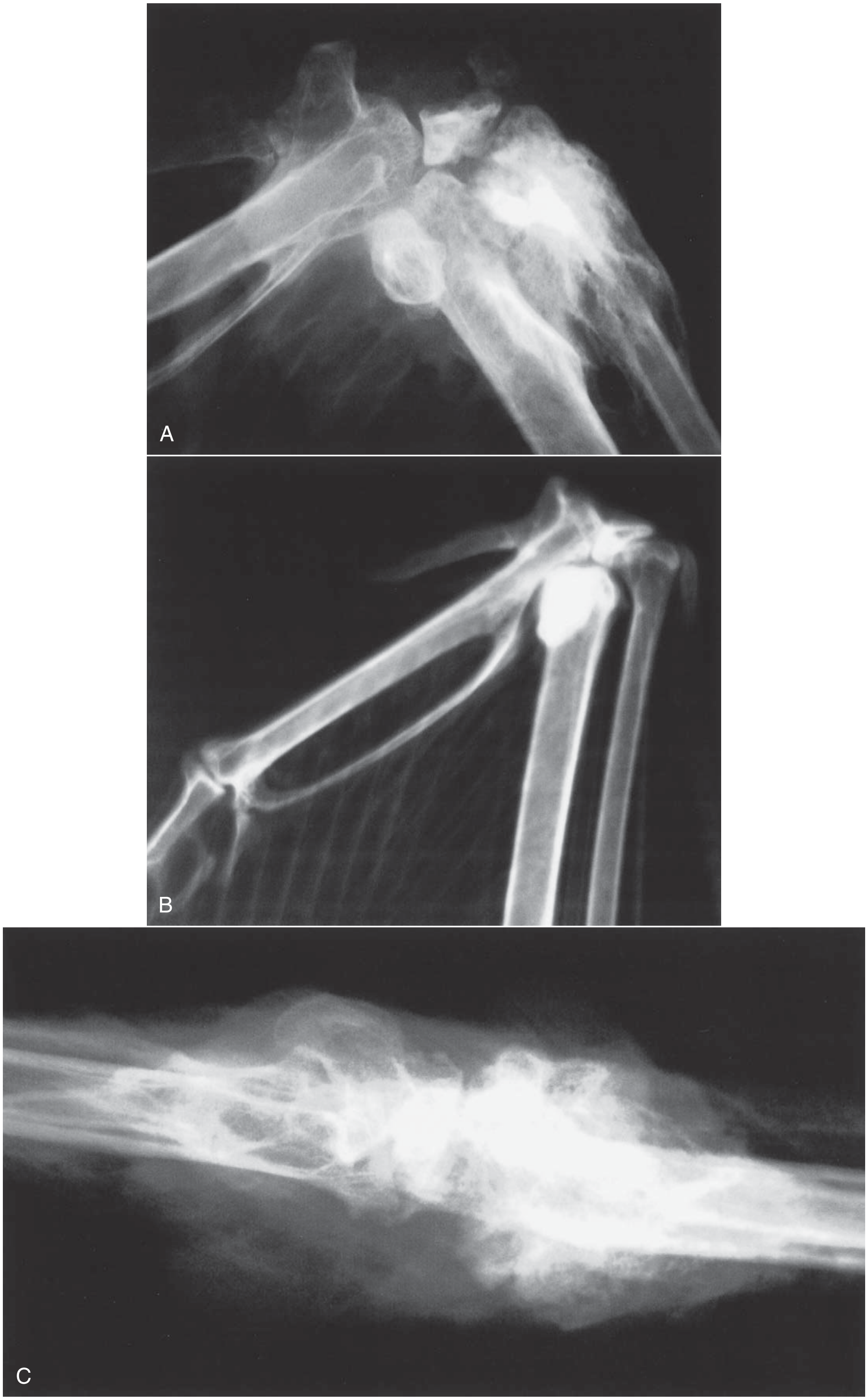

Figure 15-2 • A, Close-up ventrodorsal view of the right radiocarpal joint of a bald eagle that suffered an articular fracture of its distal radius approximately 6 months earlier. The radiocarpal joint is now severely arthritic, although the radial fracture has healed, albeit as a malunion. **B,** The uninjured left radiocarpal joint is provided for comparison. **C,** The close-up, leading edge projection of the arthritic right radiocarpal joint reveals an exceptionally large and potentially flight-limiting distal radial callus, as well as periarticular new bone surrounding the proximal metacarpus, which was not evident in the ventrodorsal view.

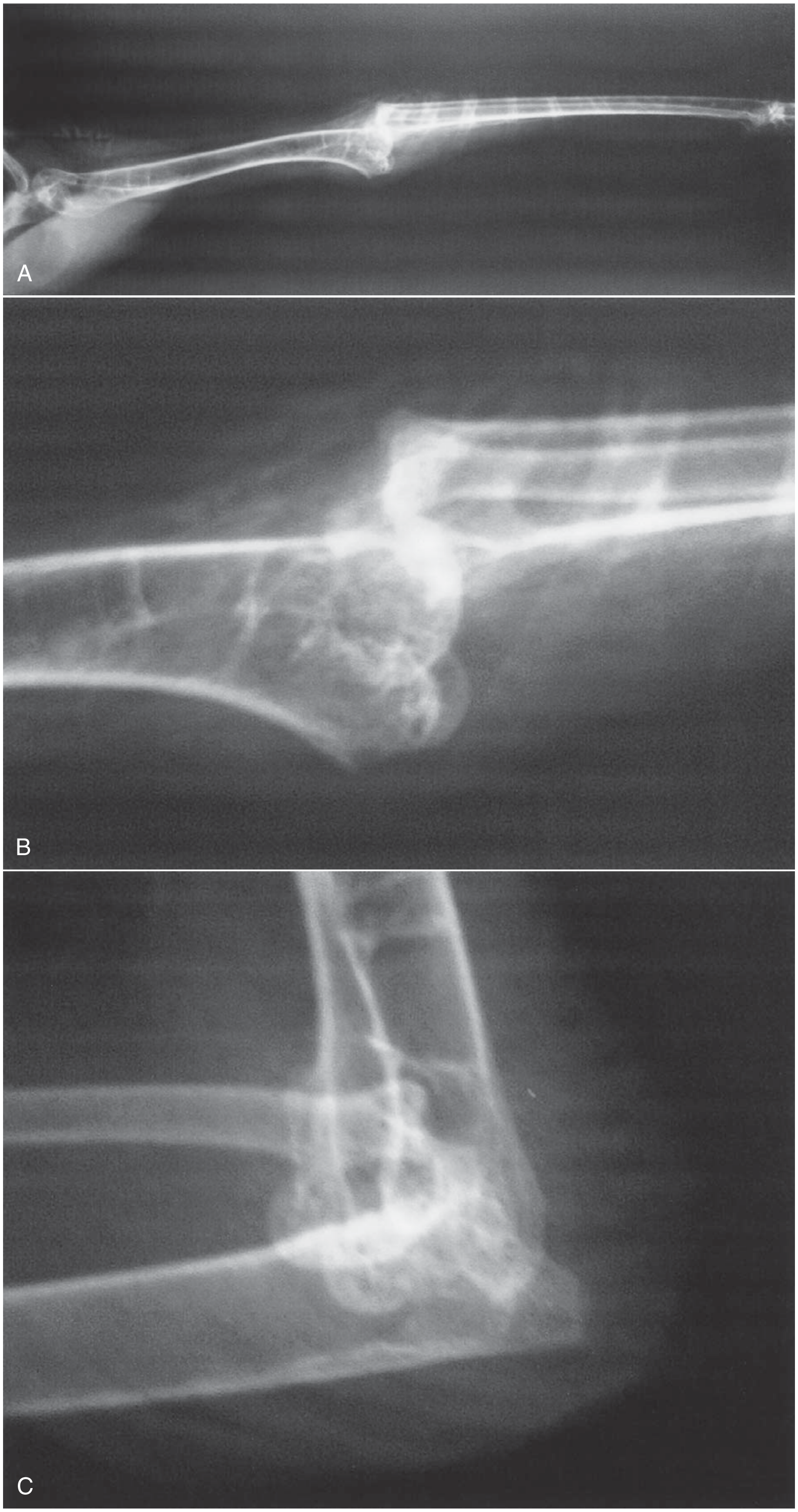

Figure 15-3 • A, Orientation and close-up **(B)** leading edge views of the left wing of a Swainson's hawk show complete dislocation. **C,** Ventrodorsal close-up and labeled negative close-up **(D)** projections reveal similar findings. **E,** A ventrodorsal close-up view of the uninjured right elbow is provided for comparison. Note that both the humeroradial and the humeroulnar joints are fully luxated.

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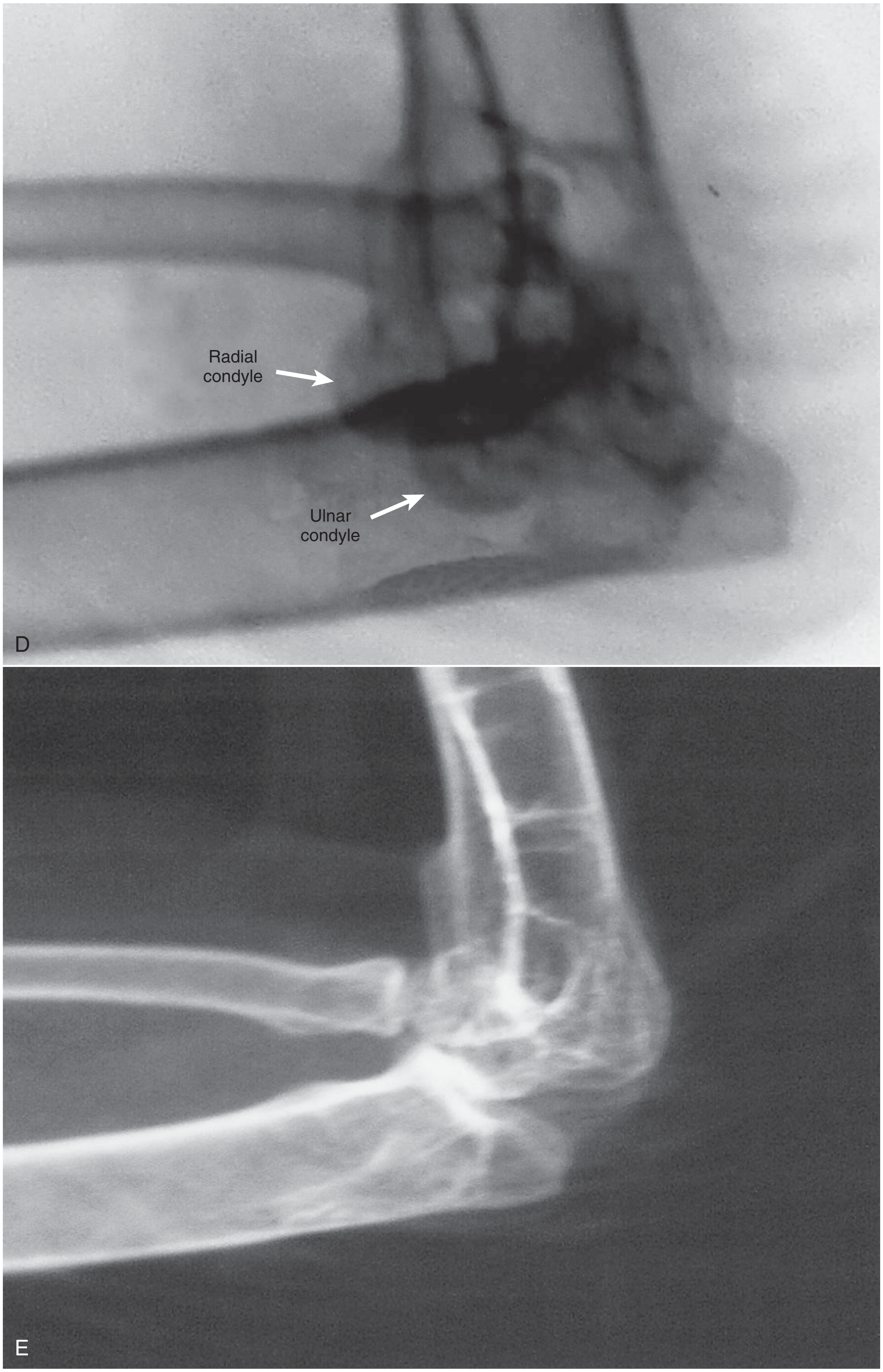


Figure 15-3, cont'd • For legend see p. 151.

Chapter 16

Spine, Pelvis, and Hips

SPINE

Normal Anatomy

The spine of birds, excluding the cervical region, differs radically from the spine of mammals, particularly with respect to regional collation. Depending on the species, there may be consolidation of a series of cranial vertebrae, termed the *notarium*, or fusion of a series of caudal vertebrae, termed the *synsacrum,* which is a fusiform structure located on the underside of the pelvis. There is a short tail section, followed by a final fusion, termed the *pygostyle* (Figure 16-1). The pygostyle is an important structure that serves to mount the tail feathers, providing critical control surfaces, especially during takeoff and landing.

Even if the fused areas of the spine are ignored, the nonfused spinal elements are equally complex because of their accessory processes that stream down the back, overlapping one another like so many icicles adorning a winter's tree (Figure 16-2). A lateral perspective of the same region appears far less confusing (Figure 16-3).

Fractures of the Central and Caudal Spinal Regions

Nondisplaced Spinal Fractures. The few nondisplaced spinal fractures seen in my practice have generally been difficult to detect, even with the use of magnification radiography. To date, I have not had the opportunity to perform computed tomography (CT) on such a bird, but I suspect CT would prove far more sensitive.

Displaced Spinal Fractures. Few birds survive a displaced spinal fracture long enough to be radiographed. These fractures are usually situated in the midback or immediately cranial to the synsacrum. Most of these injuries can be identified in both standard imaging planes. A case example is provided in Figures 16-4 and 16-5.

PELVIS

Normal Anatomy

The pelvis of most birds resembles an inverted shovel blade as seen from the rear. In the perching position, the pelvis of most birds is directed downward at a near-vertical angle. All of its component parts—the ilium, pubis, acetabulum, and ischium—are fused to one another and form a single pelvic bone, which in turn is fused to the synsacrum at the level of the ilia. At its cranial origin, the pelvis is about the width of the spine but tapers broadly once it reaches the hips, approximately one-third the way to the tail (Figure 16-6). Pelvic injuries, including fractures, are rare.

HIPS

Normal Anatomy

The coxal joints, or hips, of birds are angled forward just as they are in most mammals (Figure 16-7). Unlike mammals, however, the greater trochanter and the femoral head articulate with the acetabulum (Figure 16-8). Fractures and dislocations are rare. Occasionally, nestlings fall from their nests when first testing their wings and may fracture their proximal femoral growth plate.

Figure 16-1 • Tail and pygostyle of a Canadian goose seen from the rear in a standing specimen. The pelvis is at the top left.

Figure 16-2 • A, Orientation, close **(B),** and ultraclose **(C)** views of the central spinal region in a Canadian goose, seen from above, illustrating the anatomical complexity of the paraspinal elements.

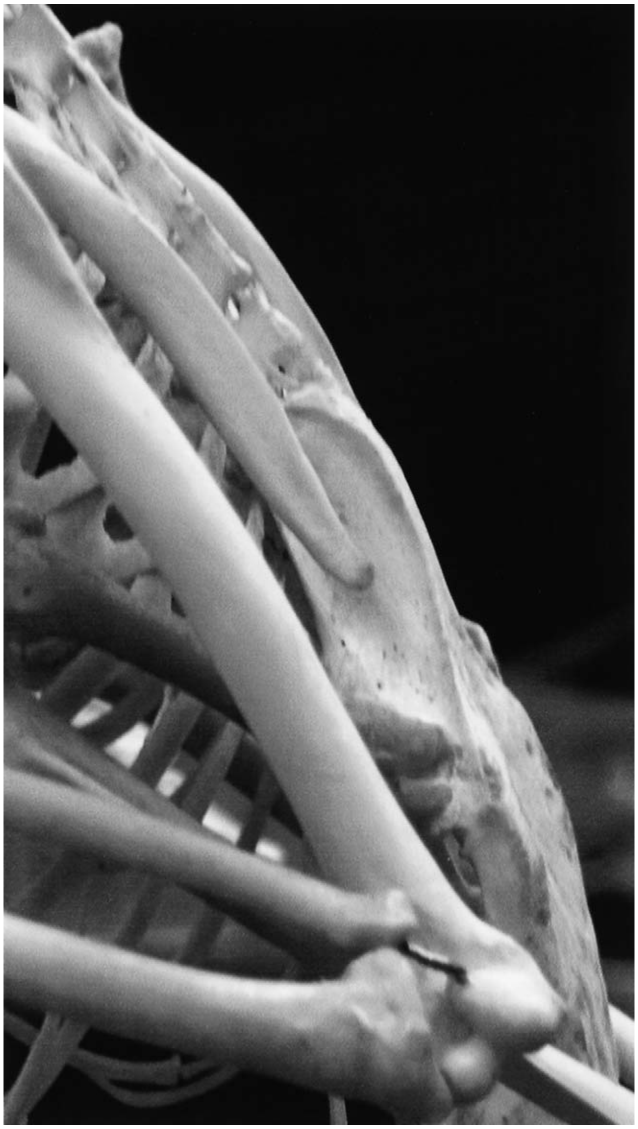


Figure 16-3 • Close-up lateral view of the central spinal region and synsacrum in a Canadian goose, as seen from a lateral perspective.

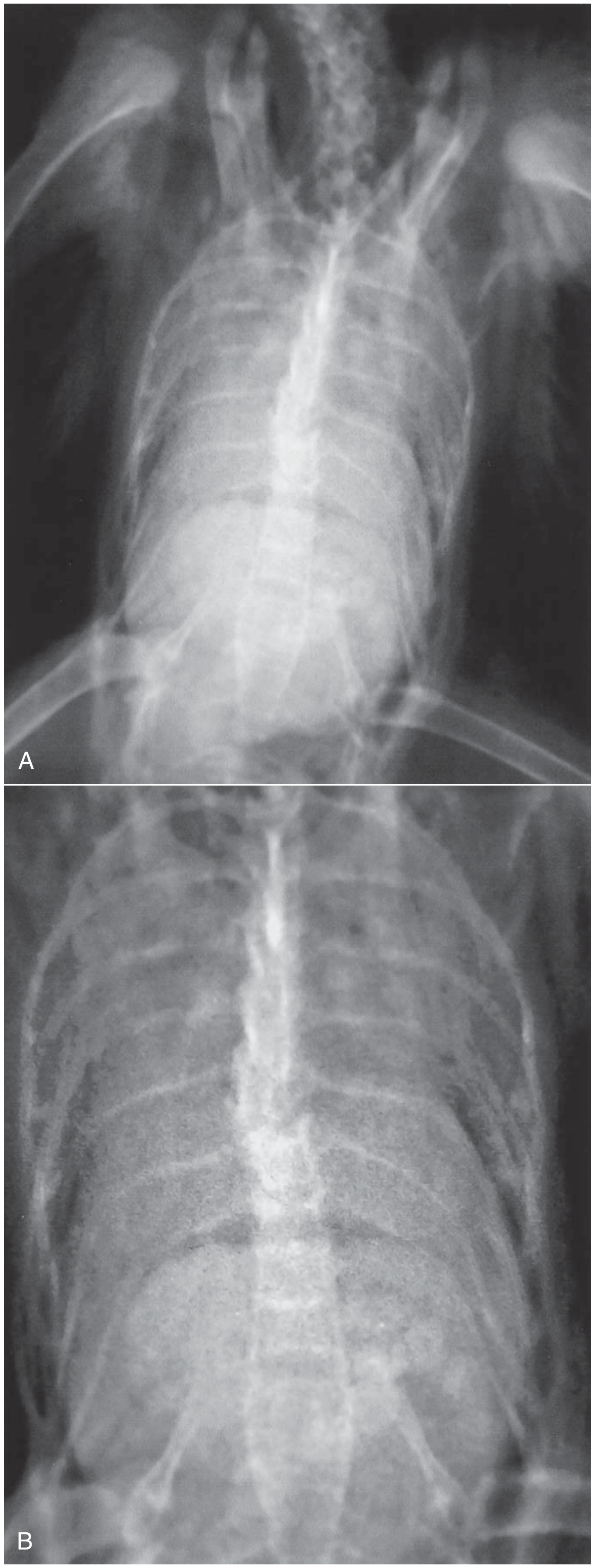


Figure 16-4 • A, Ventrodorsal and close-up **(B)** views of an immature Merlin with a dislocated fracture in the central spinal region.

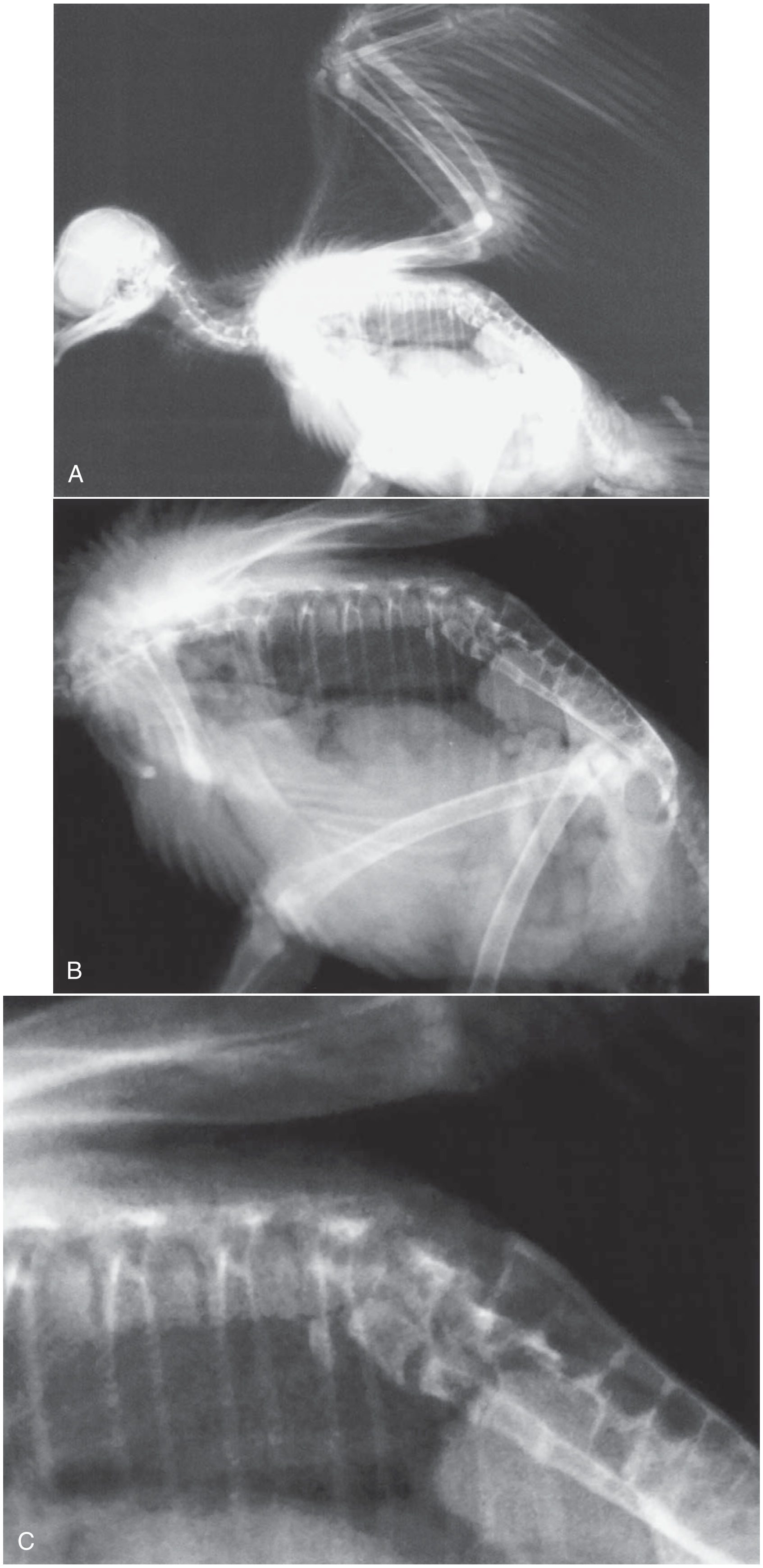


Figure 16-5 • A, Lateral, close **(B),** and ultraclose **(C)** views of a centrally located, ventrally displaced spinal fracture. Same bird as in Figure 16-4.

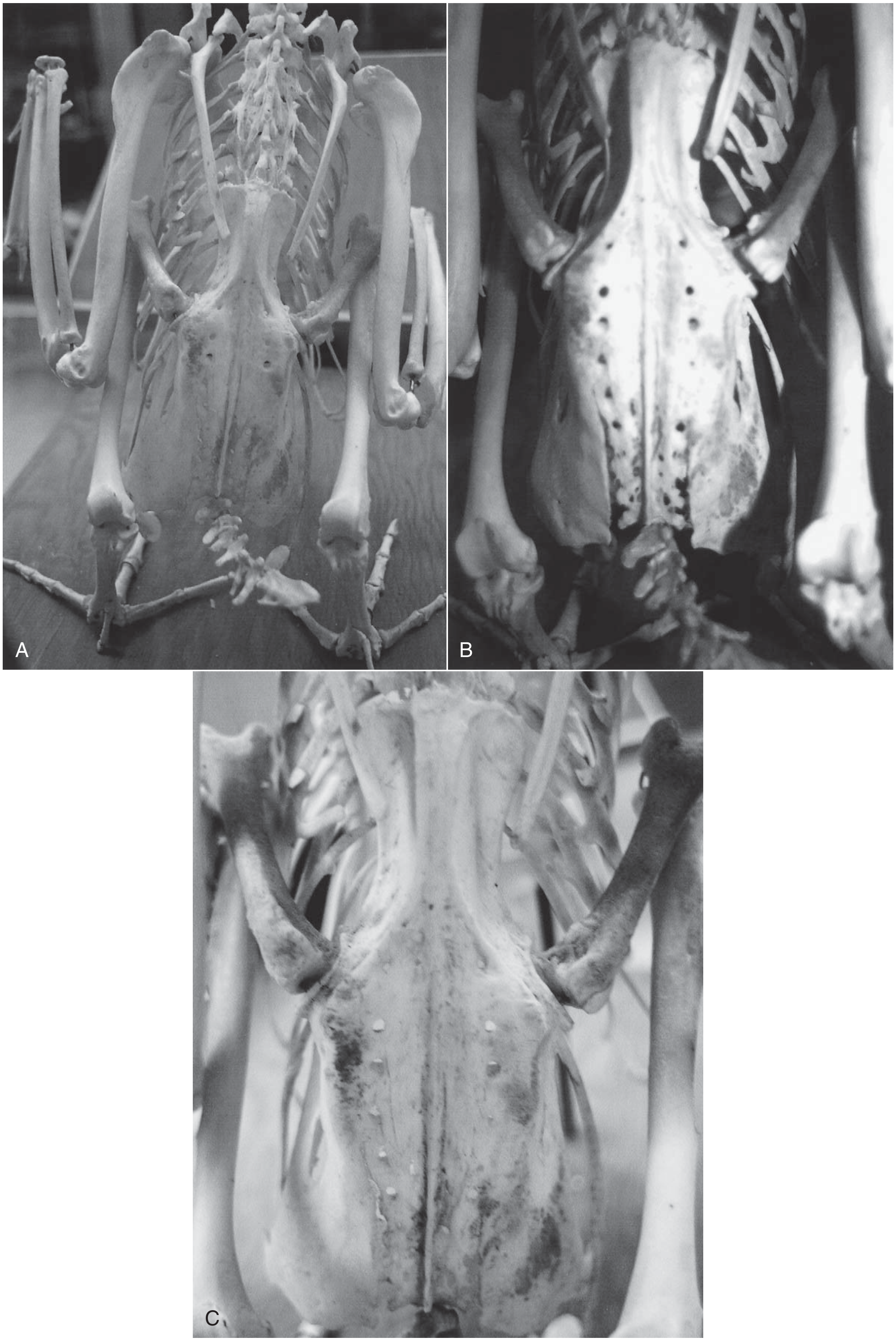


Figure 16-6 • A, Orientation, close **(B),** and ultraclose **(C)** caudocranial views of the pelvis of a Canadian goose in a standing specimen.

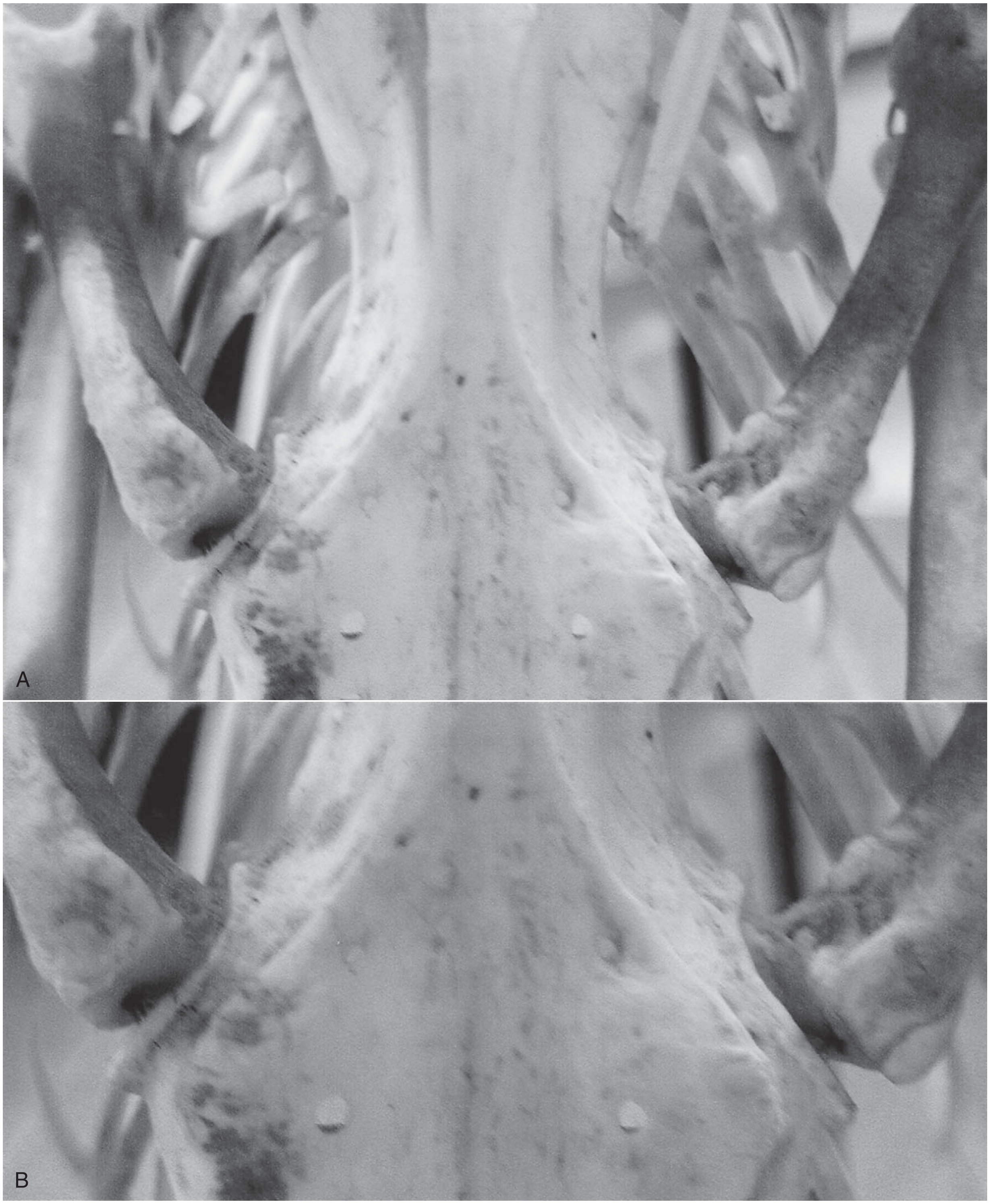


Figure 16-7 • A, Orientation and close-up **(B)** views of the coxal joints in a Canadian goose in a standing specimen.

Figure 16-8 • Close-up view of the coxal joint of a Canadian goose specimen shows that both the femoral head and greater trochanter articulate with the acetabulum, depending on the position of the femur.

Chapter 17

The Leg

NORMAL SKELETAL ANATOMY

The leg of a bird is composed of a femur, tibiotarsus, fibula, tarsometatarsus, a single metatarsal bone (the first), and four digits. Some variation exists among the various species, depending on how and where the legs are used (Figure 17-1).

RADIOGRAPHY

Radiography of the leg is similar to that of the wing (Figure 17-2) (see Chapter 1); however, there are some important additional considerations. The first consideration is safety. The talons of a raptor are potentially quite dangerous and exceedingly difficult to remove once they have been deeply embedded in the flesh of a person's hand or arm, especially if the bird is struggling to escape. For this reason, it is always advisable to wear protective leather gloves when handling raptors in preparation for radiography.

When radiographing a bird's legs, it is important to extend them fully to avoid end-on projection (termed the *gun barrel sign*), which is a sure indication the femurs were inadvertently flexed during the exposure (Figure 17-3). Failure to properly extend the legs also results in a portion of the upper thigh superimposed on the lateral aspects of the pelvis, making it hard to discern bony detail.

FEMORAL FRACTURES

Femoral fractures occur occasionally in birds but not nearly as often as midextremital or lower extremital injuries. Fractures of the femoral head, especially those involving the underlying growth plate (termed *capital physeal fractures*), are often hard to see in the ventrodorsal (VD) projection because of superimposition by the overlying pelvic bones. Oblique VD views, which are very helpful in small mammals, usually provide little or no additional information.

The radiographic diagnosis of femoral body fractures is usually straightforward, although hairline breaks are exceptions that may require one or more oblique projections to identify with certainty. Just as in small mammals, minimally displaced distal femoral growth plate fractures can also be difficult to diagnose unless a comparable projection of the opposite leg is made.

Distal femoral condylar fractures, particularly older injuries in which there is substantial fragment displacement, can prove extremely challenging, as illustrated in Figure 17-4. If the full extent of the injury is not clear or appears confusing, the standard two-view study can be supplemented with lateral and medial oblique projections, in addition to at least two comparison views of the opposite leg.

INJURIES TO THE GENUAL JOINT

Fracture

It is imperative that all displaced, intraarticular fractures of the distal femur or proximal tibia be reduced to avoid development of osteoarthritis, as well as the pain and disability that typically accompany such an outcome (Figure 17-5).

Text continued on p. 167.

Figure 17-1 • A, The legs of a burrowing owl shown in the extended position appear quite long and slender as they do in a radiograph **(B).**

Figure 17-2 • Eagle's tibia being placed on a receiver *before* radiography (thus not everyone is wearing gloves). The oblong object on the leg surface is a bandaged external fixator. The collimator light is on, and a lead marker has been taped to the cassette adjacent to the tarsometatarsus.

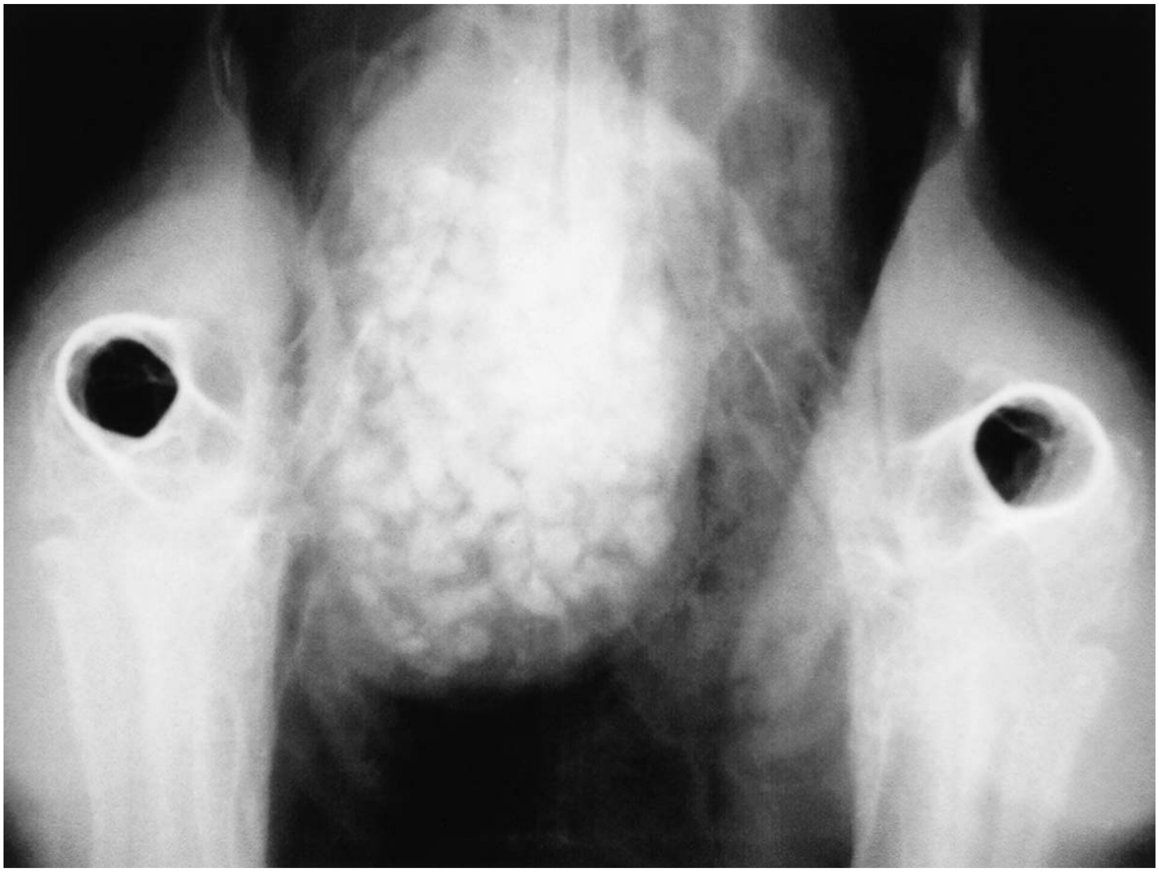


Figure 17-3 • Close-up, inadvertently flexed, craniocaudal view of the legs of a pea hen showing end-on projections of the femurs, or the gun barrel sign.

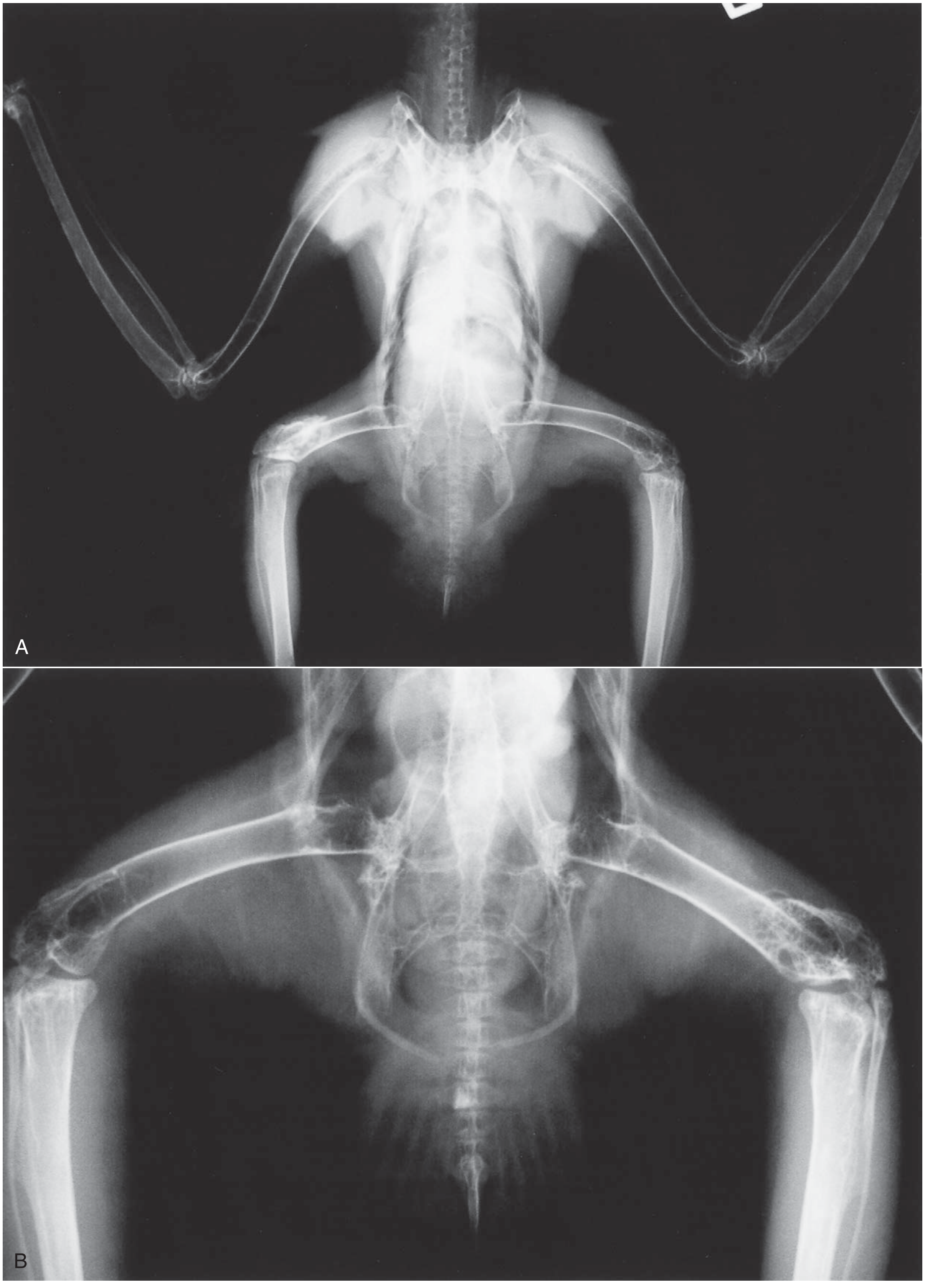
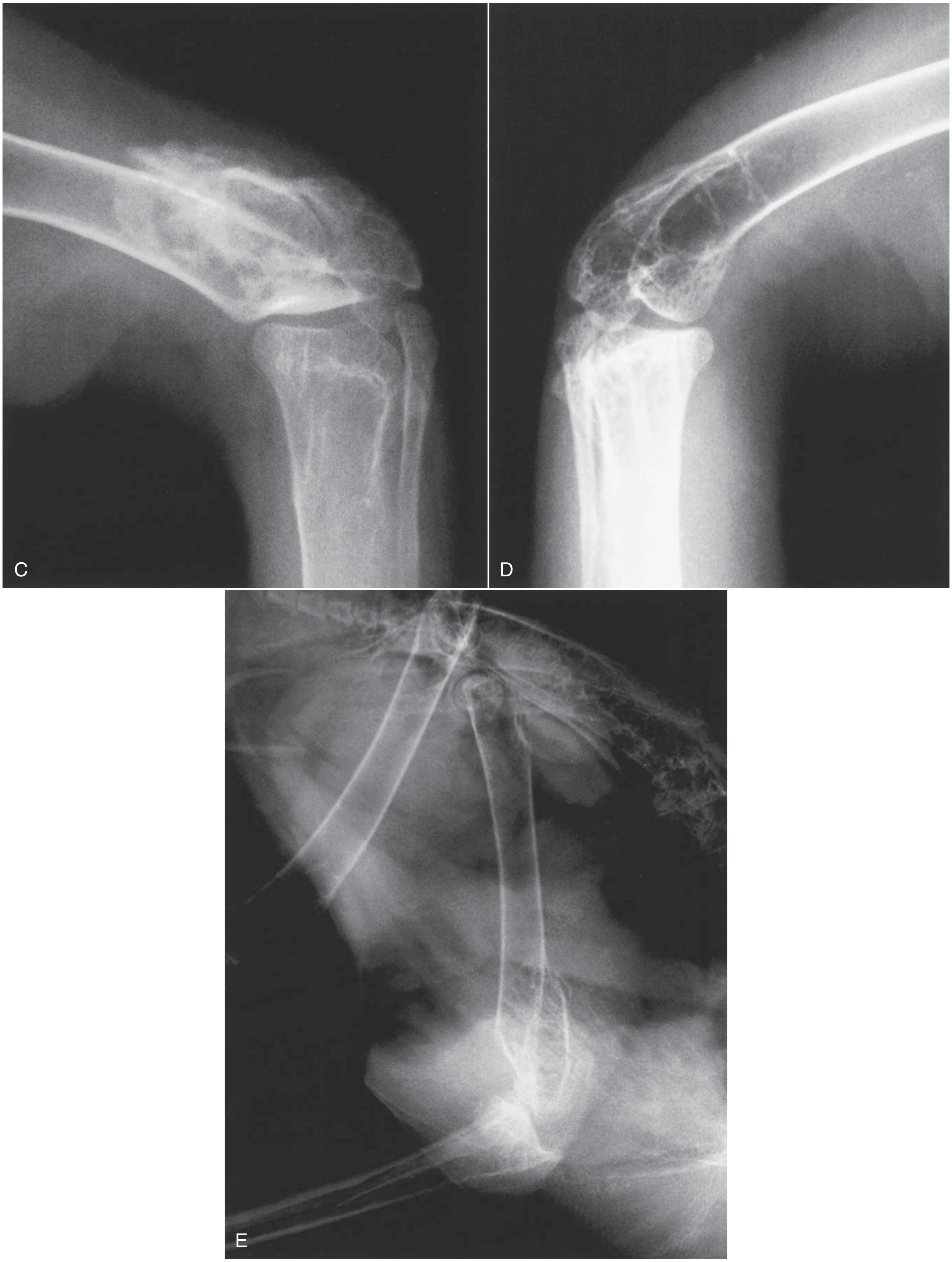


Figure 17-4 • A, Orientation, close **(B),** and ultraclose **(C)** craniocaudal views of the left distal femur of a hawk, which was fractured, failed to heal, and eventually formed a false joint. **D,** A close-up craniocaudal view of the normal right genual joint is provided for comparison. **E,** Additionally, the fracture is also shown from a lateral, slightly oblique perspective. Currently, the distal femur comprises three bone fragments plus the patella: the badly overridden femoral shaft and the medial and lateral halves of the femoral condyle, which was split in two. The false joint appears to consist of three distinct components: (1) the broken off distal femoral shaft that articulates with the proximal tibia, (2) the displaced condylar fragments that articulate with one another, and (3) the lateral condyle that articulates with the fibular head.



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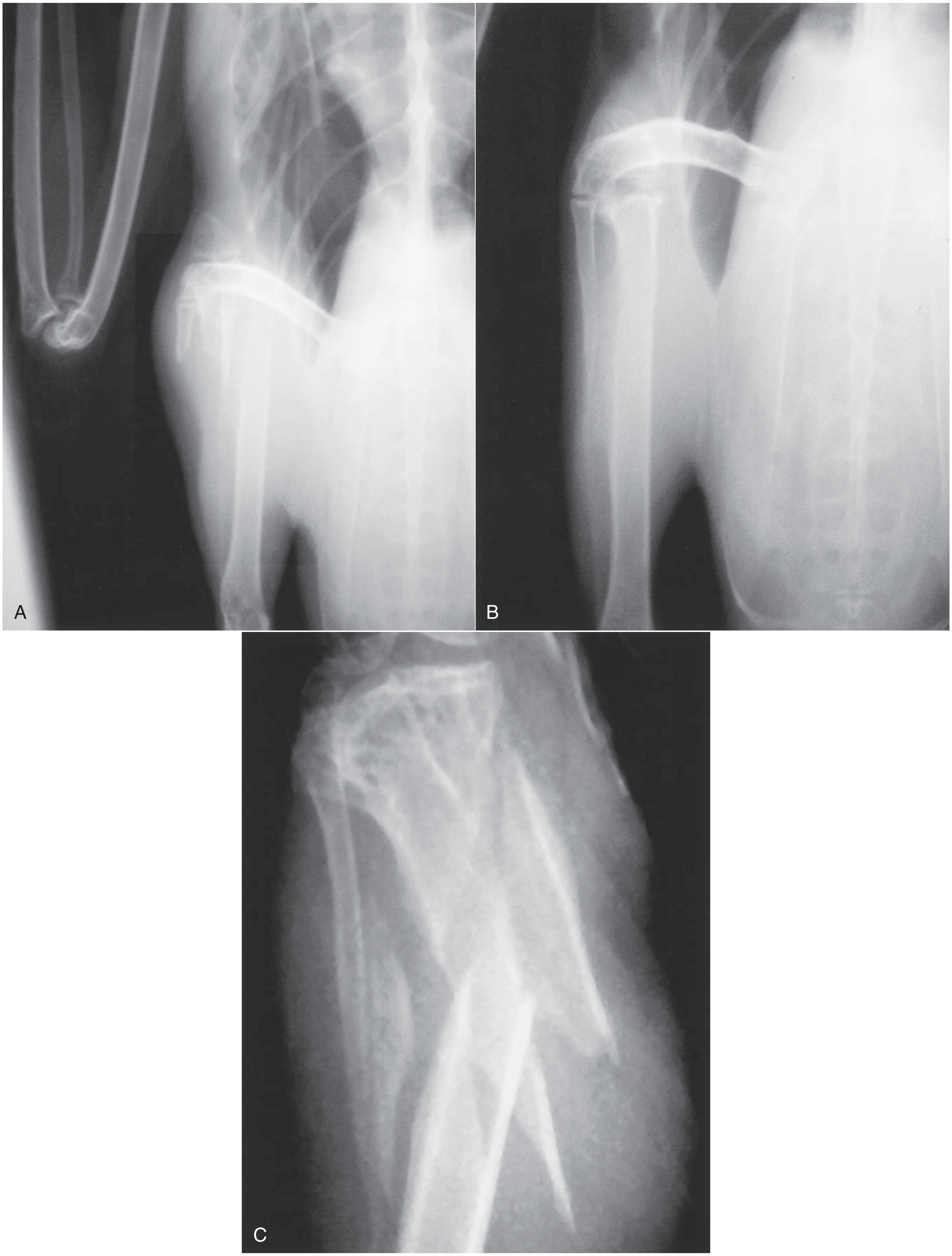

Figure 17-5 • A, Deliberately flexed, craniocaudal close-up view of the right genual joint of a cormorant shows a badly displaced, comminuted articular fracture of the proximal tibia and a short oblique fracture of the proximal fibular body. **B,** A comparably oriented, flexed craniocaudal view of the left genual is provided for comparison. **C,** Close-up, extended craniocaudal view of the proximal tibia shows a displaced, comminuted fracture of the proximal tibia believed to be 2 to 3 weeks old. This estimate is based on the presence of new bone on the outer edges of the fracture fragments and the indistinct injured tissue caused by the removal of necrotic bone.

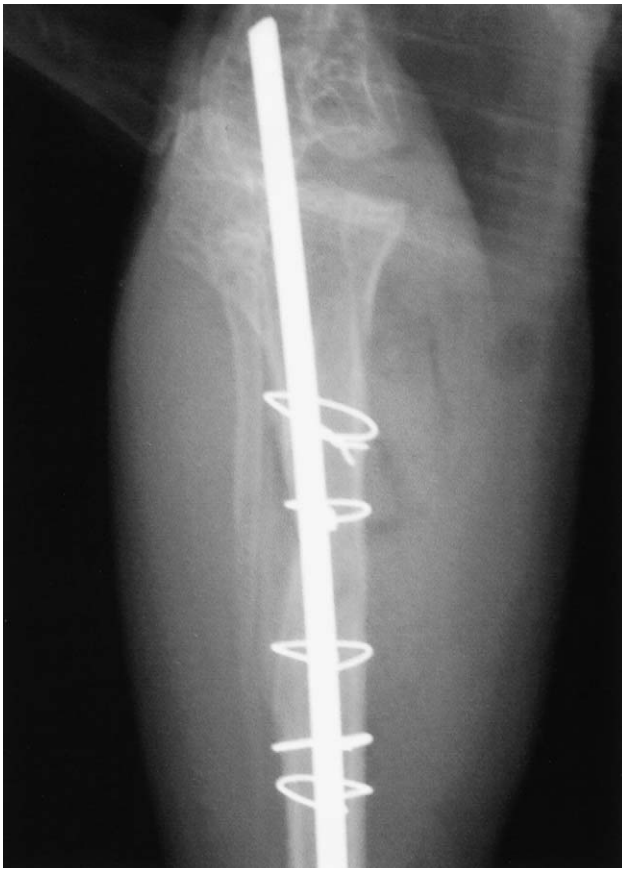

Figure 17-6 • Immediate postoperative, craniocaudal view of the proximal right tibia of a snow goose shows not only the recently installed pin and cerclage system used to repair the tibia but also a partial dislocation of the genual joint as well, which was missed in the initial radiographic assessment.

Sprain

Isolated sprains and related dislocations are rare in birds; most such injuries are caused by some form of entrapment. In my experience, fractures and fracture-dislocations of the genual joint, particularly those that involve the proximal tibia, account for the majority of third-degree knee sprains (Figure 17-6).

Infection

Infection, particularly that associated with deeply penetrating wounds, can extend to one or more of the nearby knee bones, causing osteomyelitis (Figure 17-7). Intraarticular puncture wounds can inoculate bacteria directly into the joint, causing septic arthritis.

TIBIOTARSAL FRACTURES

With perhaps a single exception, there is little that is unique about tibiotarsal body fractures, with most being readily identified using the standard two-view study. The exception is the *folding* or *bending fracture*, a form of insufficiency injury, which often accompanies *nutritional secondary hyperparathyroidism* (Figure 17-8).

Unreduced *pile-driver fractures* involving the distal tarsometatarsal shaft can resemble expansile bone tumors and admittedly are quite rare in birds. Pile-driver fractures split the bone distally, which doubles or triples its width, and then fill in the surrounding tissue void with an excessive volume of cloudlike new bone encouraged by fragment movement (Figure 17-9).

In my experience, appendicular soft tissue tumors occur more commonly than primary or secondary bone tumors. In some instances, these soft tissue tumors invade the nearby bone quite extensively and can be difficult to distinguish from infection (Figure 17-10).

Irrespective of cause or location, the radiographic diagnosis of both recent (Figure 17-11) and old (Figure 17-12) tibiotarsal injuries is best served with at least a pair of projections made at right angles to one another.

Pathological Fractures

Other than the insufficiency fractures that can accompany nutritional secondary hyperparathyroidism, pathological fractures rarely occur in birds. When they do, it is usually because of a primary bone tumor or an invasive soft tissue neoplasm (Figure 17-13).

LOWER LIMB AND FOOT

Getting a Grip: The Importance of Perching

A bird's ability to perch, or inability as the case may be, cannot be overstated. Many birds eat, drink, groom, and sleep while perched. The elaborate pebbled-pad system found on the undersurface of the digits of some birds enables them to maintain their grip even on rain-slicked or icy surfaces (Figure 17-14).

Some birds, such as jays, not only use their feet for perching but also to grasp their food as they eat (Figure 17-15). Woodpeckers typically assume a unique heads-up position as they ascend and descend the trunks of trees, constantly probing for insects as they go.

Hawks can often be seen perched on power poles, regularly swiveling their heads as they search the surrounding landscape for unwary prairie dogs. Owls, harboring similar ambitions, may remain motionless for minutes at a time, except for the occasional blink of an eye. Many cage birds, including some raptors, can conveniently be examined while perched on a hand or finger, thereby eliminating restraint-related stress (Figure 17-16).

TALONS: THE ULTIMATE EXTERNAL FIXATOR

The talons of raptors are extremely versatile, capable of stunning, impaling, and mortally wounding prey,

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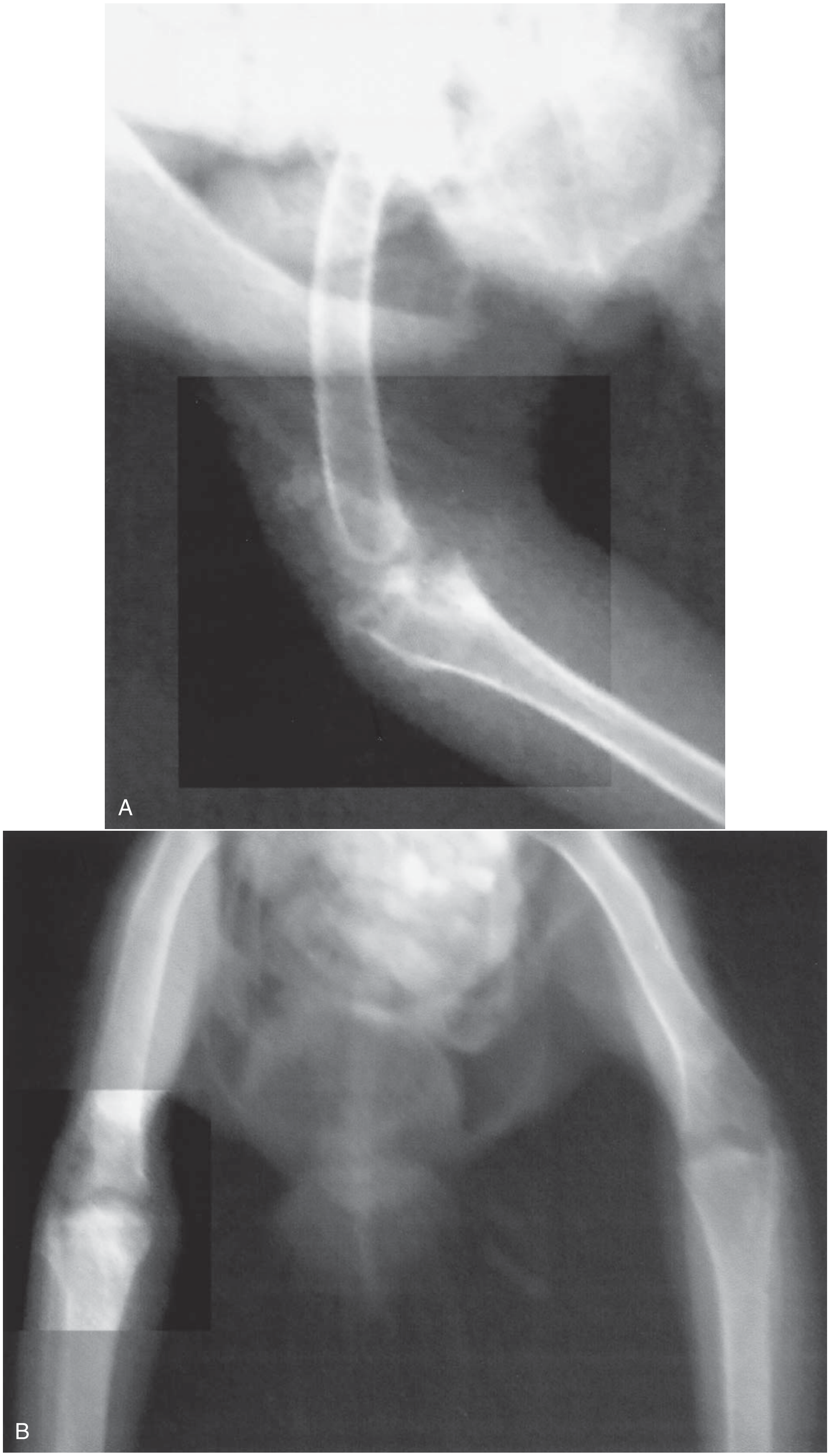

Figure 17-7 • A, Lateral and craniocaudal **(B)** views of an infected right knee in a quail show deep lysis in the proximal tibia and lateral aspect of the femoral epiphysis, with the entire stifle being enveloped in soft tissue swelling accentuated by a cloud of new bone (emphasis zones).

Figure 17-8 • A, Orientation and close-up **(B)** craniocaudal views of the left proximal tibia and left **(C)** and right **(D)** close-up craniocaudal views of the radius/ulna of an aged African Gray parrot with multiple old fractures and associated curvatures caused by nutritional secondary hyperparathyroidism. Note the old folding-type fracture in the left distal femur.

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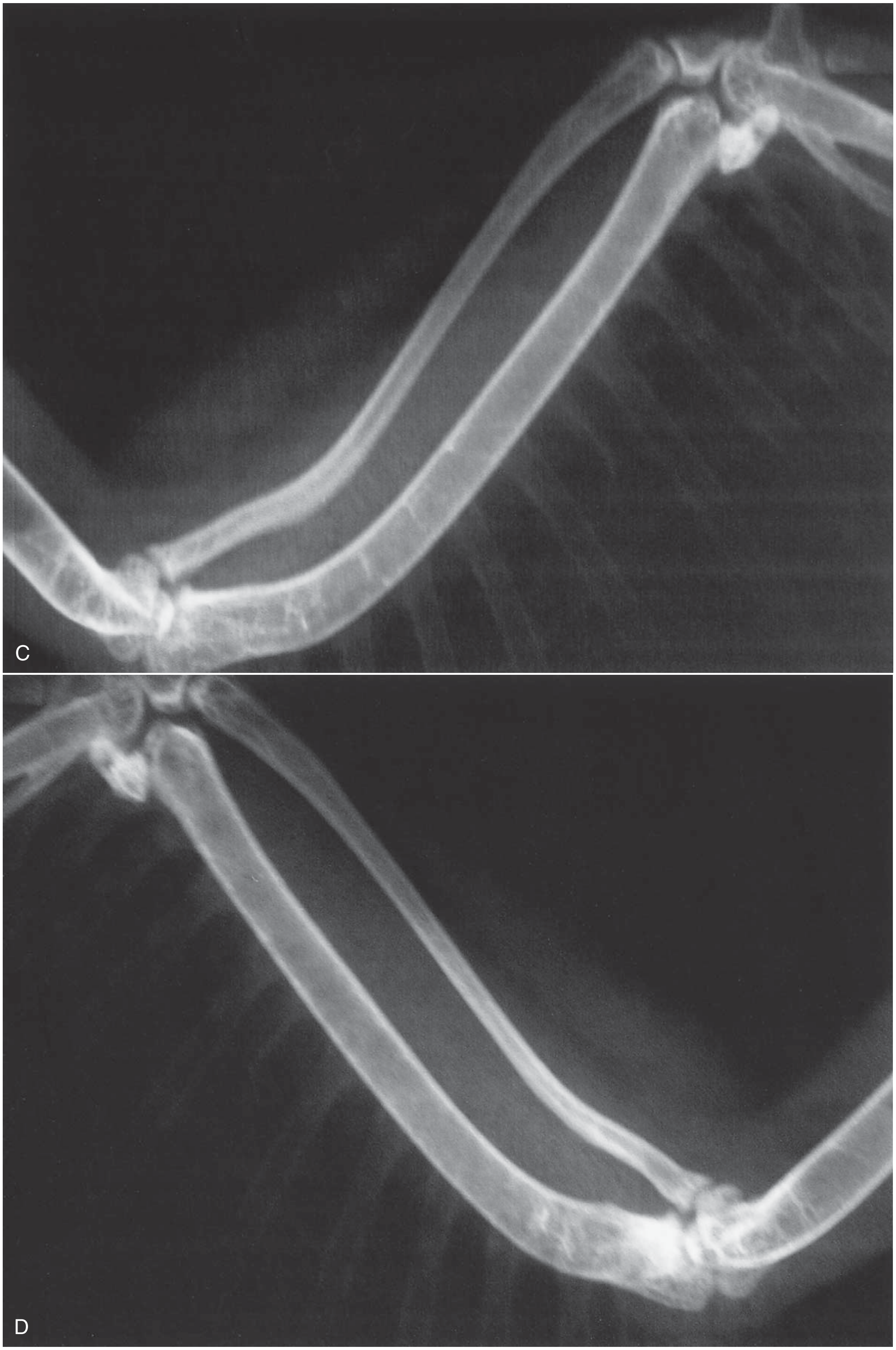


Figure 17-8, cont'd • For legend see p. 169.

Figure 17-9 • A, Orientation craniocaudal view of the proximal and midhind limbs of a bald eagle shows a fractured distal right tarsometatarsus estimated to be approximately 1 month old. **B,** A close-up view reveals a pile-driver fracture that has split and spread the distal part of the bone into three pieces and filled in the resulting gaps with a large cloudlike deposit of new bone. The end result somewhat resembles an expansile bone tumor.

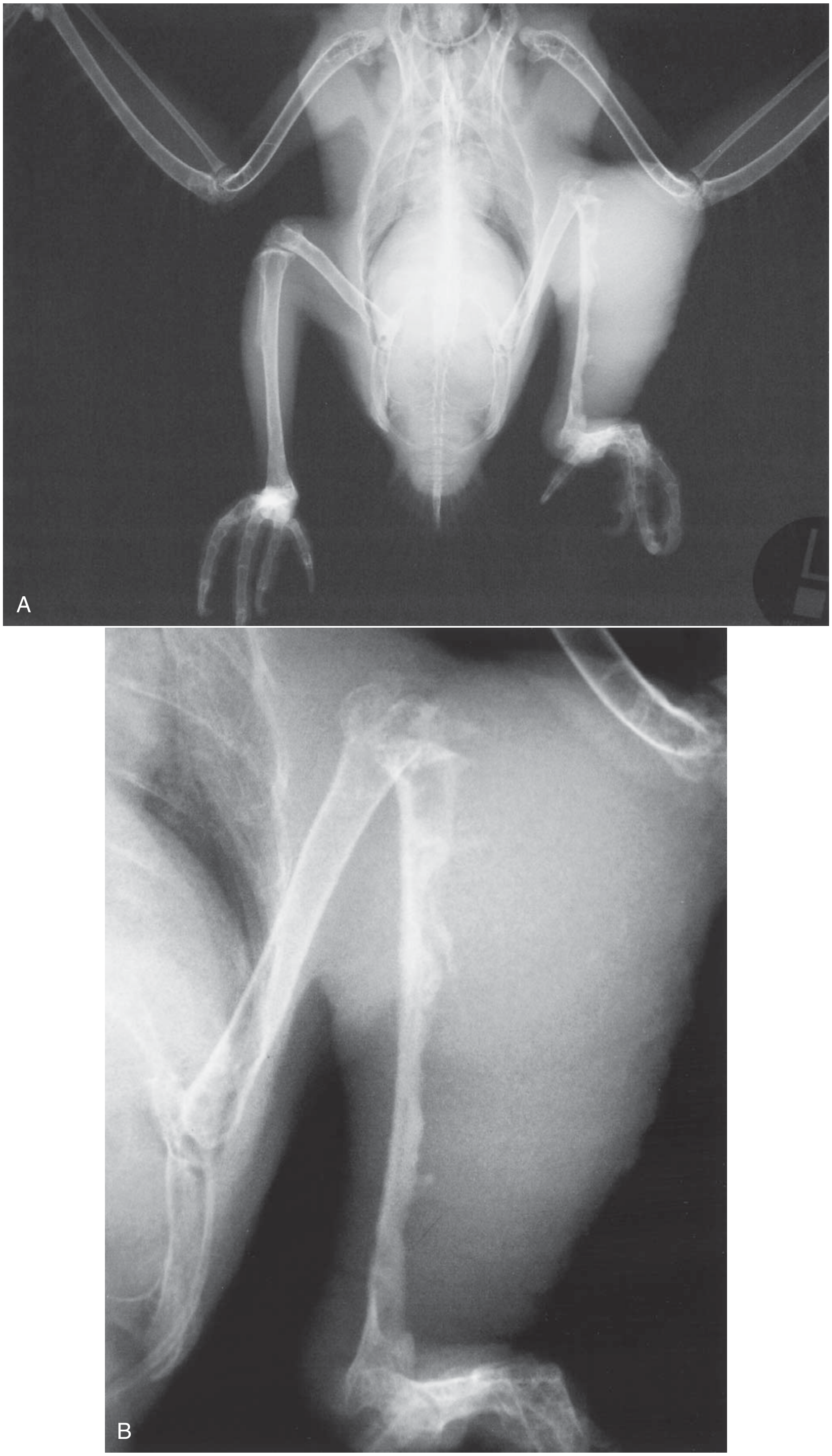
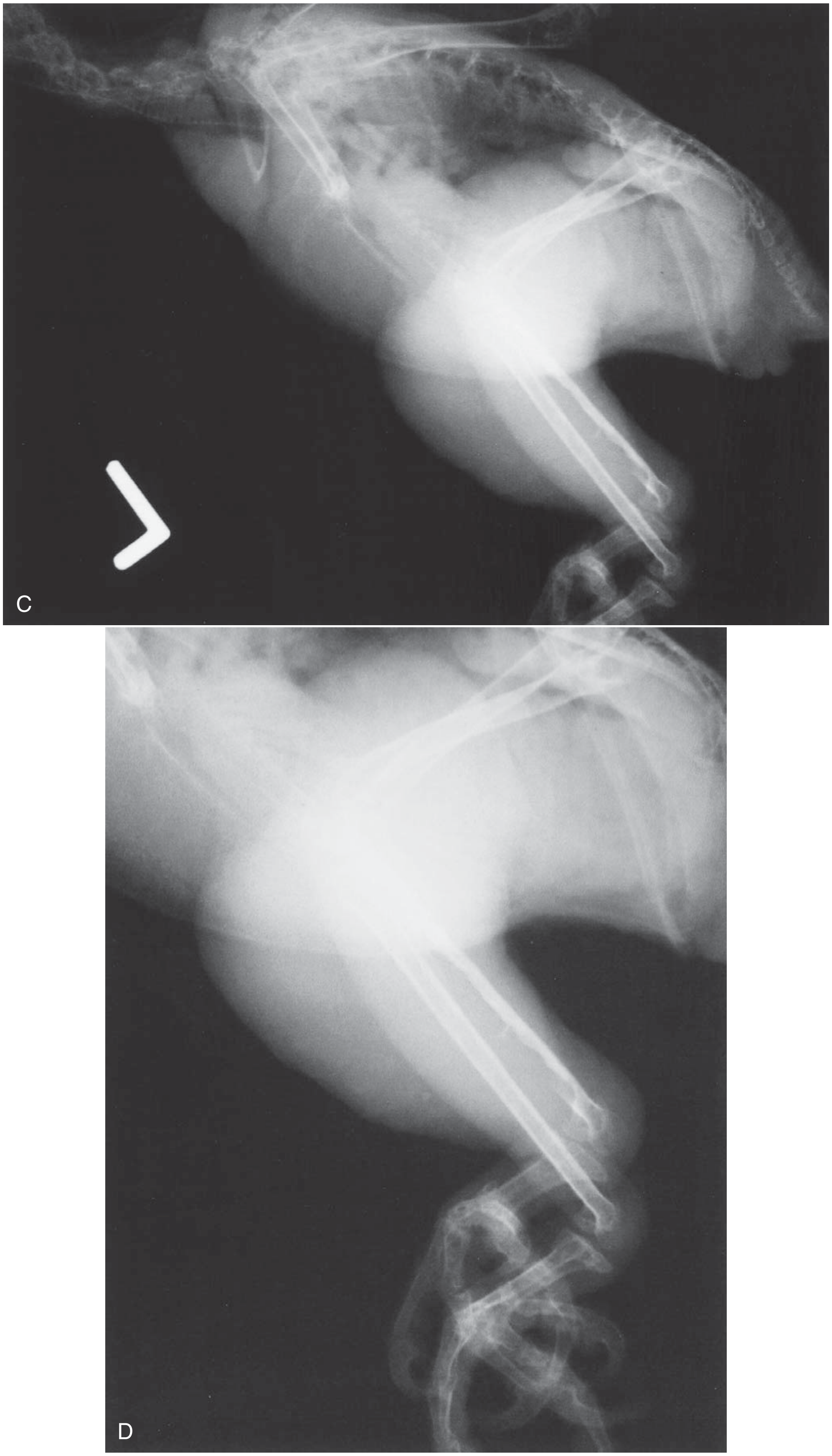


Figure 17-10 • A, Orientation and close-up **(B)** ventrodorsal views of an African Gray parrot with a probable soft tissue sarcoma of the left tibiotarsal region. The highly invasive nature of the tumor is revealed by the extent of the destruction in the nearby tibia, which contains at least one and possibly two nondisplaced pathological fractures. **C,** Orientation and close-up **(D)** lateral projections of the lesion field are also provided.



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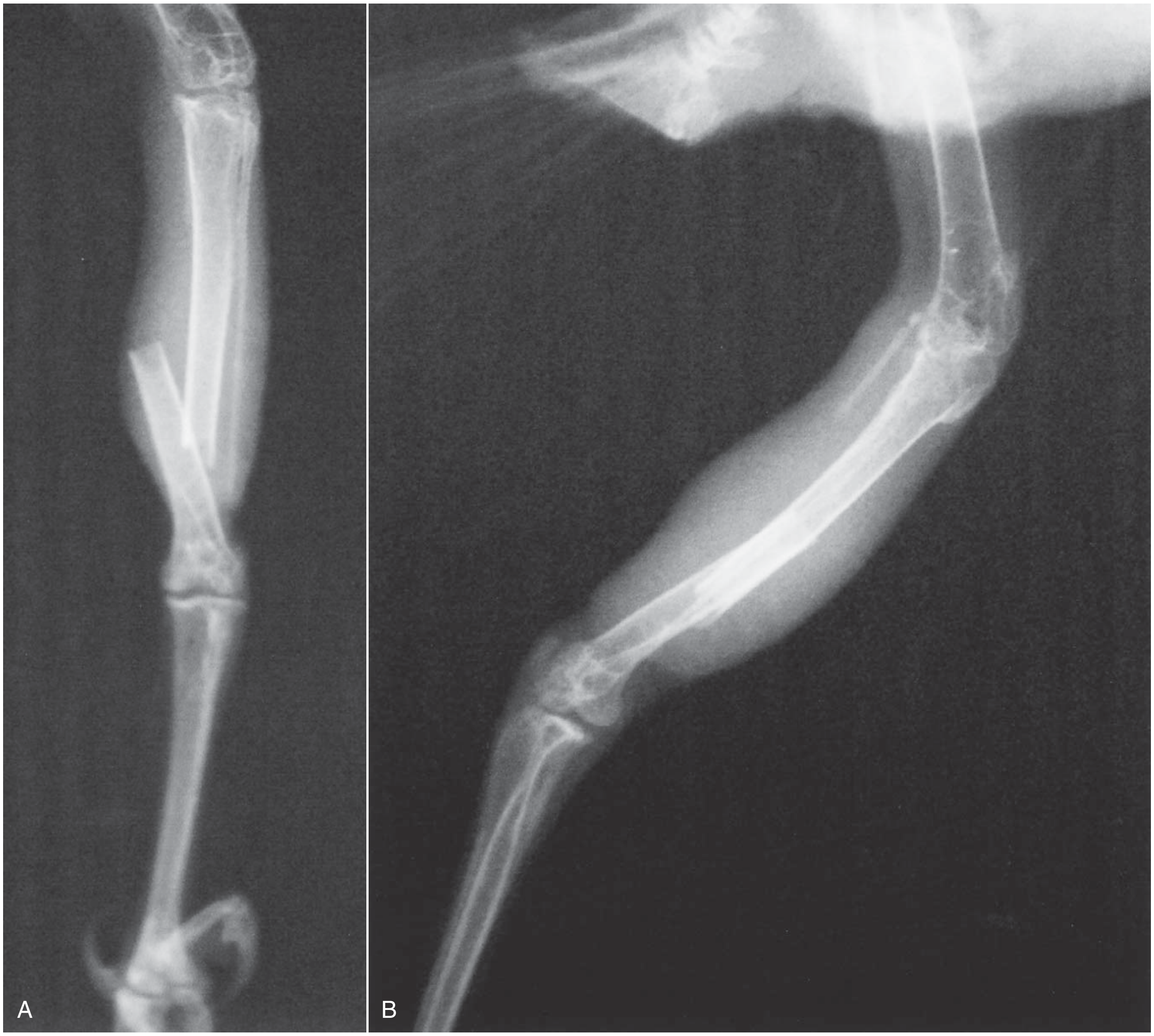


Figure 17-11 • A, Craniocaudal and lateral **(B)** views of a freshly fractured tibiotarsus in a Merlin show the injury clearly in one view but only vaguely in the other.

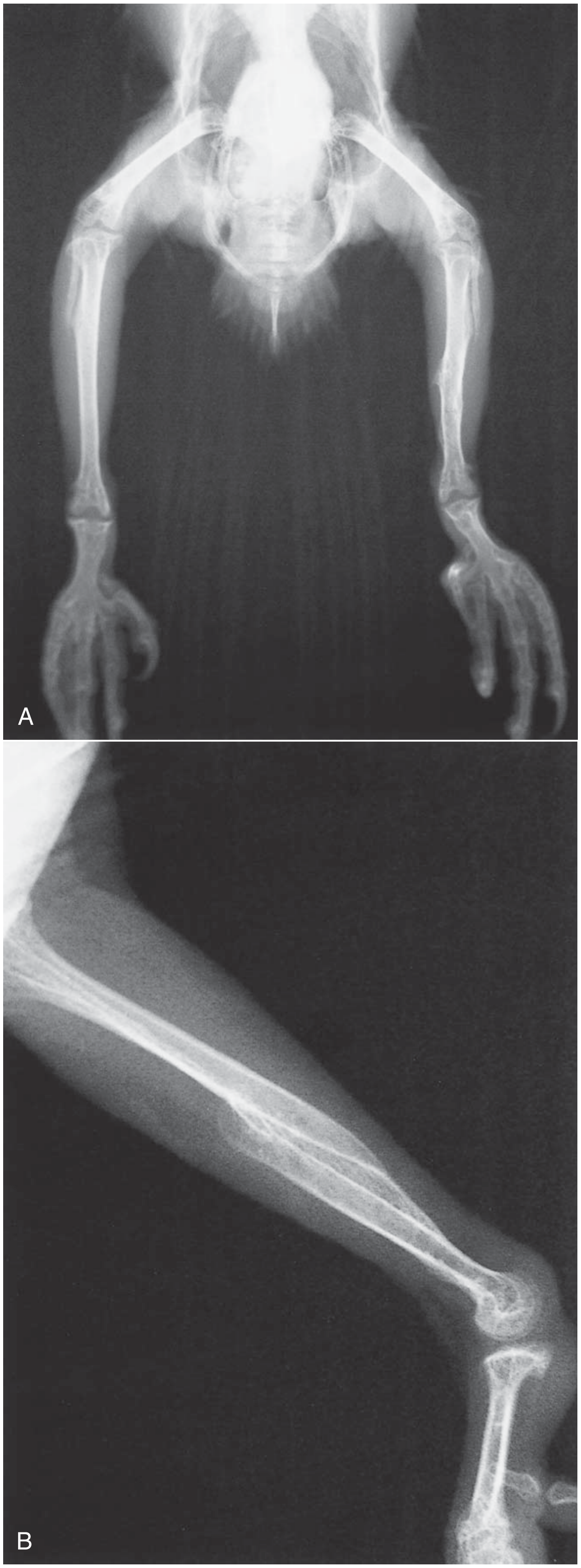


Figure 17-12 • A, Craniocaudal and lateral **(B)** views of a mature, side-to-side tibiotarsal malunion in a flicker. As in Figure 17-11, the injury is obvious in one view but almost invisible in the other. Note the difference in leg length as a result of the shortened left tibiotarsus.

Figure 17-13 • Craniocaudal close-up view of the proximal left tibia shown in Figure 17-10 reveals a pathological fibular fracture secondary to the ingrowth by an adjacent malignant soft tissue tumor.

Figure 17-14 • Extended view of the lower leg and foot of a rough-legged hawk showing the distinctive feathering after which the bird is named. Note the well-developed pads on the undersides of the digits, which provide an excellent grip, even on smooth or wet surfaces.

Figure 17-15 • Blue jay seen from the side-rear showing how the rear digit clamps the foot to the edge of the clay dish.

Figure 17-16 • An Amazon parrot perches on the hand of a resident while being examined visually.

all in the same action. The inward convergence of the three backward-directed talons, combined with the forward-directed base claw, provides a near-inescapable, lethal grip that enables a raptor to carry away its prey in either one or both feet (Figure 17-17).

During feeding, raptors often secure themselves on a branch with one set of talons, while gripping their prey with the other. The bird then feeds by tearing away the flesh and entrails of its victim with its beak.

THE ROLE OF THE FEET IN TAKEOFF AND LANDING

During takeoff, most of the larger water birds, such as geese, use both their wings and feet to become airborne, with some, like the cormorant, requiring a longer "runway" than others. Ducks can become airborne quite suddenly, especially if alarmed or startled, appearing to almost leap into the air, a kind of jump-start.

When many water birds take off, they use their feet in a manner that resembles running: initially getting the bird underway and then rapidly accelerating over the water's surface (Figure 17-18). But the feet have another important function during takeoff: to push the bird's torso off the water's surface and greatly reduce energy-robbing friction, enabling the wings to lift the bird from the water. Once airborne and just like larger commercial aircraft, the feet are retracted and stowed beneath the undersurface of the torso or below the outstretched tail.

When geese, pelicans, and cormorants land, they use their feet initially as air brakes, letting them dangle beneath their bodies as they begin to flare (Figure 17-19). Just before touchdown, the feet are swung forward, tips upward, much like a pair of water skis immediately before the skier lands a jump (Figure 17-20). Again, like commercial airliners, some landings are rougher than others, depending on the crosswinds and the roughness of the water. On touchdown, wing thrust is reversed and the feet are lowered into the water where they can function in a coordinated paddling fashion to advance, maintain position, or independently turn and maneuver.

THE VERSATILE PROPELLER: PROPULSION ON AND BENEATH THE WATER SURFACE

To most observers, the function of a water bird's feet is clear: to propel it over the surface of the water (Figure 17-21) or to dive (Figure 17-22). But what is not so readily apparent is how the feet of some water birds are used when submerged, especially predatory water birds in pursuit of prey (Figure 17-23). For example, the cormorant is an exceptionally skilled underwater predator that uses its feet to both propel and guide itself while chasing down small fish. Specifically, the cormorant's feet can be angled horizontally to act as stabilizers or vertically to function as rudders, enabling cormorants to change depth and direction almost instantaneously.

Sandshoes

The webbed feet of shorebirds serve as broad, flexible platforms on which to negotiate the sandy shoreline and its contiguous shallows. In principle, a shorebird's feet function much like snowshoes, but unlike the rigid winter counterparts, a shorebird's feet are quite flexible and are able to bend so as to contour irregular surfaces such as gravel, rocks, and vegetation. Sandshoes may also be conveniently collapsed during flight, which results in improved aerodynamics.

Foot Injuries

The most common serious foot injuries encountered in our practice are traumatic toe amputations, followed

Figure 17-17 • Foot of a hawk showing four tonglike talons in the partially open position. **A,** Seen from below. **B,** Seen from the side.

Figure 17-18 • Diving duck begins upriver takeoff, leaving "footprints" in the water. Ice flows can be seen in the background.

Figure 17-19 • A pair of Canadian geese dangle their feet in the airflow to further reduce speed just before advancing them for landing.

Figure 17-20 • Moments before landing a cormorant extends its feet forward, tips up, much as a water skier lands a jump.

Figure 17-21 • Cormorant maintains its position in heavy hydraulics by using its feet as paddles and its partially extended wings and tail as outriggers.

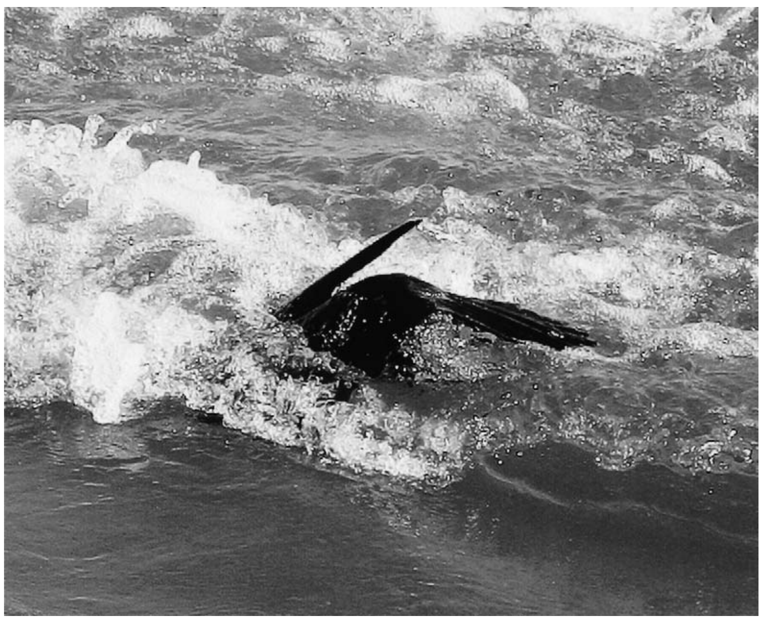


Figure 17-22 • Cormorant begins a deep dive by spreading and flexing its tail, followed by a powerful kick of its feet, much as a whale shows its flukes.

Figure 17-23 • Hunting cormorant cruises just beneath the surface of the water. Its hind foot is seen in the foreground alongside the tail and resembles a scuba diver's swim fins.

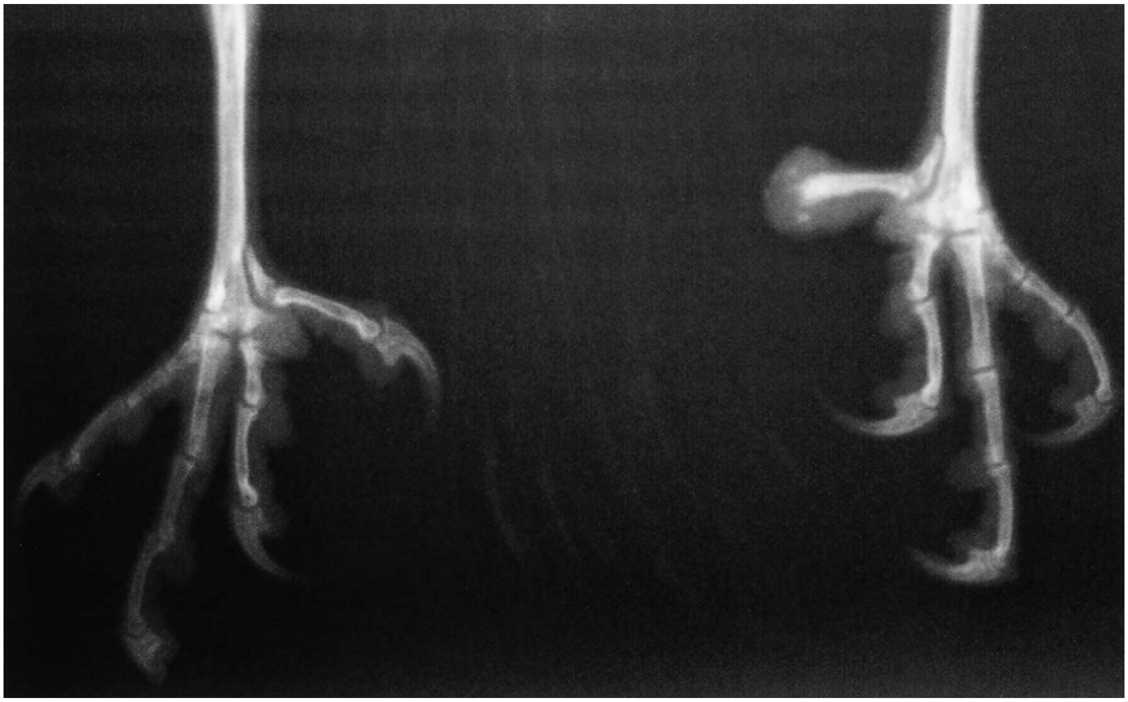


Figure 17-24 • Feet of a hawk showing a traumatic amputation of the nail on the right base claw.

by dislocations and fractures. Amputations may involve any digit at any level, but are inclined to occur more distally, often involving the claw (Figure 17-24). Likewise, fractures, dislocations, and combined fracture-dislocations may also occur anywhere but are most apt to involve the distal aspect of the digit (Figure 17-25).

Figure 17-25 • Left foot of an eagle shows dislocation of the distal interphalangeal joint of the central digit.

Chapter 18

The Head

NORMAL ANATOMY

The typical bird head is composed of a beak (or bill), the upper part of which contains the nostrils and tongue; a facial region dominated by the eyes; and a cranium. All but the beak are covered in feathers.

BEAK AND TONGUE: AN ANATOMICAL PERSPECTIVE

The Beak

Enormous variability exists in the heads of birds, especially in beaks, which for the most part reflect their individual diets. For example, the enormous sharply hooked beak of the bald eagle is capable of flaying flesh from bone as if it were paper (Figure 18-1), or the powerful brutish beak of a parrot is able to crack a Brazil nut as easily as it might a grape (Figure 18-2).

Other variants include the long gracefully curved beak of a flicker, which is designed to extract insects from deep beneath the bark of trees (Figure 18-3), or the pikelike beak of a jay (Figure 18-4), which is capable of grasping a peanut, puncturing its shell, and withdrawing its content, all within a few moments. Even the small stout triangular beak of the sparrow has been optimized for the task of finding seed whether in the urban canyons or the great boreal forests (Figure 18-5).

The beaks of water birds are equally varied, ranging from the expandable pouch of a pelican (Figures 18-6 and 18-7) to the raptor-like hook of a cormorant (Figure 18-8). Ducks (Figure 18-9) and geese (Figure 18-10) possess broad flat beaks that resemble the blade of an inverted shovel; these work in conjunction with their filter-equipped tongues to remove nutrients from the bottoms of wetlands, lakes, and rivers or, if the opportunity (or necessity) arises, to graze the nearby shorelines.

The Tongue

As in the case of the beak, the design of the tongue reflects the diet. Geese and ducks have tongues designed to filter the bottom material on which they feed (Figure 18-11). Raptors possess a short thick muscular tongue that propels chunks of flesh back into the throat to be subsequently swallowed (Figure 18-12).

Woodpeckers, the anteaters of the bird world, have an extremely long tongue, thin as a pencil lead, that is capable of extending well beyond the tip of the beak in search of insects (Figure 18-13). Parrots have a particularly dexterous tongue that is guided by the rostral elements of the hyoid system, a pair of bony structures embedded in the tongue, the *entoglossum* bones (Figure 18-14).

THE JAWS, FACIAL REGION, AND CRANIUM: A RADIOGRAPHIC PERSPECTIVE

Jaws, Nasal Cavities, and Paranasal Sinuses

Unlike mammals, many birds have dynamic jaws that achieve maximal opening either by a system of adjustable bony levers and pivot points, or in the case of psittacines, by a jointed beak, termed the *craniofacial*

Text continued on p. 189.

Figure 18-1 • **A,** Lateral and quarter-front **(B)** views of a bald eagle moments after the bird regained consciousness from general anesthesia for radiography. Note the elongated, distinctively hooked beak and the prominent oval-shaped nostril.

Figure 18-2 • Frontal view of an Amazon parrot, looking somewhat possessed, just as it begins to regain consciousness after general anesthesia for radiography. Note the large powerful beak.

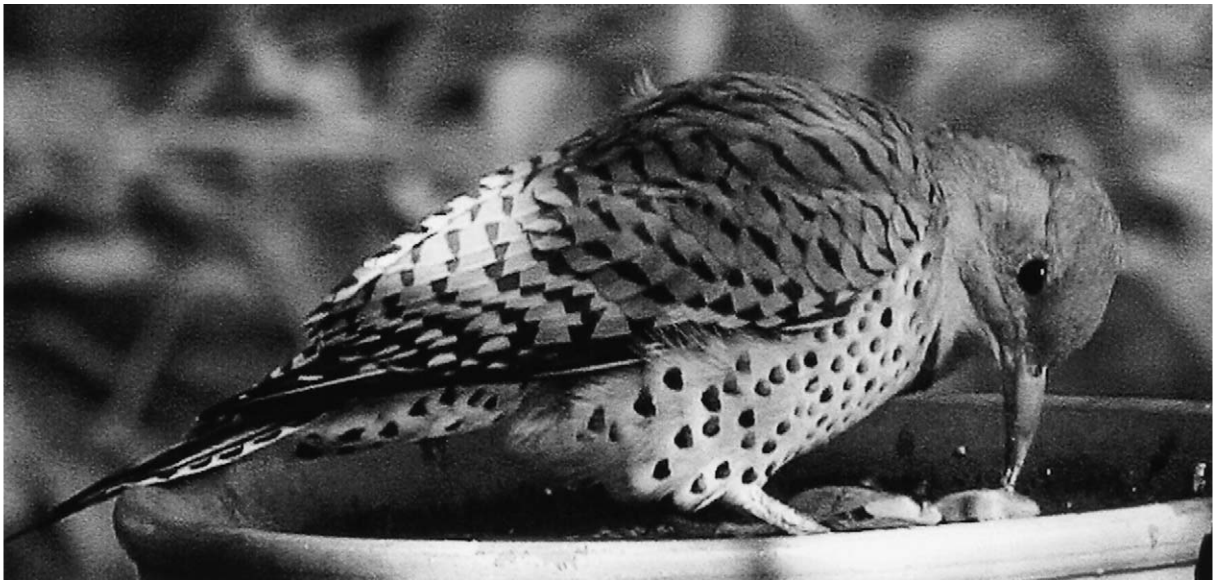


Figure 18-3 • A flicker, normally a vertical feeder, demonstrates the versatility of its beak by eating horizontally from a bird feeder.

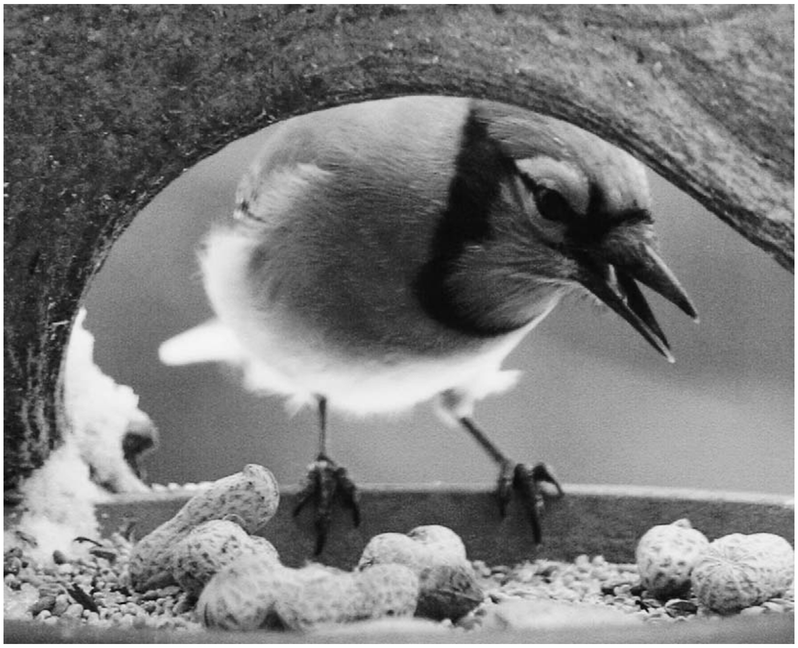


Figure 18-4 • A jay warns off other birds before feeding with its distinctive strident call. Its all-purpose beak is typical of the Corvidae.

Figure 18-5 • A sparrow eyes a clump of frozen seed, showing off its short triangular beak.

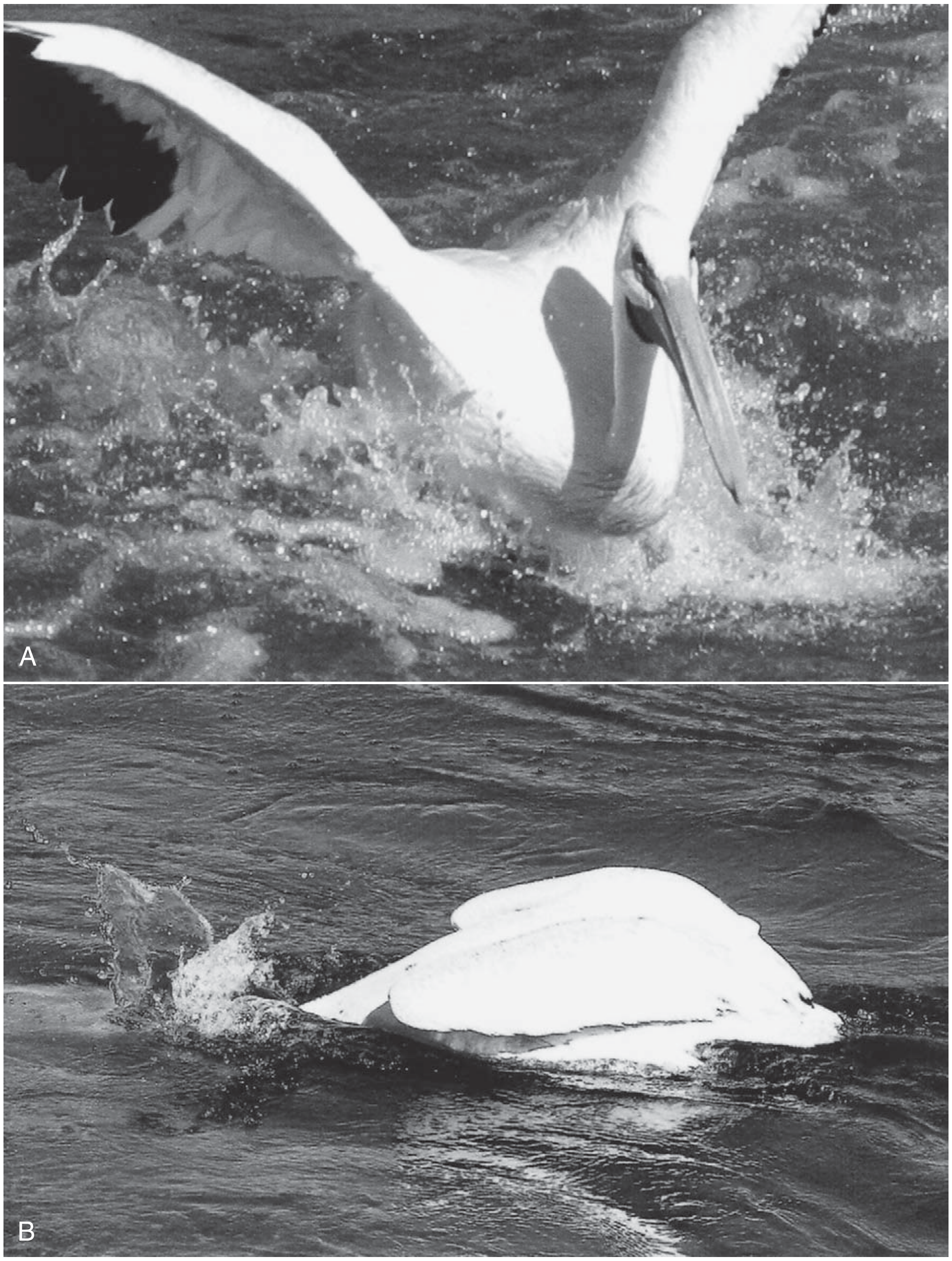


Figure 18-6 • A pelican executes a splashy landing, providing a view of its distinctive beak (pouch collapsed), which from above resembles a miniature surfboard with a beveled center ridge **(A).** This design serves not only to support the loaded pouch but also to move under water with a minimum of resistance **(B).**

Figure 18-7 • A pelican withdraws its beak from the water, its pouch bulging, forcing the bird to use its powerful neck muscles to make the lift.

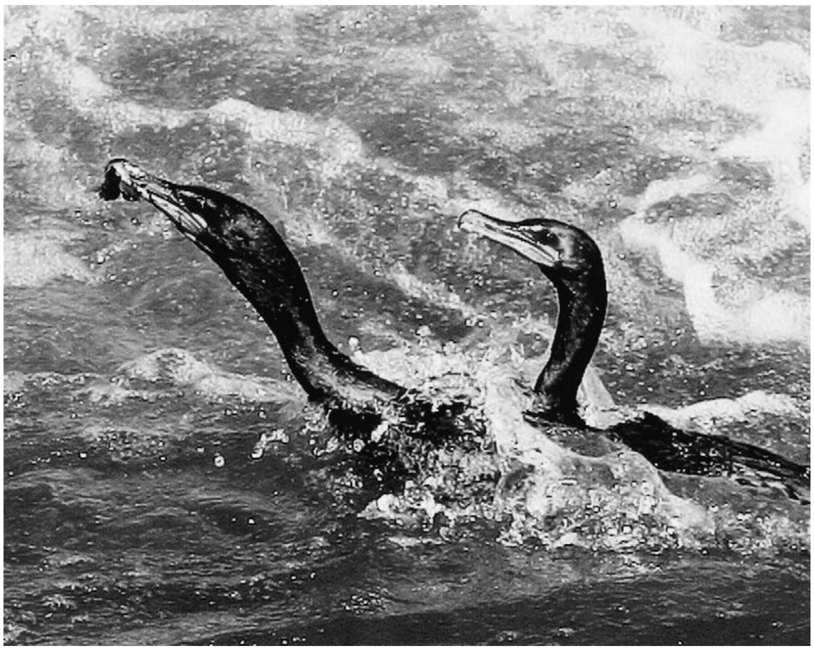


Figure 18-8 • A pair of just surfaced cormorants contest the ownership of a small fish. Note the raptor-like hook at the end of their beaks.

Figure 18-9 • A mallard duck still unconscious from an earlier general anesthesia. Note the broad, gently arched bill and the small oval-shaped nostril just above the radiographers thumb.

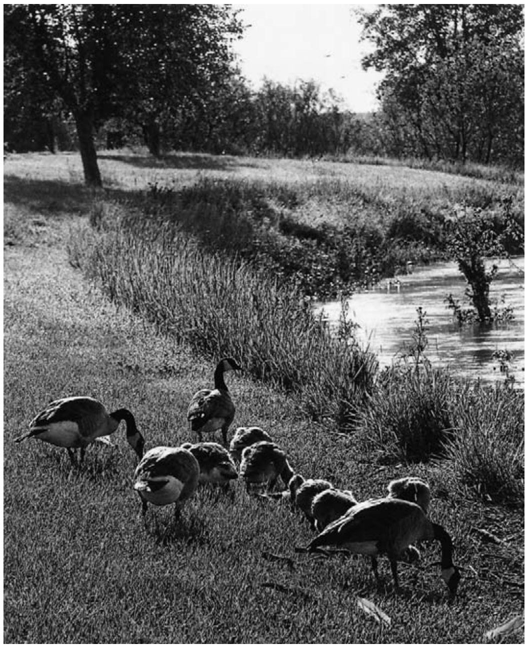


Figure 18-10 • Combined family of Canadian geese graze the fresh summer grass just beyond the shoreline of the South Saskatchewan river.

Figure 18-11 • Close-up view of a Canadian goose, its beak wide open while its oral cavity is transilluminated. Note the teethlike serrations along the edge of the mandible.

Figure 18-12 • Close-up view of the open beak of a great horned owl exposing its thick muscular tongue.

hinge joint. The latter can be readily appreciated on a radiograph.

The maxilla and mandible are encased within the upper and lower elements of the beak. The maxilla contains the nasal cavity, which is composed of a system of longitudinally stacked conchae divided along the midline by a septum that can only be appreciated in the ventrodorsal (VD) projection (Figure 18-15). The conchae are not clearly discernible in either standard projection, other than with computed tomography (Figure 18-16). As with mammals, these elements warm, humidify, and filter the incoming air.

Facial Region

The facial region of birds features the eyes, which are preeminent in some species such as raptors (Figures 18-17 and 18-18). Radiographically, the eyes appear as large circular densities, nearly as large as the adjacent brain (Figure 18-19).

Birds also have facial sinuses, which are quite elaborate in parrots and related birds. The primary sinus chamber, the *infraorbital sinus*, encircles the ventral half of the obit and then extends outward around the eyes and ears in an elaborate system of irregular channels, or *diverticula.* Some of these channels reach as far forward as the central conchae and mandible and as far caudally as the neck in the form of the *cervicocephalic air sac*.

Most of this intricate system of air-filled space is difficult or impossible to identify as individual structure, but it is possible to identify some of the larger elements such as the rostral portion of the infraorbital sinus, which appears as a triangular lucency immediately forward of the eye, as seen in a lateral projection of the head (Figures 18-20 through 18-24).

THE CRANIUM AND BRAIN

We see few cranial injuries, probably because of the low survivability associated with this kind of trauma. The most common cranial injury occurs when a bird is knocked unconscious trying to fly through a *closed* window or patio door. Some of these birds are dead on arrival, most likely having died where they fell (Figure 18-25). Others appear stunned but eventually manage to fly off (Figures 18-26 and 18-27). Occasionally, I have the opportunity to ultrasound the brains of birds suspected of having secondary hydrocephalus (Figures 18-28 and 18-29).

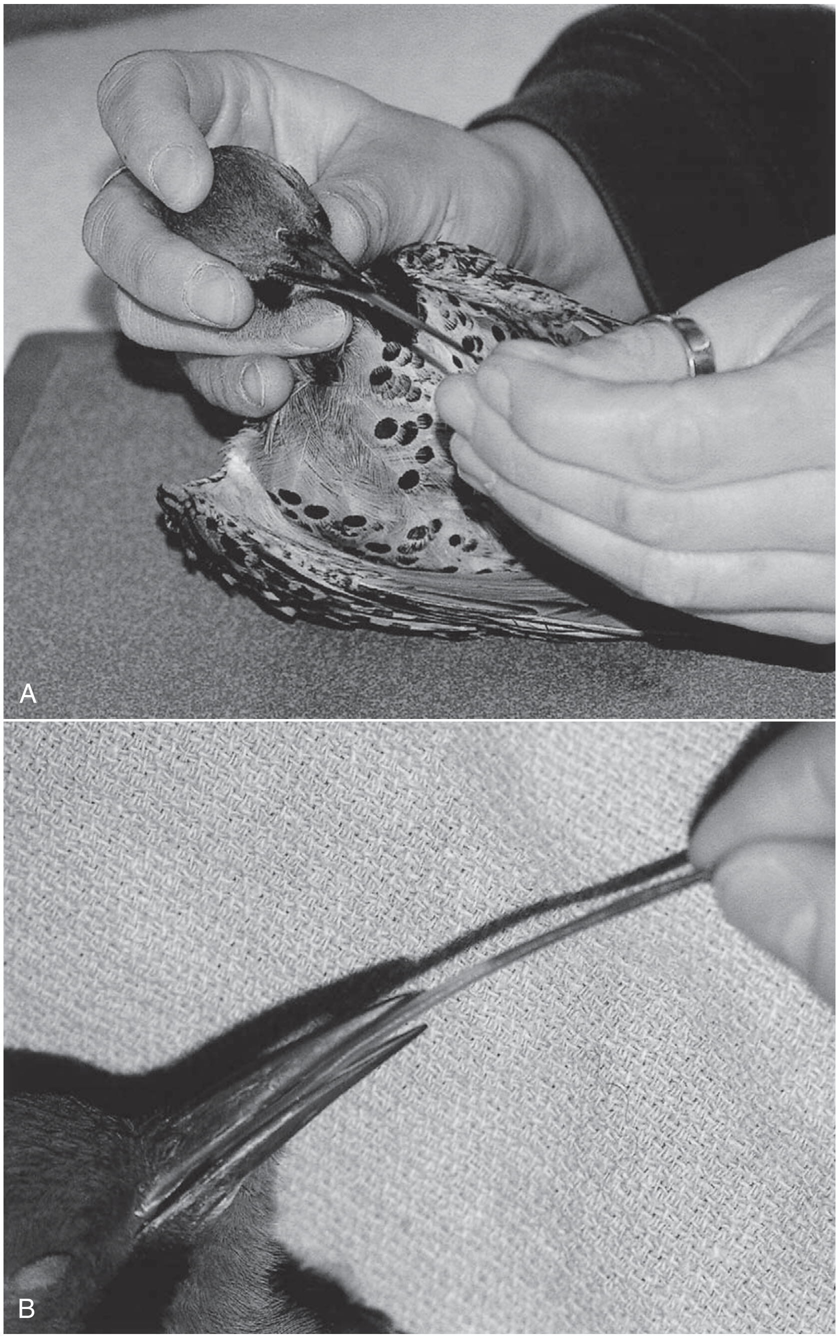


Figure 18-13 • A, Orientation and close-up **(B)** views of the fully extended tongue of a flicker.

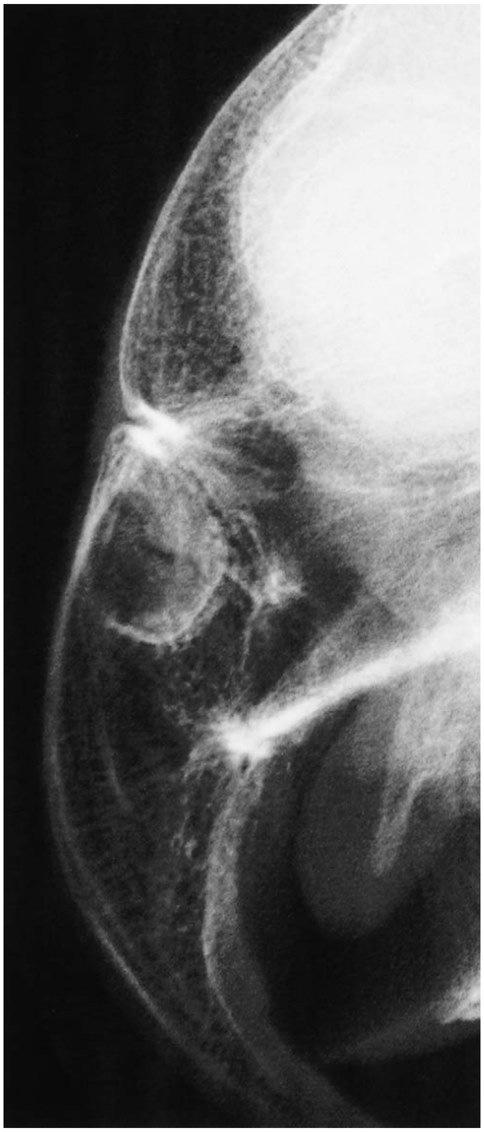


Figure 18-14 • Ultra-close lateral view of the rostral surface of the beak and cranium of an African Gray parrot showing a pair of unique psittacine features: (1) a jointed beak (seen here as a small gap in the left-hand margin of the image) and (2) a bone embedded in the base of the tongue, a so-called entoglossum bone.

Figure 18-15 • Ventrodorsal projection of the head typically provides a relatively low-contrast, low-detail view of the nasal conchae and intervening septum.

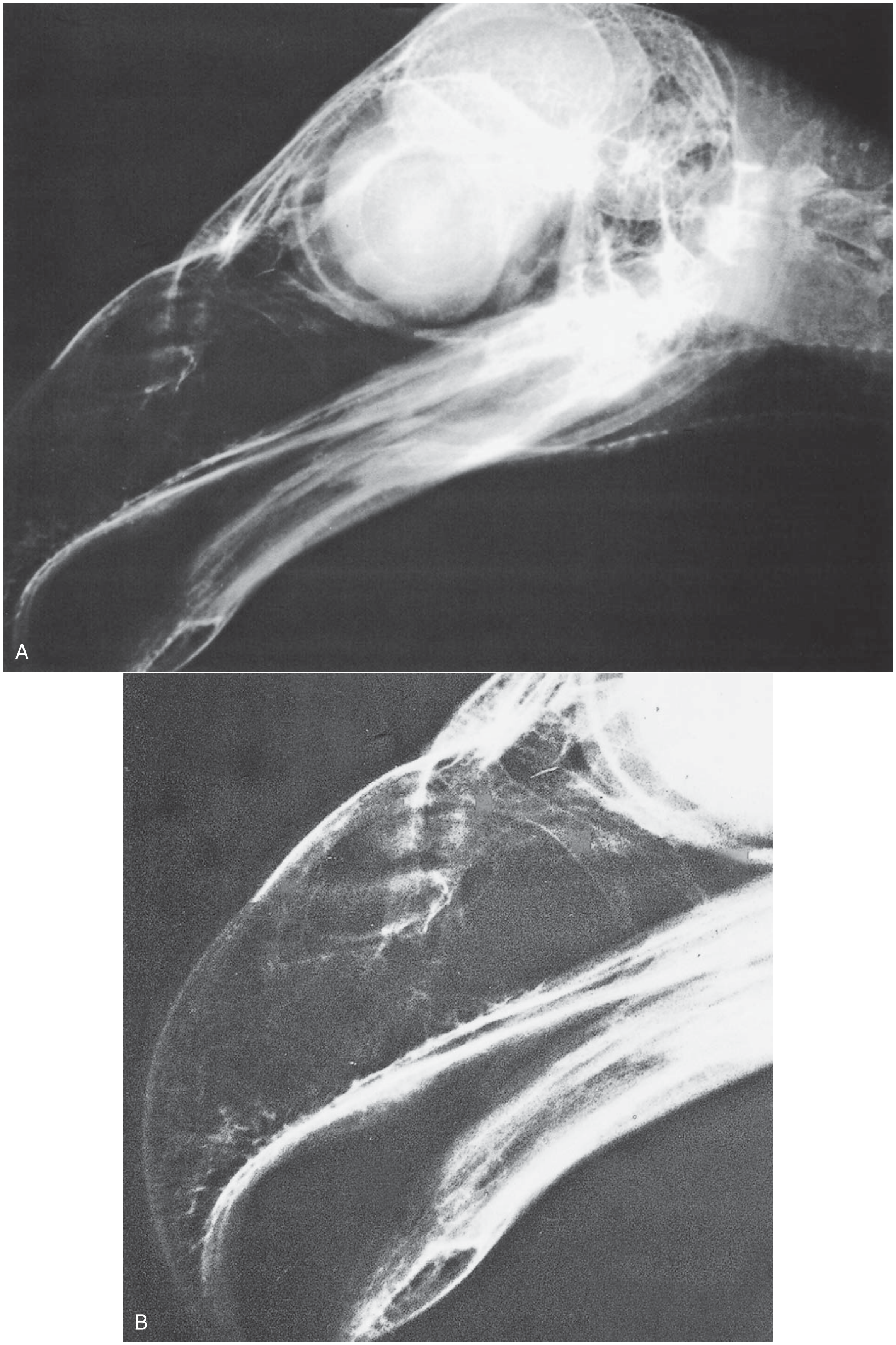


Figure 18-16 • A, Lateral view of the head of a bald eagle using bone technique, which typically overpenetrates the nasal cavity and obscures the conchae. **B,** Close-up lateral view of the nasal cavity of the same bird in **A** but with soft tissue technique, which provides some conchal detail.

Figure 18-17 • Ophthalmologist examines the eye of a raptor while assistant holds down lower lids, exposing the globe.

Figure 18-18 • Close-up view of the eye of an owl.

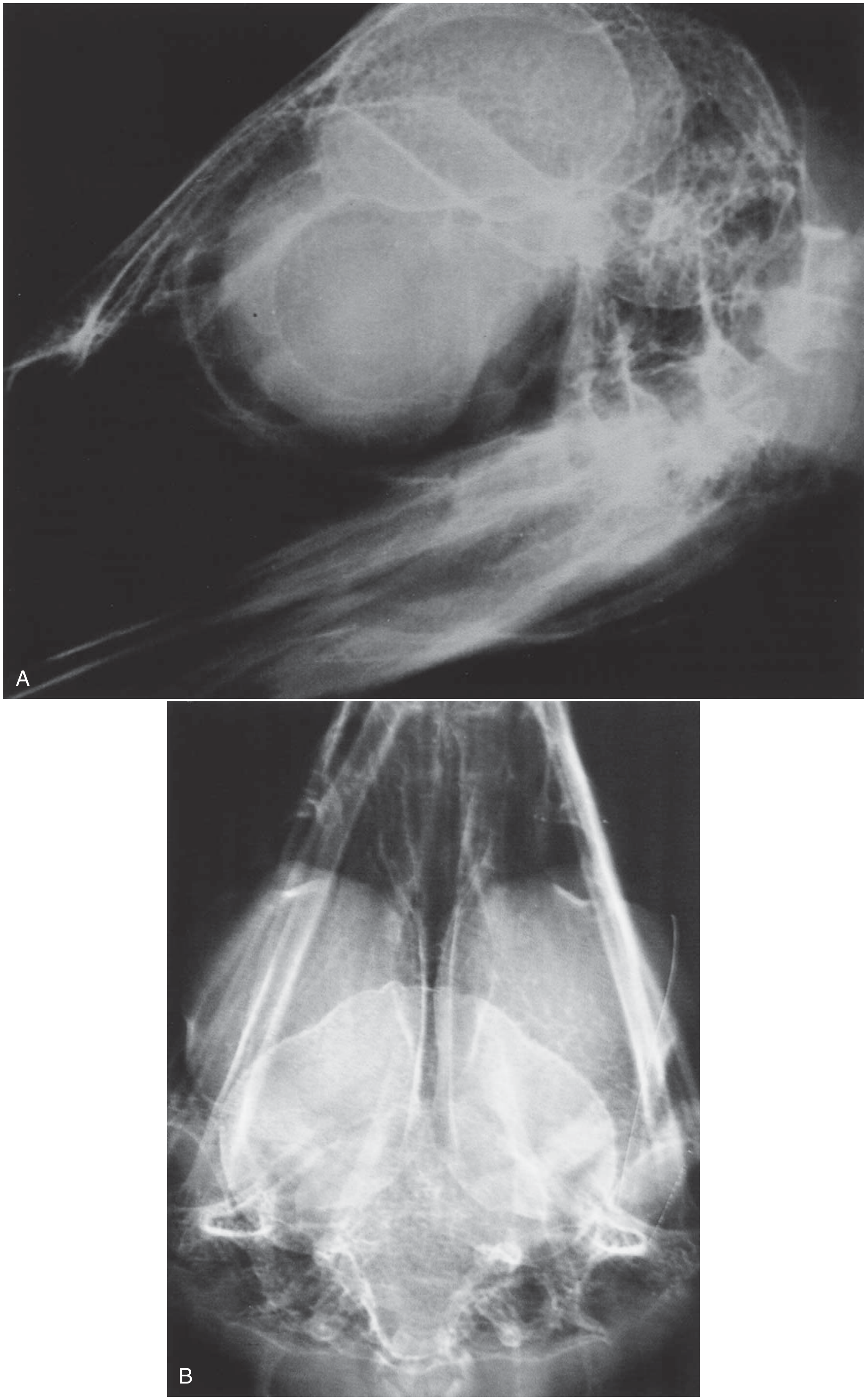


Figure 18-19 • A, Lateral and ventrodorsal **(B)** views of an eagle's head emphasizing the eyes, which are individually nearly as large as its brain.

Figure 18-20 • Lateral view of the head of a healthy hawk showing normal anatomical variations of the beak, nasal cavity, sinuses, eyes, and cranium.

Figure 18-21 • Lateral view of the head of a healthy parrot showing normal anatomical variations of the beak, nasal cavity, sinuses, eyes, and cranium.

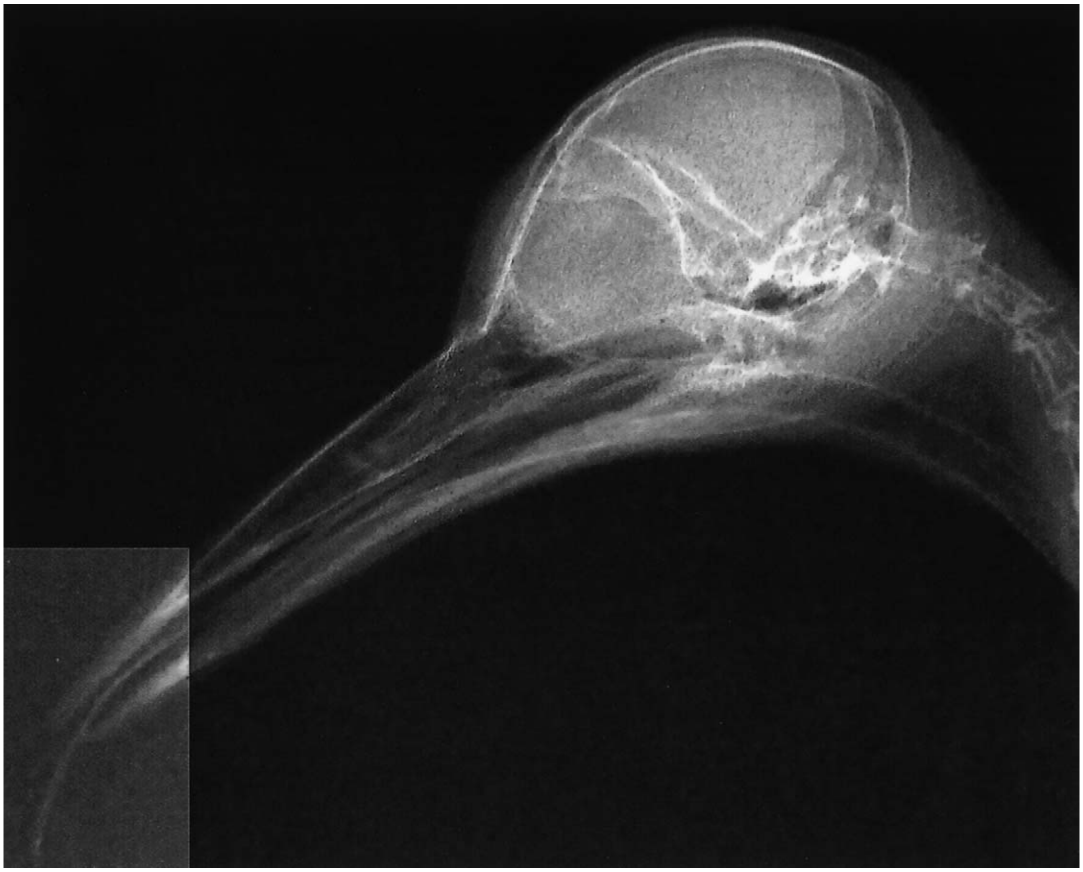


Figure 18-22 • Lateral view of the head of a healthy flicker showing normal anatomical variations of the beak, nasal cavity, sinuses, eyes, and cranium. Note exceptionally long tongue protruding from beak (emphasis zone).

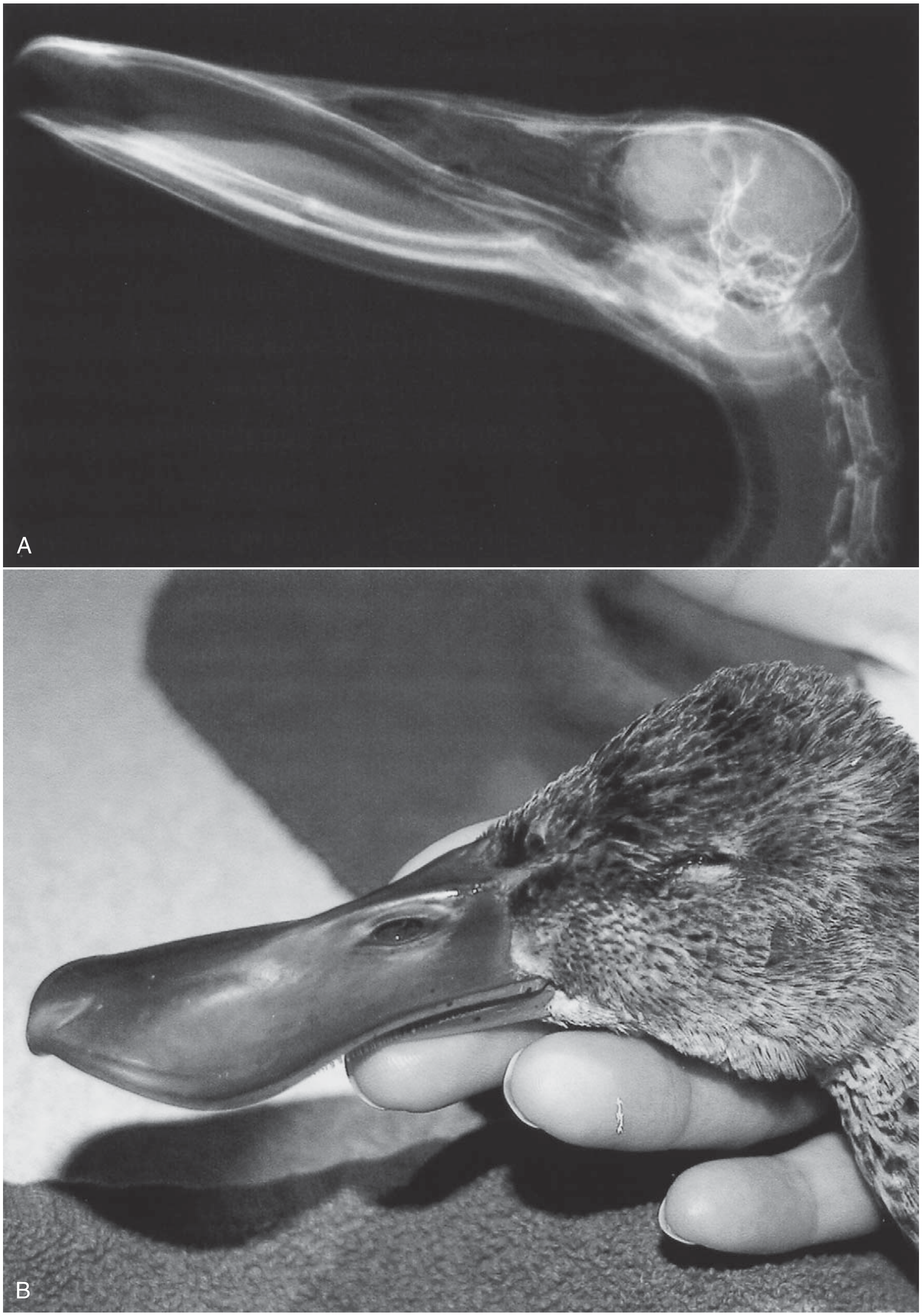


Figure 18-23 • A, Lateral view of the head of a healthy shovel-nosed duck showing normal anatomical variations of the beak, nasal cavity, sinuses, eyes, and cranium. **B,** Note the highly distinctive beak, sloped face, and unobtrusive eyes in this portrait shot of the bird as it recovers from gas anesthesia.

Figure 18-24 • Lateral view of the head of a healthy grebe showing normal anatomical variations of the beak, nasal cavity, sinuses, eyes, and cranium.

Figure 18-25 • A junco lies dead where he fell after flying into a closed window.

Figure 18-26 • A young robin in an open-mouth rigid spread-wing position, often assumed by birds after slamming into a closed window. This form of transient catatonia is usually short-lived, with most birds recovering within a few minutes.

Figure 18-27 • A small song bird crouches in a snow bank, still stunned after striking a patio door. Moments after the picture was taken the bird flew away.

Figure 18-28 • Head of young hawk, secured for sonography, feathers displaced, and caudal dorsal cranium coated with coupling gel.

Figure 18-29 • Caudal dorsal cranium of a young hawk undergoing ultrasound for evidence of hydrocephalus.

Chapter 19

The Throat and Neck

The throat and neck regions are approximately one-third of the total length of the average bird with its head and neck extended (Figure 19-1). Obviously, in some birds, such as herons, this proportion is much greater.

THROAT

Tongue

The tongue is more important to some birds than to others, especially when feeding. The flicker, for example, is like an anteater, as it extends its stringlike tongue deep into the crevice of a tree to capture a beetle or into a freshly mowed lawn to feed on some unwary ants.

Larynx

The avian larynx allows air but prevents food and water from entering the trachea. The larynx lacks an epiglottis and is silent; there is no soft palate. The task of producing sound is relegated to the more caudally situated syrinx (see Chapter 20). The avian larynx appears as a slitlike opening (rima glottis) at the rear of the throat just above the base of the tongue. Using the associated musculature, the larynx can dilate to receive air from either the nose or mouth or constrict to prevent food from going into the trachea.

NECK

The principal structures of the neck are the cervical portion of the spine (discussed later), the trachea, and the esophagus, which includes the crop. Without content, the esophagus and crop are normally invisible.

Trachea

In general, the morphology of the trachea reflects that of the neck: A raptor has a relatively short, gently curved trachea, whereas a goose has a much longer, almost serpentine windpipe. As one might anticipate, the configuration of the trachea changes according to the position of the head and neck (Figure 19-2).

Esophagus and Crop

In most species the esophagus contains a localized dilation proximal to the thoracic inlet, termed the *crop*, which serves to store and sometimes soften food (Figure 19-3). Unlike the stomach, the crop serves no digestive function. Other than the occasional impaction, crop disease is rare. Perhaps the most unusual case involving the crop was a crow with a large intramural abscess that could be seen with plain film, contrast, and ultrasound (Figure 19-4).

CERVICAL SPINAL REGION

Age-Related Differences

As a bird passes successively through its various stages of development—from nestling to fledgling and eventually adulthood—the appearance of its cervical spinal region undergoes a parallel transformation, although not nearly so dramatic.

The cervical spine of the nestling, viewed laterally, is characterized by elongated and hollow-appearing vertebral bodies, wide convex disks, and abbreviated,

Figure 19-1 • Ventrodorsal view of a healthy African Gray parrot showing the relative length of its throat and neck compared with its total body length, which in this instance is approximately one-third.

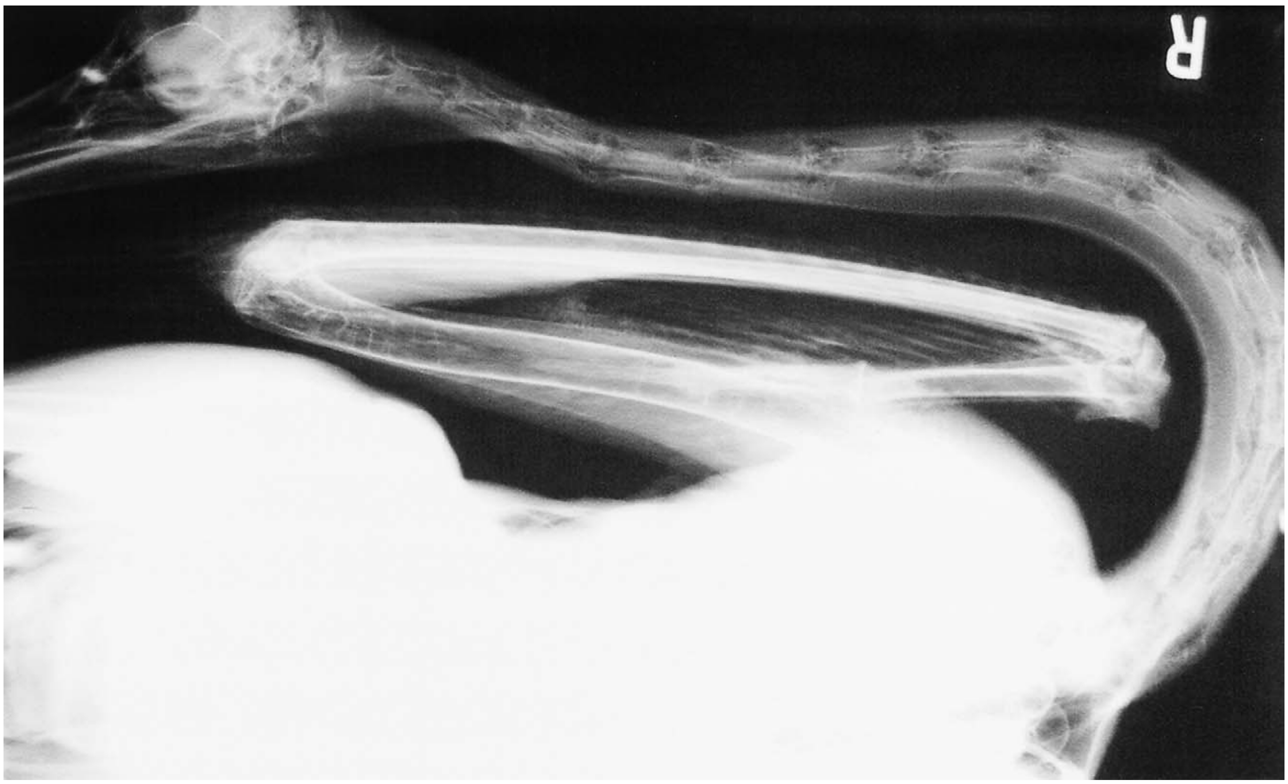


Figure 19-2 • Ventrodorsal oblique view of a dead whooping crane being screened by the Fish & Game service for suspected gunshot injuries. Note the bird's exceptionally long neck, which reaches nearly to the end of its torso.

Figure 19-3 • Close-up ventrodorsal view of the neck of an owl containing the bones of a small mammal in its crop.

centrally rounded dorsal elements (vertebral arches, facet joints, and rudimentary dorsal spinous processes) (Figure 19-5). Seen from a ventrodorsal perspective, the cervical spine resembles a string of triangle-shaped beads that gradually become larger as they near the shoulder region (Figure 19-6).

Approaching maturity, the cervical spine fills out, causing the disk spaces to become much less distinct and the dorsal elements to appear almost fused, especially when the neck is imaged laterally and in an upright position (Figure 19-7). In the opposite view, the mature cervical spine appears more mammalian, featuring rectangular bodies, proportionately sized disks, and discrete facetal joints and transverse processes (Figure 19-8).

Normal Positional Variants Mimicking Spinal Injury

The cervical spine of long slender-necked water birds, such as herons, grebes, and cormorants, can appear dislocated at points of maximum flexion, especially the C5-6 and C6-7 spinal units (Figure 19-9). Oblique lateral projections, particularly in struggling birds, frequently mimic serial fracture-dislocations (Figure 19-10).

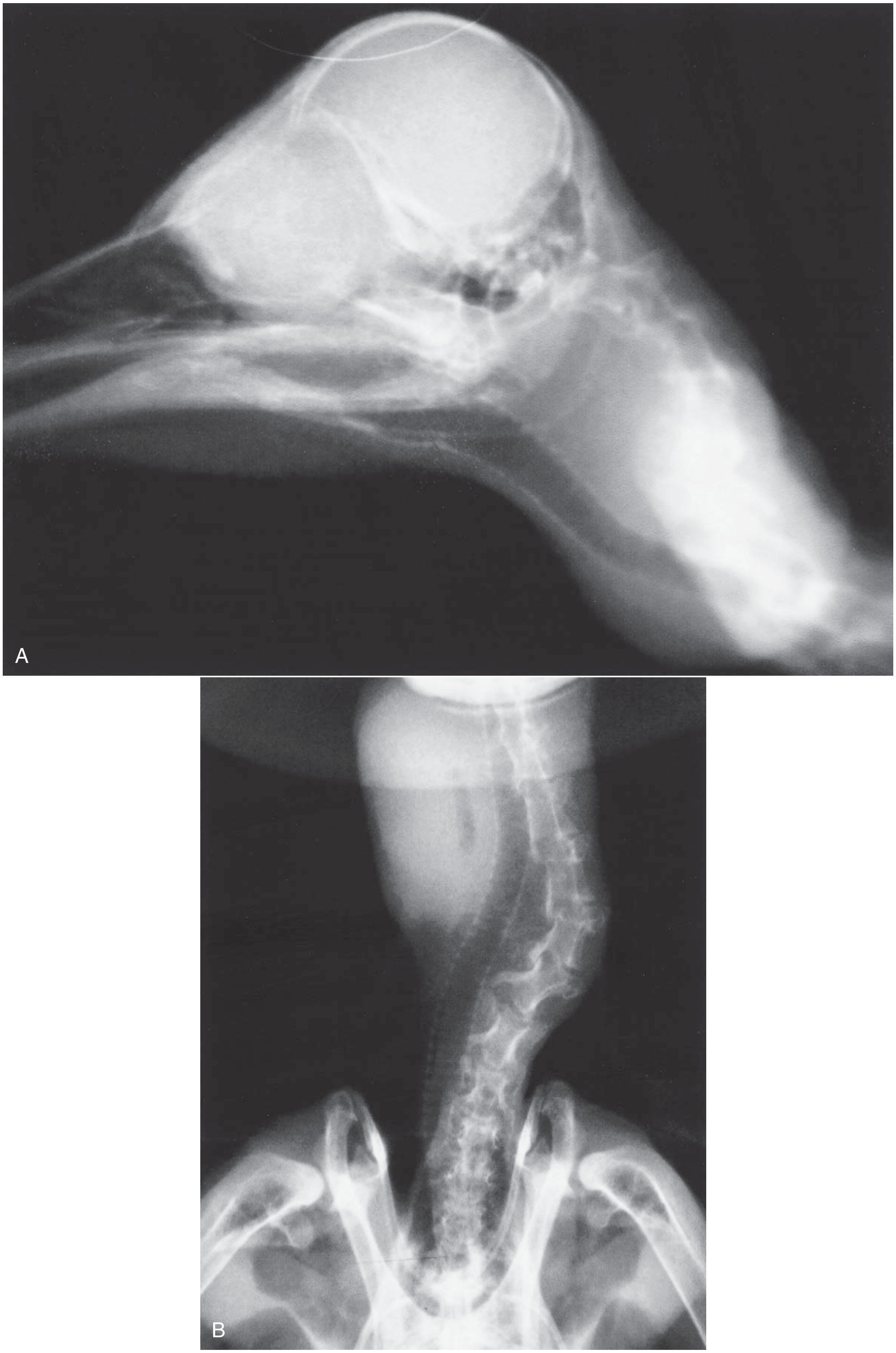
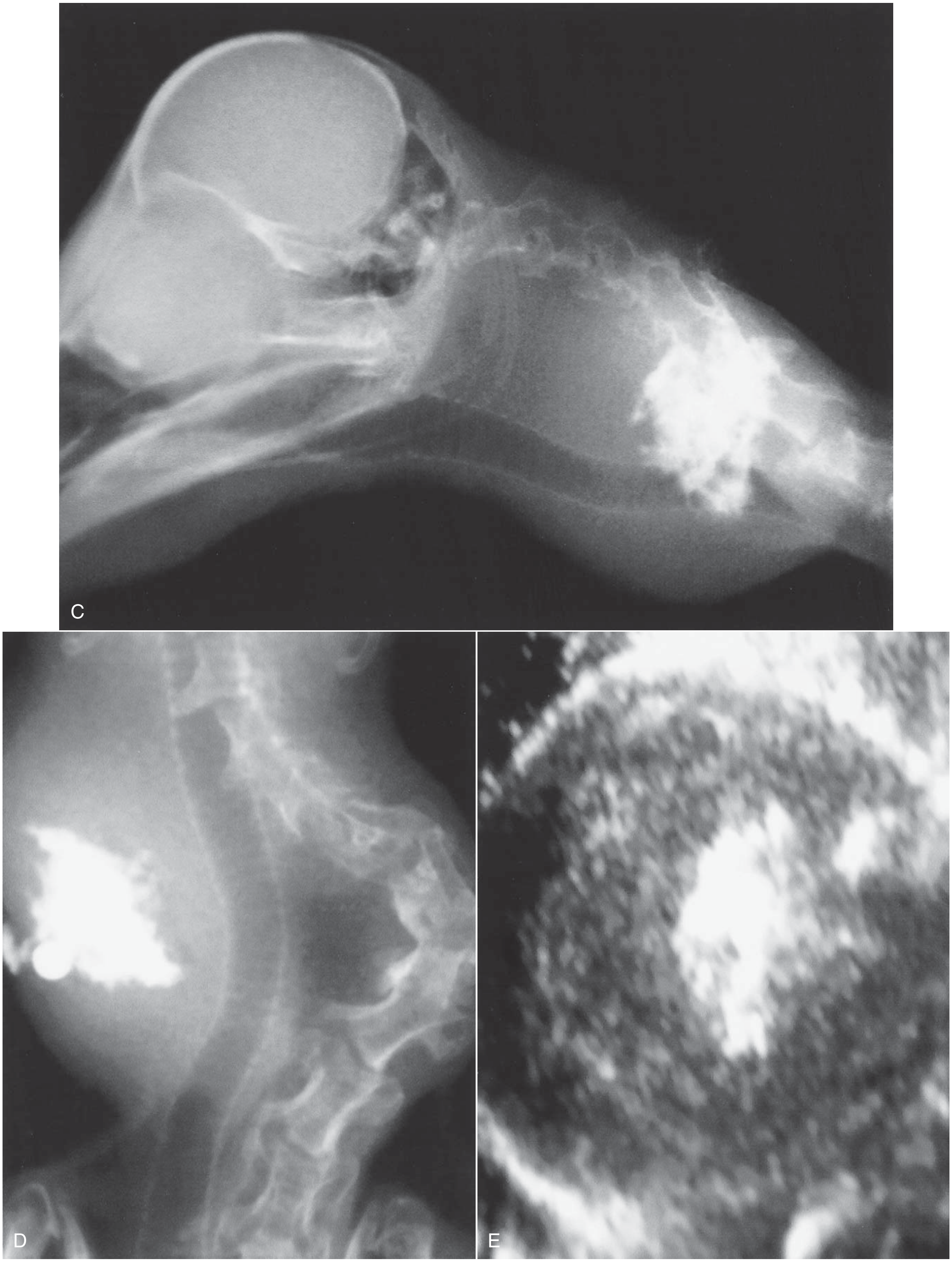


Figure 19-4 • Crow with a partial esophageal obstruction. **A,** Close-up lateral and ventrodorsal **(B)** views of the proximal esophagus show moderate localized swelling that is displacing the trachea in a ventromedial direction. **C,** A ventrolateral sonogram shows what appears to be a well-defined accumulation of pus with air at its center and along its perimeter. **D,** Close-up lateral and ventrodorsal **(E)** esophagrams reveal contrast retention coincident with the aforementioned swelling. The lesion proved to be an abscess in the wall of the esophagus.



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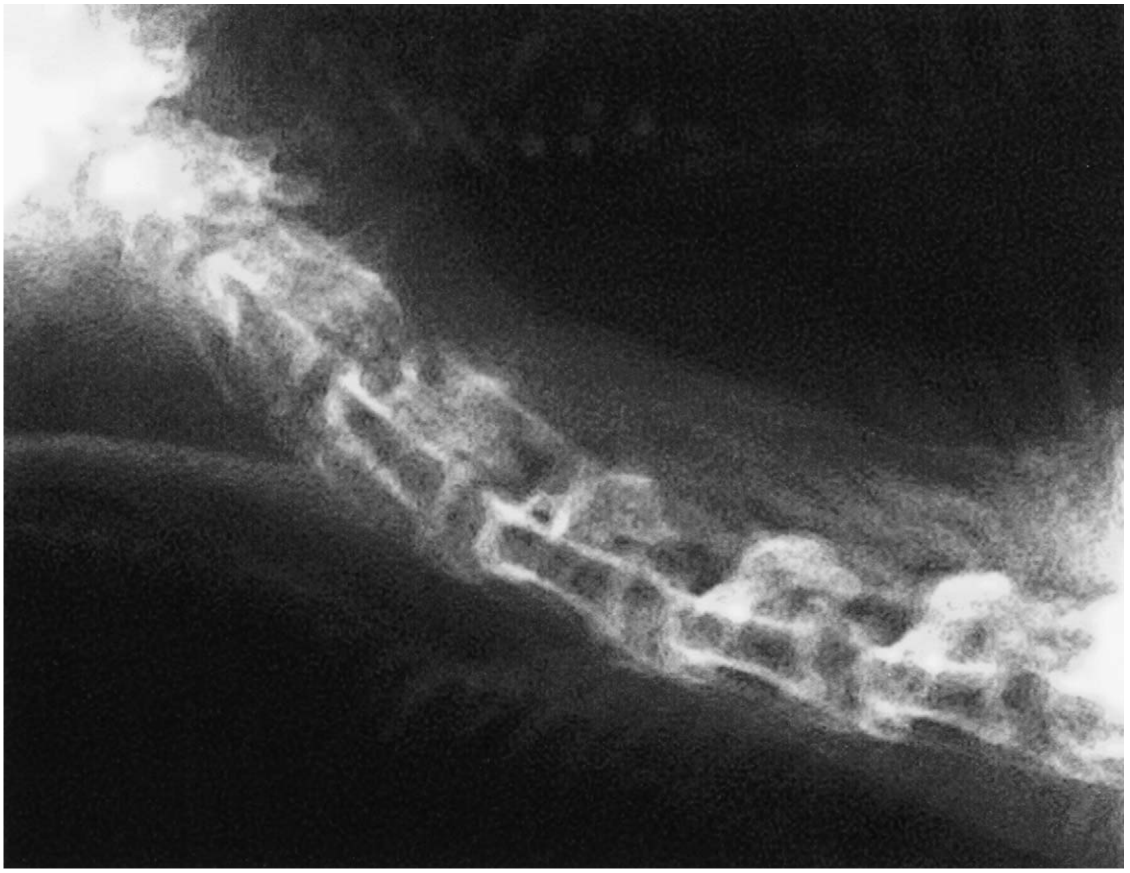

Figure 19-5 • Close-up lateral radiograph of the cervical spine of a nestling owl showing the characteristic appearance of an immature spine: (1) elongated, hollow-appearing vertebral bodies; (2) wide convex disks; (3) abbreviated, centrally rounded dorsal elements (vertebral arch and facet joints); and (4) rudimentary dorsal spinous processes.

Figure 19-6 • Close-up ventrodorsal radiograph of the cervical spine of a nestling owl showing the characteristic diamond-shaped appearance of an immature spine.

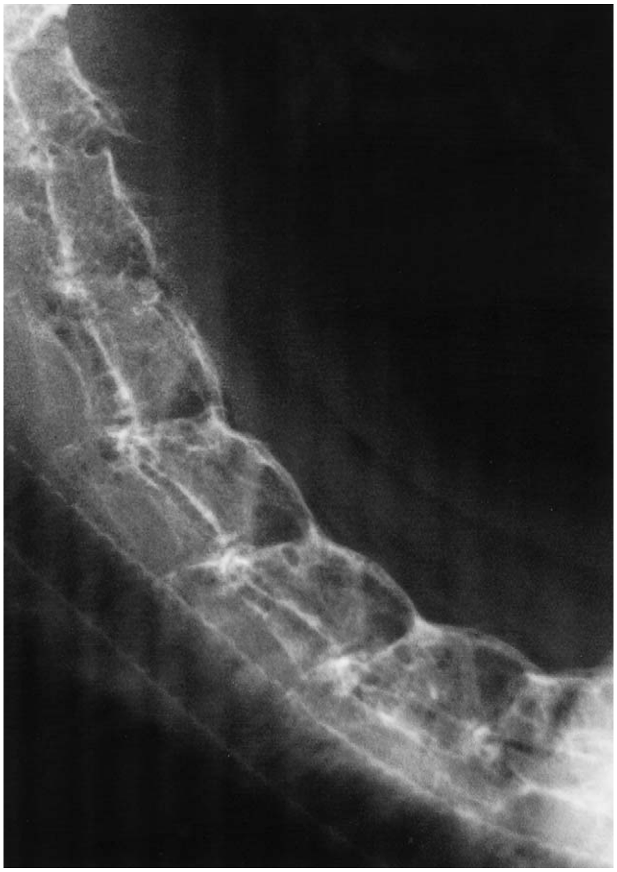

Figure 19-7 • Close-up lateral radiograph of a young adult owl shows (1) small indistinct intervertebral disks, (2) vague spinal canal, and (3) fused-appearing dorsal elements.

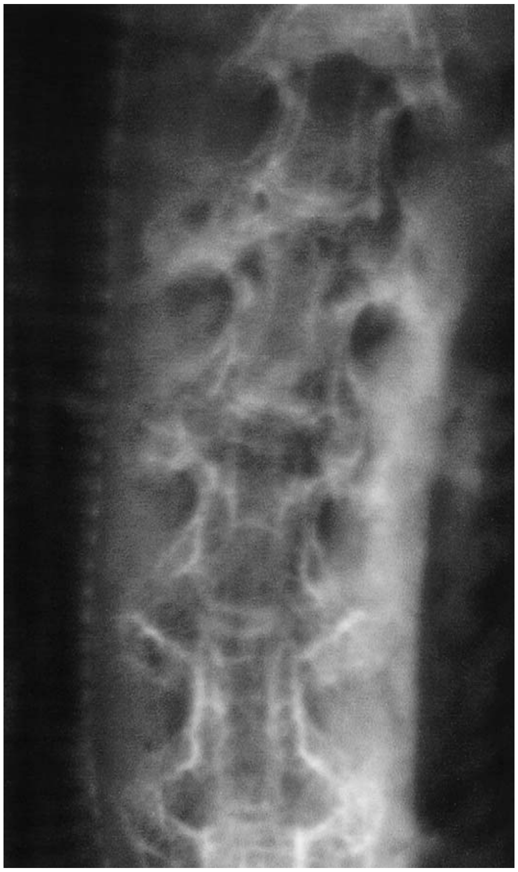

Figure 19-8 • Close-up ventrodorsal view of a young adult owl shows (1) rectangular bodies, (2) proportionately sized disks, and (3) discrete facet joints and transverse processes.

Figure 19-9 • Close-up lateral view of the cervical spine of a grebe shows apparent dislocation caudally *(lower right),* which is a normal finding in many birds depending on the degree of flexion.

Figure 19-10 • Close-up lateral view of the cervical spine of a drugged but struggling grebe shows apparent caudal cervical dislocation, which is a normal finding in many lateral oblique projections.

Chapter 20

The Torso

NORMAL ANATOMY

Birds lack a diaphragm—at least in the mammalian sense of the word—and instead have a thin sheet of connective tissue separating the lung from the remaining viscera. This tissue is called the *horizontal septum* and serves no respiratory function.

Thus there is no internal division into a thorax and abdomen but rather a single large cavity termed the *celom* or *celomic cavity*, which contains the abdominal organs, including air sacs. Figures 20-1 through 20-7 sequentially reveal the exposed viscera of a red-tailed hawk positioned on its back during the dissection.

ANATOMICAL-RADIOLOGICAL CORRELATION

Using conventional radiography, the abdominal viscera are necessarily displayed as a kind of two-dimensional montage, with the shadows of individual organs superimposed on one another in a single flattened layer (Figure 20-8, *A*). The resulting absence of depth perception can be partially mitigated by the addition of one or more right-angle (orthogonal) or oblique projections, but one should remember that not every organ may be seen in every view (Figure 20-8, *B*).

In any event, it generally is the larger organs, such as the heart and liver, or those containing natural contrast, such as the gizzard and bowel, that are most visible and thus are radiographically detectable. In effect, the diagnostic exercise becomes one of silhouette analysis, discussed later in this chapter.

THE EXTERIOR TORSO

The Thoracic Spine, Ribs, Keel, and Body Wall

As with the radiographic assessment of any symmetrical part or parts of the body, accurate positioning is the key to success. The exterior torso is no exception. If equipped with well-positioned lateral and ventrodorsal (VD) views of the torso, the film reader is afforded the opportunity of comparing and contrasting either side of the rib cage, along with the intervening soft tissues and surrounding bones and joints. The diagnostic benefits of a comparative radiographic assessment cannot be overemphasized (Figure 20-9).

Although lateral projections do not lend themselves to right-left comparisons, they nevertheless constitute a valuable diagnostic asset, especially when projected in a true lateral manner (Figure 20-10), thus reducing or eliminating geometric distortion, a potential source of radiographic misdiagnosis.

Fractures of the thoracic spine and ribs are associated with high mortality, and as a consequence, few such birds are radiographed. Sternal fractures, although not usually fatal in their own right, are often associated with serious wing fractures and untreatable internal injuries leading to euthanasia.

The incidence of deep and superficial subcutaneous emphysema in birds is surprisingly low given the frequent occurrence of wing fractures, probably a result of protection provided by the feathers. When

Text continued on p. 216.

Figure 20-1 • Great horned owl dissection. The bird is positioned on its back, and its pectoral and supracoracoideus muscles are laid open, exposing the keel, which is the principal attachment for the major flight muscles. The V-shaped object at the bottom is formed by the clavicles, which in some species is fused and termed the *wishbone*.

Figure 20-2 • Great horned owl dissection. The bird is positioned on its back but is now seen from in front and to one side, revealing the distal attachment of the coracoid *(lower left),* the keel *(center),* and much of the rib cage *(far right).*

Figure 20-3 • Great horned owl dissection. Similar orientation to Figure 20-2 shows the full length coracoid, including its articulation with the other principal components of the humeral joint, the scapula and humerus *(bottom left).*

Figure 20-4 • Great horned owl dissection. The bird is on its back, its keel and associated musculature removed, revealing the ventral-most viscera: (1) the heart's apex is suspended by a four-point harness of connective tissue and (2) the liver is wrapped around and over the unseen stomach.

Figure 20-5 • Great horned owl dissection. The heart has been separated from its suspensory harness and reflected forward, exposing the carina, which consists of the distal portion of the trachea, the syrinx, and proximal portions of the principal bronchi. The object directly below the carina is the stomach, below that, the reflected liver lobes, the cloaca, and to the far right, the lung.

Figure 20-6 • Great horned owl dissection. Close-up view of the stomach, also termed the *ventriculus* or *gizzard,* which has been split open, revealing its thick muscular rugal folds.

Figure 20-7 • Great horned owl dissection. The stomach has been reflected and shows that the deeper viscera of the caudal abdomen include the (1) pancreas, (2) aorta and its terminal bifurcation, (3) kidney, (4) bowel, and (5) cloaca.

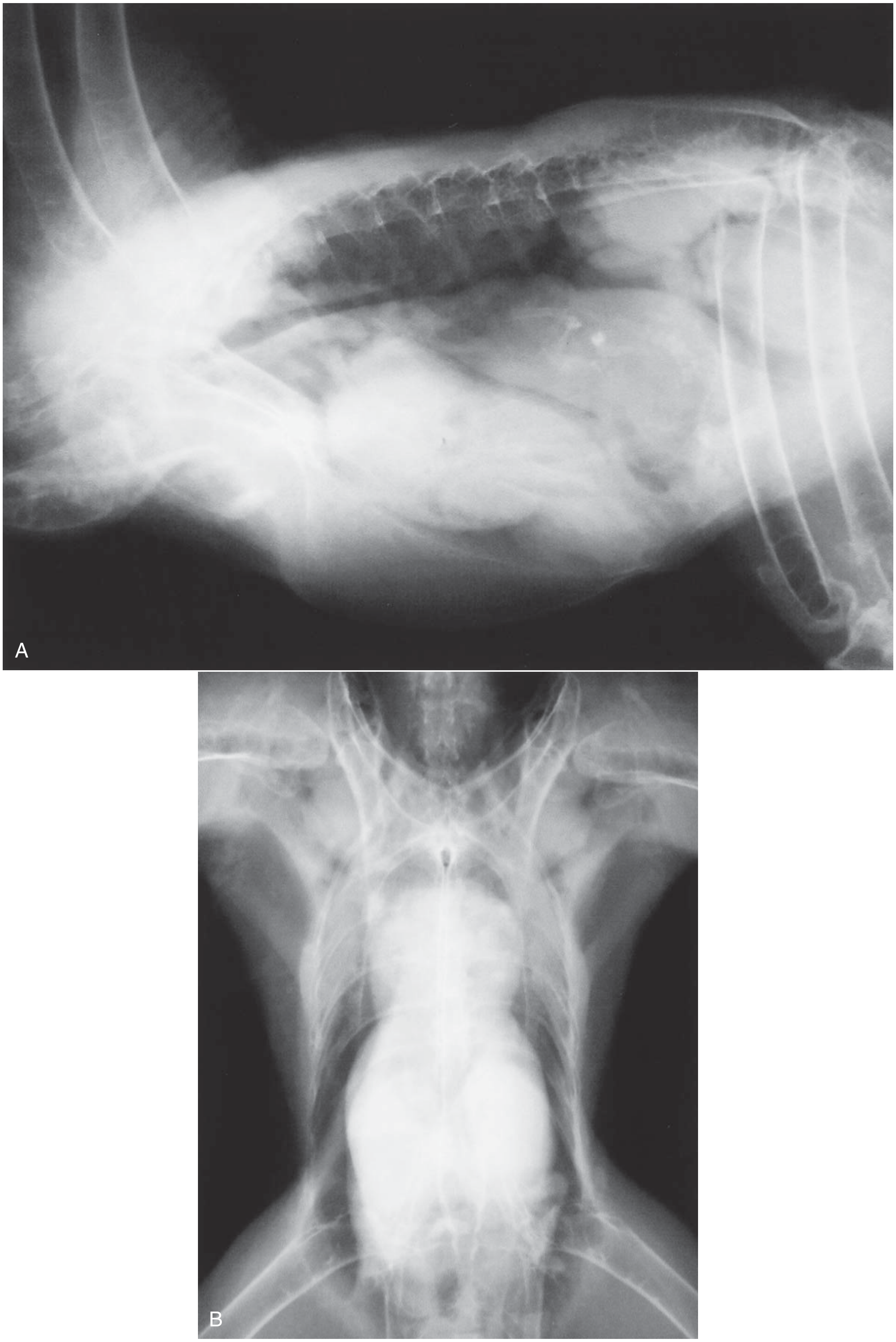

Figure 20-8 • Visceral montage. **A,** Ventrodorsal and lateral **(B)** views of the torso of an African Gray parrot show how the silhouettes of various organs are altered by the superimposition of their neighbors, sometimes appearing quite differently depending on projection angle.

Figure 20-9 • A, Orientation, close **(B),** and ultraclose **(C)** views of the torso of a normal kestrel show the diagnostic advantage of being able to compare one side of the image with the other, an opportunity only afforded by symmetrically positioned ventrodorsal projections.

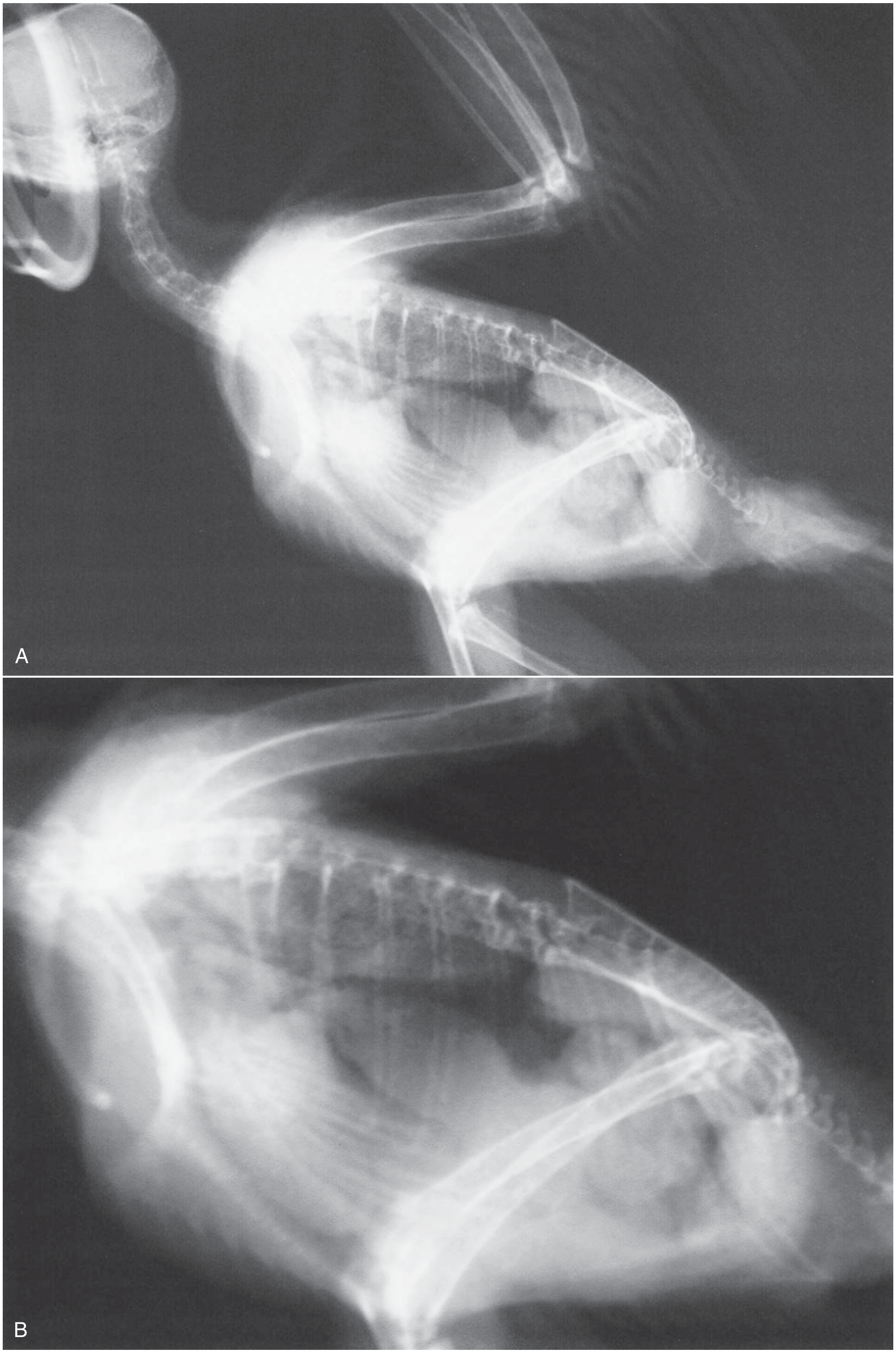

Figure 20-10 • A, Orientation and close-up **(B)** views of the torso of the kestrel shown in Figure 20-9 illustrate the diagnostic advantages of a true lateral projection in which the geometric distortion of organs has all but been eliminated and along with it the potential for misdiagnosis.

subcutaneous emphysema does occur, it is often symmetrical (Figure 20-11). *Free celomic air*, from whatever cause, is a radiographic rarity.

THE INTERIOR TORSO

Central Visceral Silhouette Analysis

The term *central visceral silhouette*, as used here, refers to the outline of the partially superimposed heart and liver of a bird as they appear in a VD radiograph. As mentioned previously, this is obviously somewhat of an artificial construct because other viscera may also contribute to this shape, in some instances, quite substantially. Nevertheless, the cardiohepatic silhouette and in particular its disproportionate size have been used by some authorities as a radiographic disease indicator.

For example, if the cardiac portion of the central silhouette appears disproportionately large, it may then be asserted that cardiomegaly, a strong indicator of heart or pericardial disease, exists. However, one might instead argue that the heart is not actually enlarged but only appears enlarged because of a diminished hepatic component, and in fact, the bird has liver disease.

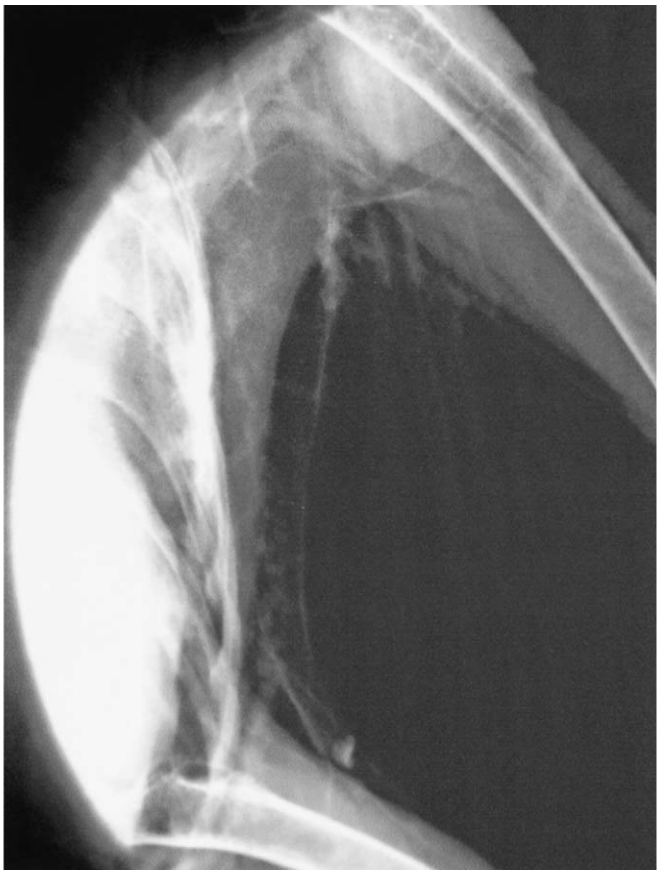

Figure 20-11 • Isolated superficial subcutaneous emphysema. Close-up ventrodorsal view of the lateral thoracic region of a red-tailed hawk attacked by dogs shows a small volume of air beneath the skin on the left side.

Given the variability of nondisease-related changes in the size of the heart and liver of birds and the influence of surrounding viscera, especially the stomach, central silhouette analysis is generally an unreliable means of *consistently detecting* all but the most pronounced departures from normal and can contribute to diagnostic errors (Figures 20-12 and 20-13). Although I routinely assess the central silhouette of birds, I do so with diagnostic caution and advise others to do the same.

INDIVIDUAL ORGAN ASSESSMENT

The Carina: Terminal Trachea, Syrinx, and Main Stem Bronchi

The terminal portion of the trachea, the syrinx, and main stem bronchi lie dorsal to the heart as seen on lateral projection and directly beneath the heart as viewed ventrodorsally. Collectively, these structures are termed the *carina*, the Greek word for crown. Structurally, the main stem bronchi of birds differ considerably from those of mammals, principally in their flattened, scabbard-like appearance (Figure 20-14).

Birds vocalize using their *syrinx*, the functional equivalent of the mammalian larynx, but without vocal cords. The syrinx may be located in the distal part of the trachea, carina, or bronchi, depending on the species. The syrinx, composed of specialized cartilages, muscles, and vibrating membranes, behaves in some respects like a bagpipe insofar as it uses the surrounding interclavicular air sac as a resonator. The syrinx is not visible radiographically, other than as a radiographic field.

Lung and Air Sacs

The lung and air sacs of birds share the work of breathing: the lung provides gas exchange and the air sacs perform ventilation. This division of respiratory labors enables birds to supplant conventional, biphasic respiration, with a continuous air flow system that is far more energy efficient, especially during flight.

Lung. The lung of birds can be difficult to accurately assess, especially in the VD view where the outer halves of the lung are superimposed on muscle, causing the lung to appear overly dense (termed *pseudoopacification*) and, in places, completely opaque (Figure 20-15). Depending on the clinical context, these abnormal densities can be mistaken for lung contusion or pneumonia.

The lateral projection is not as susceptible to soft tissue superimposition, provided the wings are drawn up and away from the torso. Depending on the diagnostic aim of a particular study, it is sometimes beneficial to produce two lateral views using different radiographic techniques: one designed to image bone and soft tissue (a so-called compromise technique) and the other a deliberate underexposure optimized for the lung (Figure 20-16).

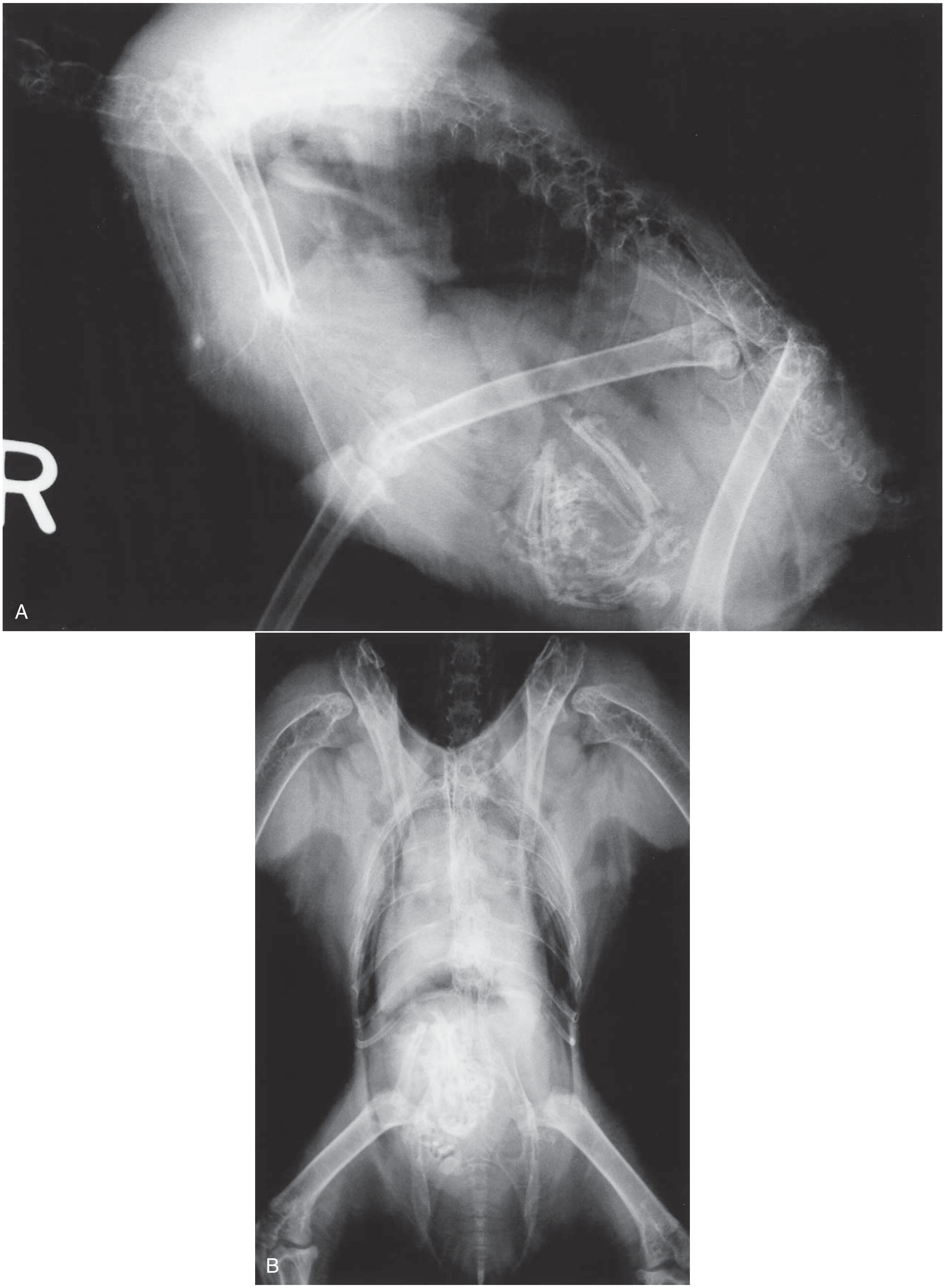

Figure 20-12 • **A,** Lateral and ventrodorsal **(B)** views of the torso of an eagle with the bones of a small mammal in its stomach, which have caused spreading and cranial displacement of the liver, creating the misimpression of hepatomegaly *(pseudohepatomegaly)*.

Figure 20-13 • Close-up view of the central visceral silhouette of an eagle conveying the *misimpression* of cardiomegaly as a result of (1) oblique positioning causing the heart to falsely appear widened and (2) a genuinely small liver caused by starvation.

Figure 20-14 • Ultraclose view of the carina of a great horned owl (seen from below) shows the terminal portion of the trachea, the syrinx, and the flattened angular principal bronchi.

Figure 20-15 • Close-up ventrodorsal projection of a budgie's cranial torso shows pseudoopacification of the lung fields caused by superimposed musculature.

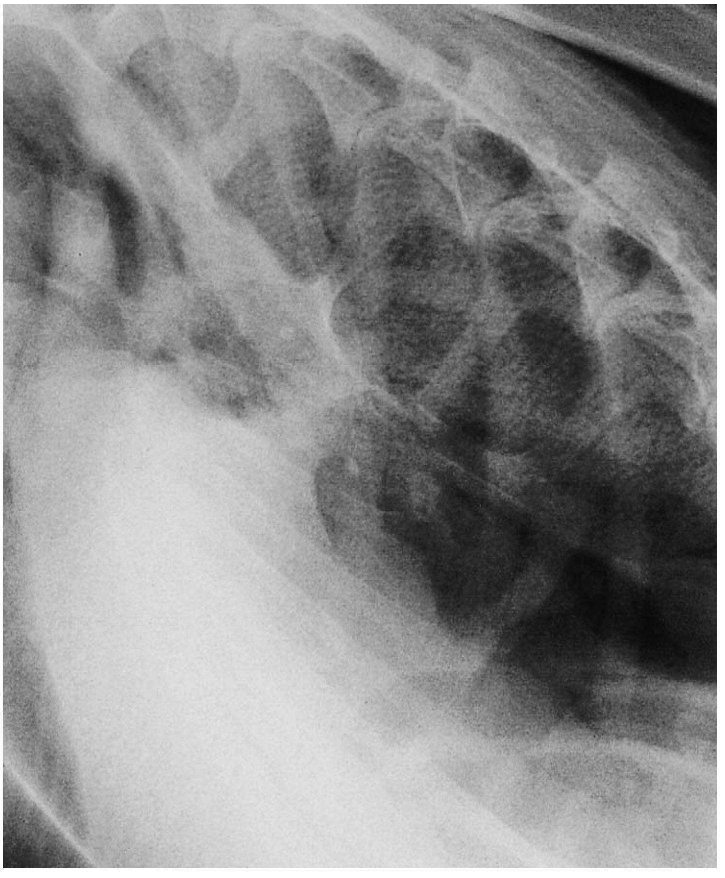

Figure 20-16 • Close-up lateral view of the lung fields of a normal loon using pulmonary technique.

Lung hemorrhage (pulmonary contusion) is occasionally identified in birds, often in conjunction with other serious injuries such as fractured ribs, fractured or dislocated shoulder, subcutaneous emphysema, and asymmetrical air sacs (Figure 20-17).

Lung infection is uncommon in our practice in both wild and cage birds. When it occurs, it is quite variable, lacking any sort of regular appearance consistent with *community pneumonia* (Figure 20-18).

Air Sacs. Most avian species have five principal air sacs, all of which are at least in part contiguous with some part of the lung. From cranial to caudal these air sacs are: (1) cervical, (2) clavicular, (3) cranial thoracic, (4) caudal thoracic, and (5) abdominal.

Diseased air sacs, whether accompanied by lung pathology or not, can be difficult to diagnose radiographically because of a combination of factors, but especially because of their close proximity to the lung surfaces. Unless it is possible to incriminate a bronchus and certify lung involvement, it is extremely hard to discriminate between pulmonary and contiguous air sac disease.

The humeral components of the clavicular air sacs are subject to injury, especially those that result in fracture or dislocate the shoulder joint. The clavicular air sacs may also appear overly dense because of superimposed or compressive hemorrhage (Figure 20-19). Conversely, inflammatory obstruction to intersaccular air flow can lead to *saccular emphysema* (Figure 20-20).

Heart and Associated Vasculature

The Concept of the Vascular Pedicle. The term *vascular pedicle* is used routinely in human thoracic radiology to describe the vessels in the precardiac portion of the cranial mediastinum. I have used vascular pedicle to describe congenital and acquired heart disease in dogs and cats and more recently have begun to use it in describing cardiovascular disease in birds.

To be seen in the VD projection, the cardiac base must be deliberately overpenetrated to visualize the vascular pedicle. Its three principal elements are the aorta and its two primary branches, the left and right brachiocephalic trunks (Figure 20-21). It may also be possible to identify the right and left vertebral and common carotid arteries as they branch from the brachiocephalic arches.

Heart. A clear view of the heart is difficult to obtain, again because of the superimposition of nearby organs, especially the liver, which is wrapped snugly around the caudal portion of the heart like a cloak (Figure 20-22). Considering the fact that many heart diseases

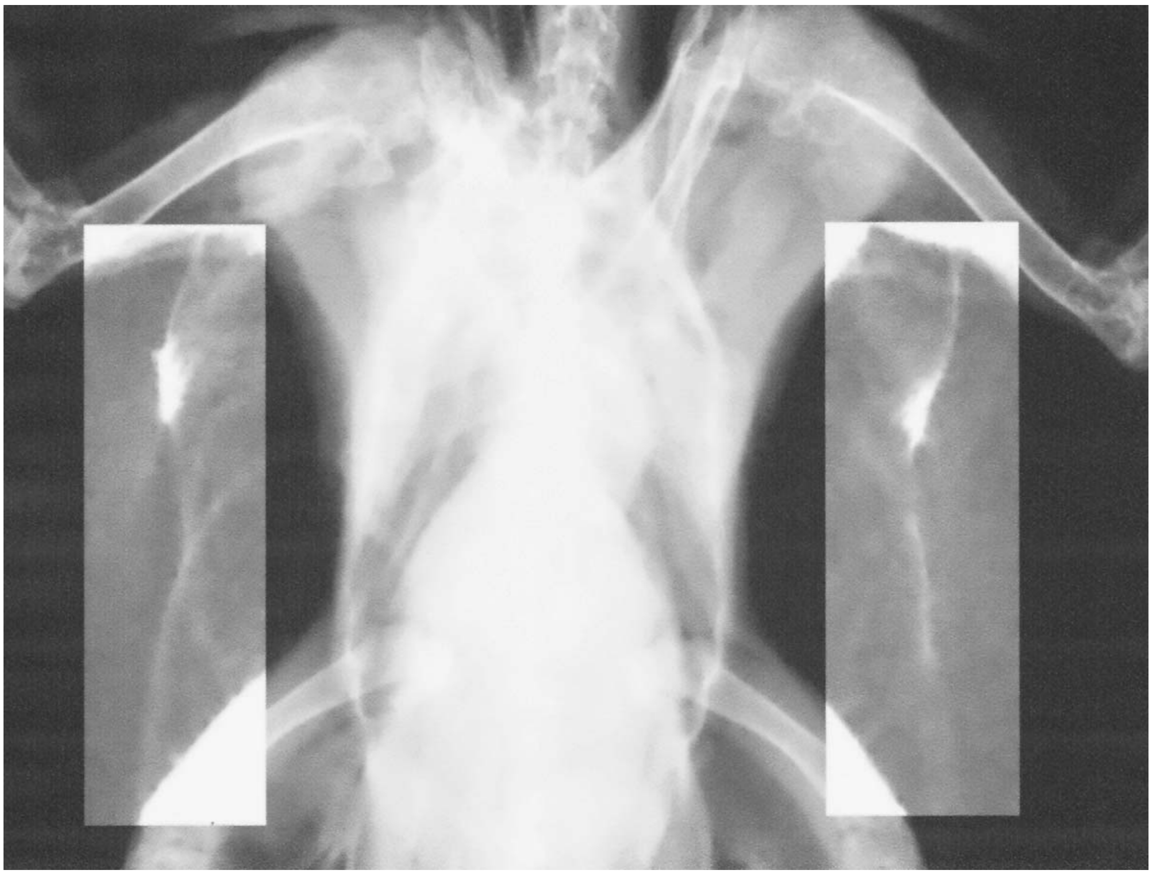

Figure 20-17 • Ventrodorsal projection of the torso of an injured flicker shows (1) large volumes of subcutaneous air on both the right and left sides, (2) asymmetrical air sac inflation, (3) a left-sided rib fracture, (4) a left cardiac shift, and (5) consolidation of the left lung as a result of hemorrhage.

Figure 20-18 • Ventrodorsal view of the thoracic region of a raven shows extensive bilateral pneumonia that has spread to the nearby cranial and caudal thoracic air sacs.

Figure 20 19 • Close-up view of the shoulders of a snowy owl shows increased density in the right clavicular field consistent with regional hemorrhage.

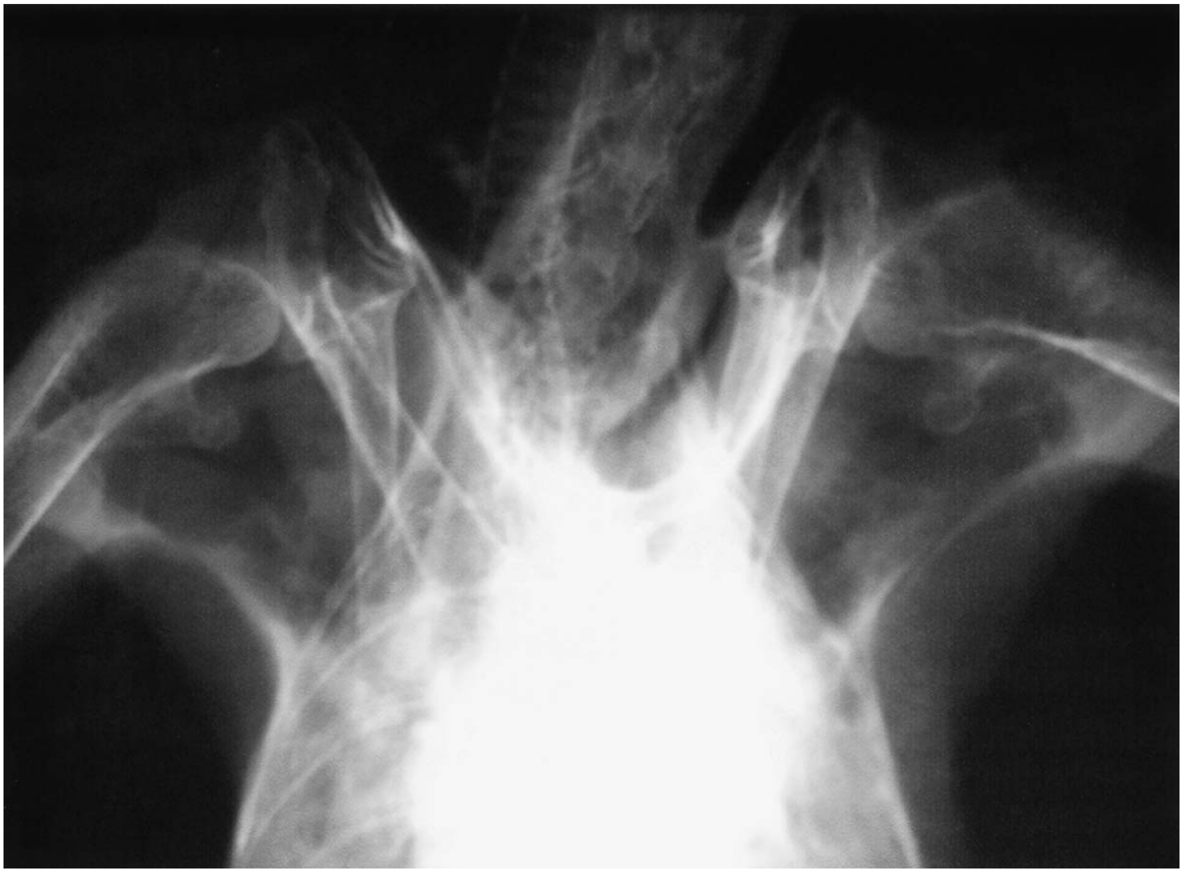

Figure 20-20 • Close-up view of the pneumonic raven shown in Figure 20-18 illustrates the extent to which emphysematous clavicular air sacs can enlarge when outflow becomes obstructed.

Figure 20-21 • Close-up, penetrated view (a deliberate increase in kVp over what is called for by the technique chart) of the cranial portion of the heart of an eagle shows the vascular pedicle and its principal arterial components: the (1) aortic root, (2) right brachiocephalic trunk, and (3) left brachiocephalic trunk.

Figure 20-22 • Close-up view of the thoracic region of a great horned owl (ventral perspective, keel and associated muscles removed) showing the cranial aspect of the heart at the top with the caudal aspect directly below, partially obscured by the surrounding liver.

result in asymmetrical enlargement and displacement within the celomic cavity, the likelihood of obtaining closely comparable lateral and VD views of the cardiac silhouette is quite small.

There is no predictable or consistent advantage yet identified to making right and left lateral views in birds with suspected lung disease. Theoretically speaking, the larger the bird and the more lateralized the disease, the greater the likelihood that alternate side radiography would reveal a difference, which in turn might enable one to determine the side that was diseased. My sense is that the VD view, even with its acknowledged limitations, would likely serve the same purpose but with a greater degree of confidence, much as with pets like dogs and cats.

Liver

The liver is the lower half of the central visceral silhouette, which loosely resembles that of an hourglass when projected ventrodorsally, albeit a highly variable one. As mentioned previously, the presence of an asymmetrical central visceral silhouette has yet to establish itself as a *reliable indicator* of either cardiac or hepatic disease (Figure 20-23). If this is the case, it must be acknowledged that there are instances where little or no doubt exists as to the presence of hepatomegaly (Figure 20-24).

Diminished liver size in wild birds is far more common than hepatomegaly and in most instances results from starvation brought about by some sort of debilitating injury, particularly to the wing, forcing these birds to become ground dwellers (Figure 20-25). Small cage birds, such as canaries and budgies, that suffer from chronic disease-related inappetence may also show varying degrees of radiographically detectable liver shrinkage.

Spleen and Pancreas

The spleen is a small, rather nondescript organ located near the stomach (ventriculus-proventriculus). It is highly variable in shape, ranging from circular to oval to elongate, depending on the species. Its principal functions are to remove aged or damaged red cells from the circulation and to aid in the production of lymphocytes and antibodies. The spleen of birds does not serve as a blood reservoir as in mammals. The spleen is rarely injured and only occasionally enlarged to the extent that its altered appearance can be appreciated radiographically. A healthy pancreas cannot be

Figure 20-23 • The appearance of the central visceral pedicle in birds is highly species-dependent as exemplified in this ventrodorsal view of a healthy great blue heron. Because the liver is more caudally situated in this bird, more of the caudal aspect of the heart is apparent, especially the cardiac apex. For its part, the liver forms more of a silhouette with the bowel mass than with the heart.

detected radiographically. Likewise, sonographic assessments typically prove unrevealing.

Esophagus, Stomach (Ventriculus-Proventriculus), and Bowel

Although legitimate parts of the alimentary canal, the throat, crop, and proximal portion of the esophagus are discussed in a more anatomically appropriate context in Chapter 19.

In raptors, the oblong stomach, also known as the ventriculus, or gizzard, lies immediately caudal to the esophagus, just above and behind the liver. This anatomical arrangement is apparent in the lateral but not the VD projection where the superimposed liver hides the ventriculus from view.

Radiographically, the bowel often appears more like a single object rather than a long hollow tube, especially when the gas content is minimal.

Plain Film Assessment. As stated previously, the lateral view of the torso provides the most complete view of the caudal esophagus, ventriculus, and bowel mass, although not all of these organs are always visible in a particular radiograph (Figure 20-26).

Using Nature's Contrast. Identification of the crop is made easier when it contains a recent meal, particularly if bones are present, for example, a mouse in the gullet of a Merlin (Figure 20-27). The same is true of the ventriculus, although in this location there is usually more disintegration of whatever the bird has eaten (Figure 20-28). High-density material, such as bone, can also be seen in the bowel mass, but because of ongoing digestion, it may be harder to specifically identify. Cage birds and some wild birds may have grit in their stomachs or bowel; grit is characterized radiographically by its granular appearance and high density (Figure 20-29)

Gastrointestinal Foreign Material. Of all the things a wild bird might consume, lead is of the greatest concern because of its toxicity. As a heavy metal, even small quantities of lead are readily identifiable on a radiograph (Figure 20-30), while most pesticides, equally harmful in their own right, are radiographically invisible.

Assessment of the Digestive Tract with Barium and Other Diagnostic Opaque Materials. Barium solutions, or pastes, are the diagnostic opaque material of choice for evaluating the alimentary canal. If a perforation is suspected, however, a nonionic organic iodine solution should be employed on the possibility that it may escape into the celomic cavity. A nonionic diagnostic iodine solution is better than an ionic one because the ionic solution will draw water to itself and thus temporarily dehydrate the bird. Examples of a limited barium series are shown in Figures 20-31 through 20-33.

Kidneys

The kidneys are tucked up high on either side of the caudal abdomen just below the cranial part of the pelvis. Radiographically, avian kidneys lack the distinctive bean shape of the typical mammalian kidney, instead appearing as a variably shaped, somewhat ill-defined mass. Some forms of kidney disease, particularly those that cause significant enlargement, can present as lameness because some of the nerves that innervate the hind limbs first pass through the substance of the kidneys.

Occasionally, birds receive nonfatal gunshot wounds; pellet and BB guns seem to be favorites. These projectiles can end up in a variety of places: in the lumen of the stomach or bowel, within the cloaca, or embedded in one of the solid organs such as a kidney (Figure 20-34). Even though the precise location of a projectile can sometimes be located, for example, within the left kidney, it is not always possible to accurately predict the path of the pellet and the tissues through which it may have passed.

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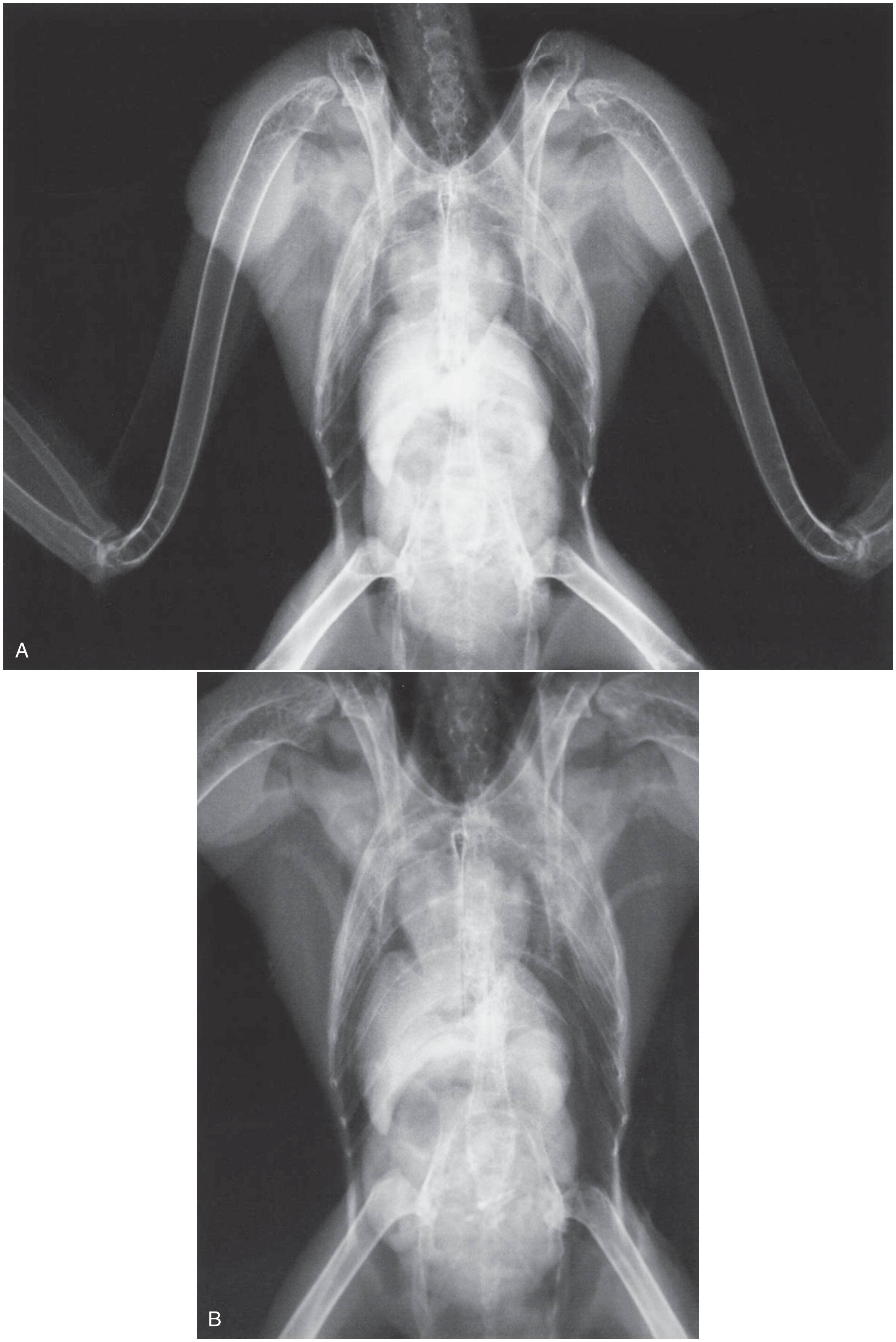

Figure 20-24 • A, Orientation and close-up **(B)** ventrodorsal views of an owl show a bottom-heavy asymmetrical central visceral silhouette, the result of an enlarged liver.

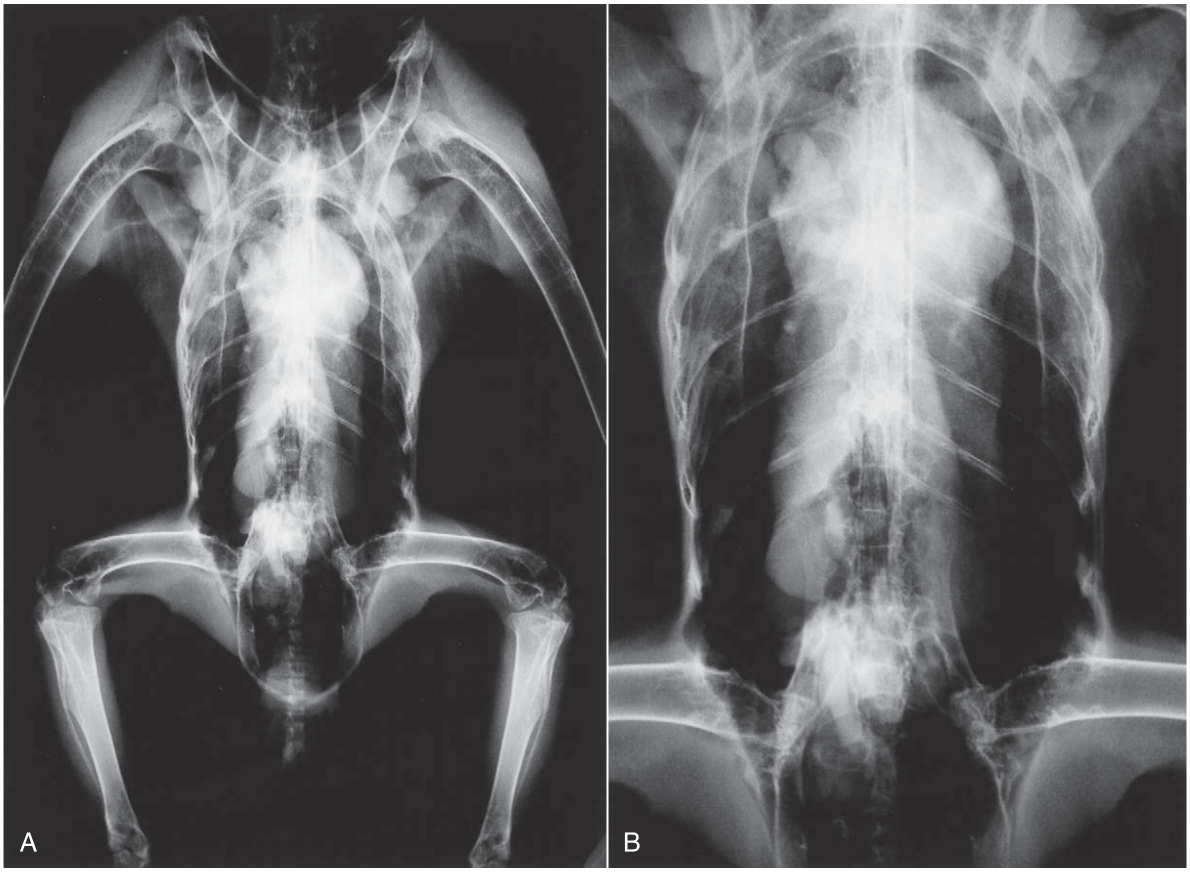

Figure 20-25 • A, Orientation and close-up **(B)** ventrodorsal views of an owl show a top-heavy asymmetrical central visceral silhouette, the result of a shrunken liver.

Figure 20-26 • Lateral view of an eagle's abdomen shows the distinctive pear-shape of a full stomach situated in the central abdomen midway between the spine and underlying heart and liver.

Figure 20-27 • **A,** Orientation, close-up **(B),** and emphasized close-up **(C)** ventrodorsal views show a Merlin with the bones and soft tissue of a mouse in its crop. **D,** Lateral orientation and close-up **(E)** projections of the crop and its content are also provided.

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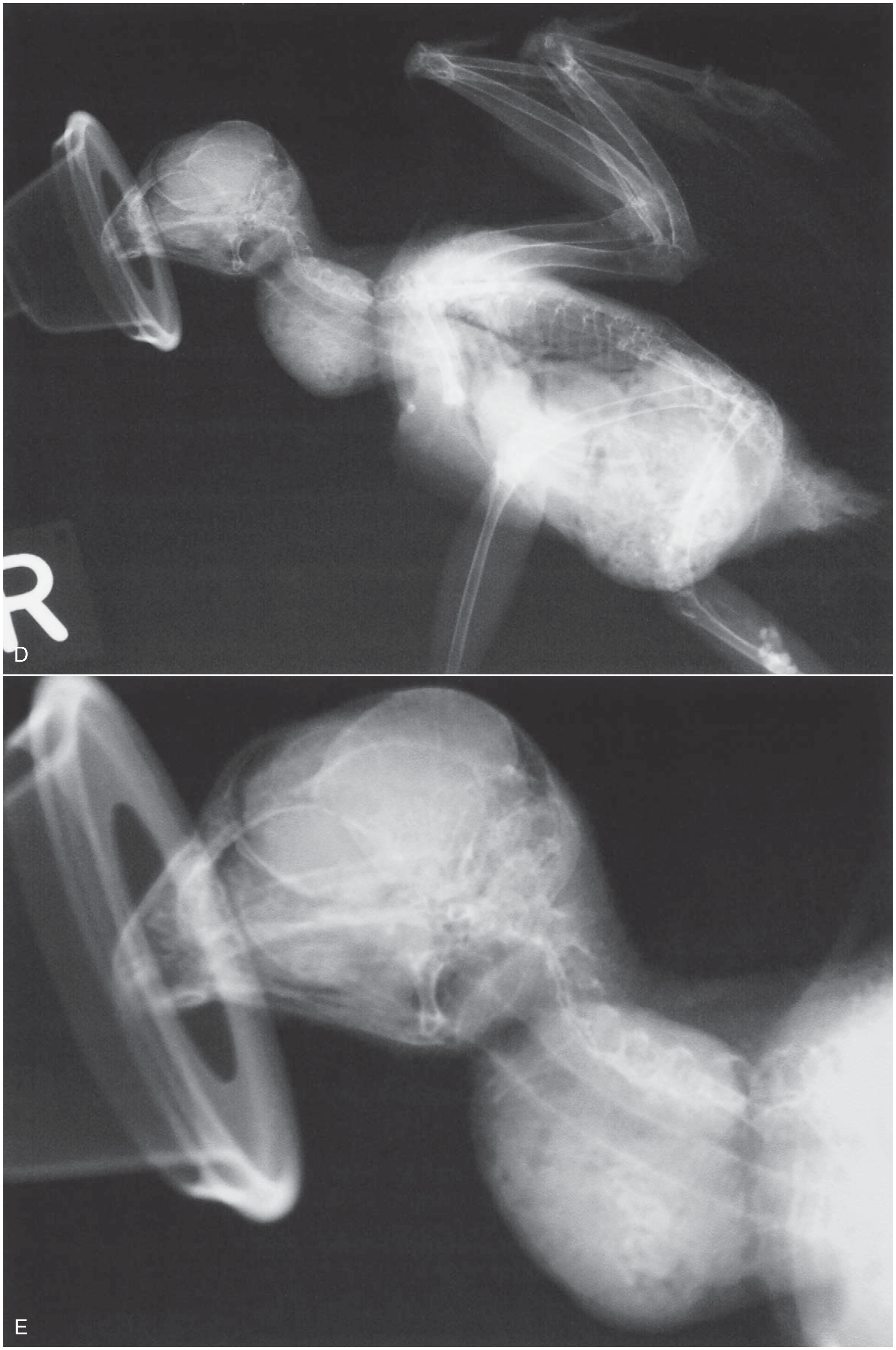

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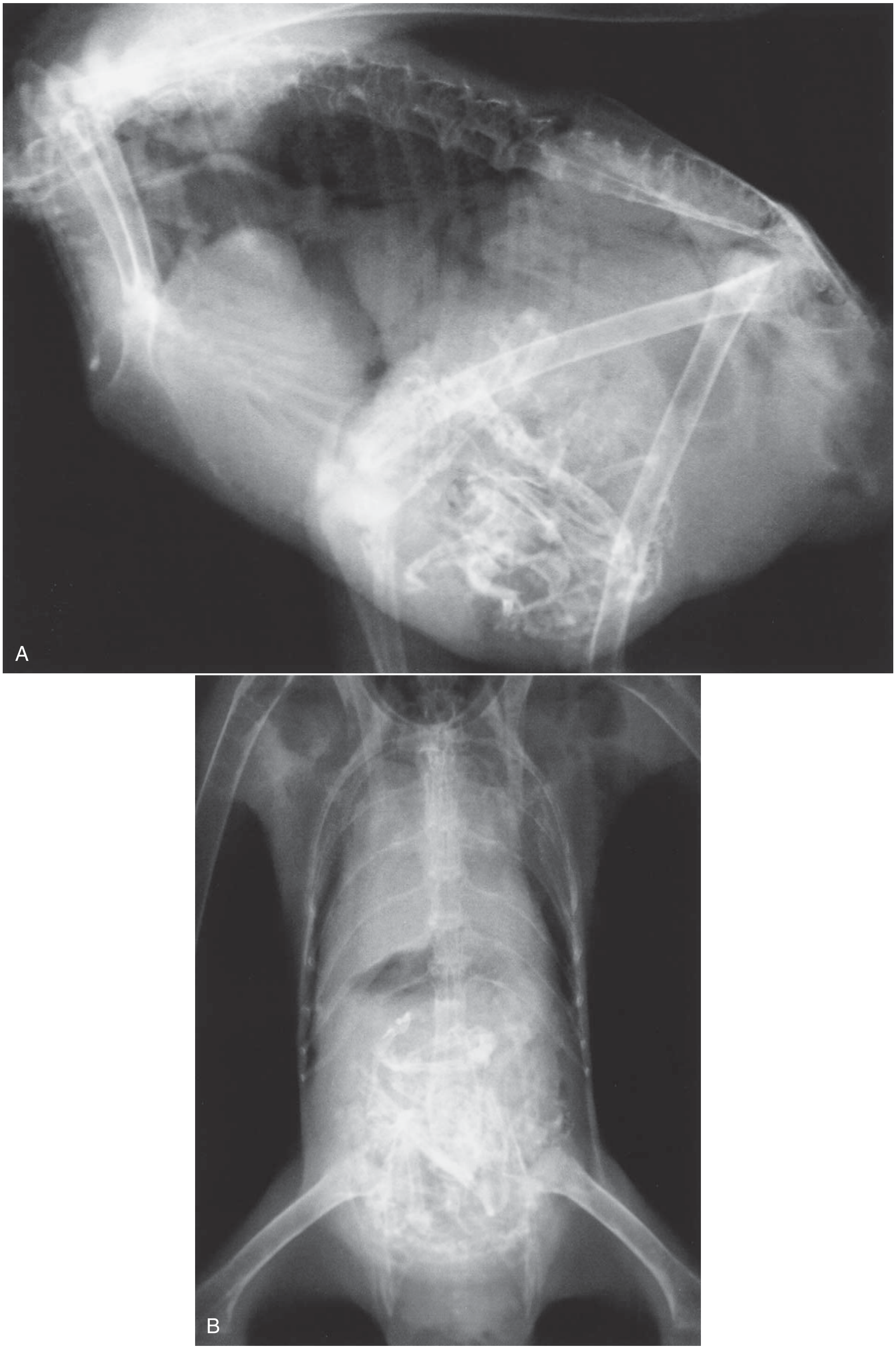

Figure 20-28 • A, Lateral and ventrodorsal **(B)** images of a great gray owl show the disintegrating carcass of a small mammal in the ventriculus. Note how the enlarged stomach has displaced the liver cranially, and in the process, spread apart the individual lobes, making the organ appear much wider than usual. The effect on the size and shape of the central visceral silhouette is dramatic.

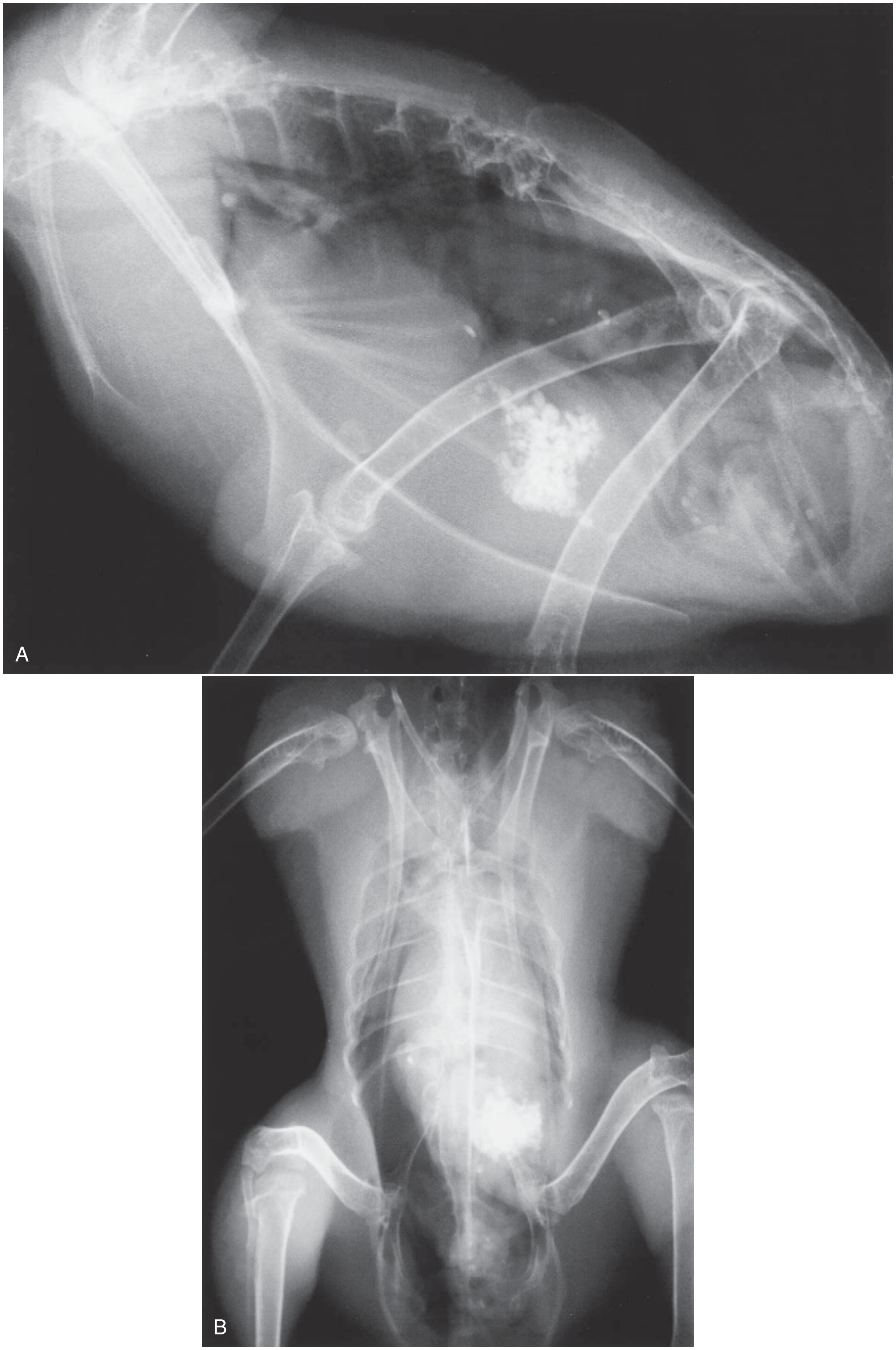

Figure 20-29 • A, Lateral and ventrodorsal **(B)** views of a healthy partridge with high-density material in its stomach. Note the effect of unintended obliquity on the appearance of the celomic content, especially the central visceral silhouette and air sacs.

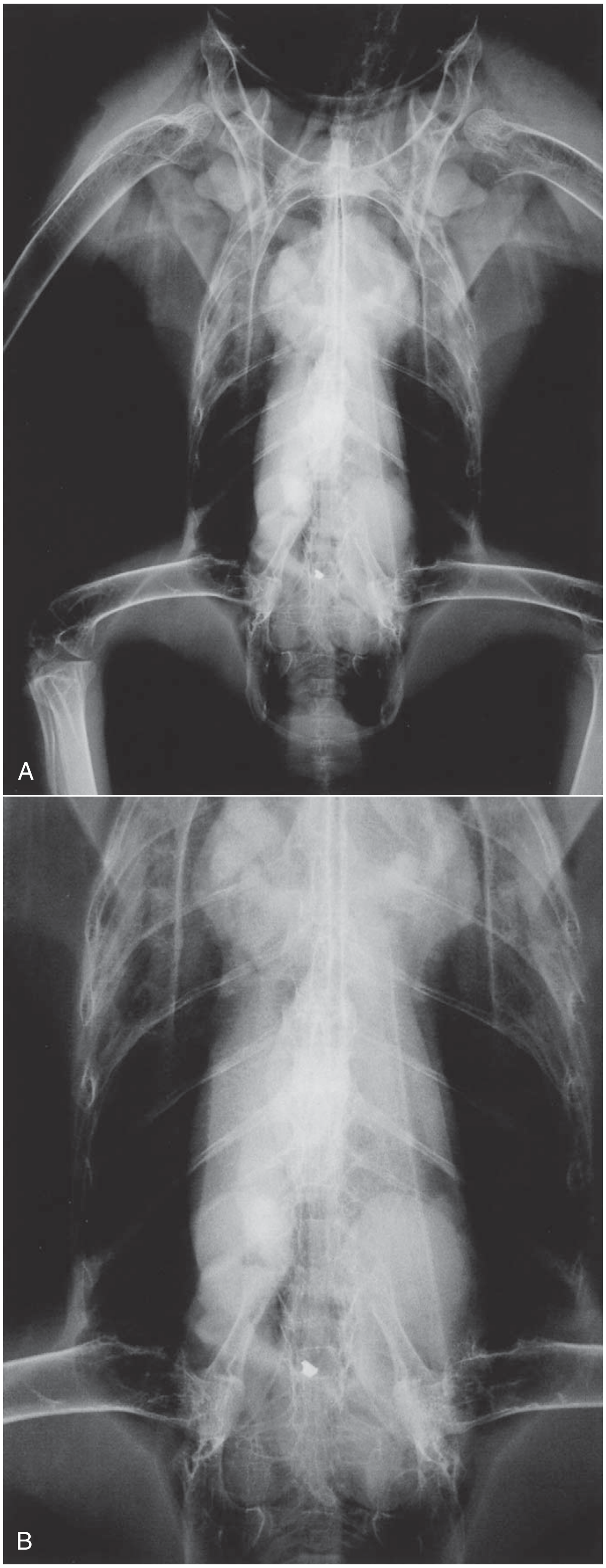

Figure 20-30 • A, Orientation, close-up **(B),** and ultraclose **(C)** ventrodorsal views of an eagle with a lead fragment in its stomach or bowel (uncertain which). A lateral projection is also provided **(D).**

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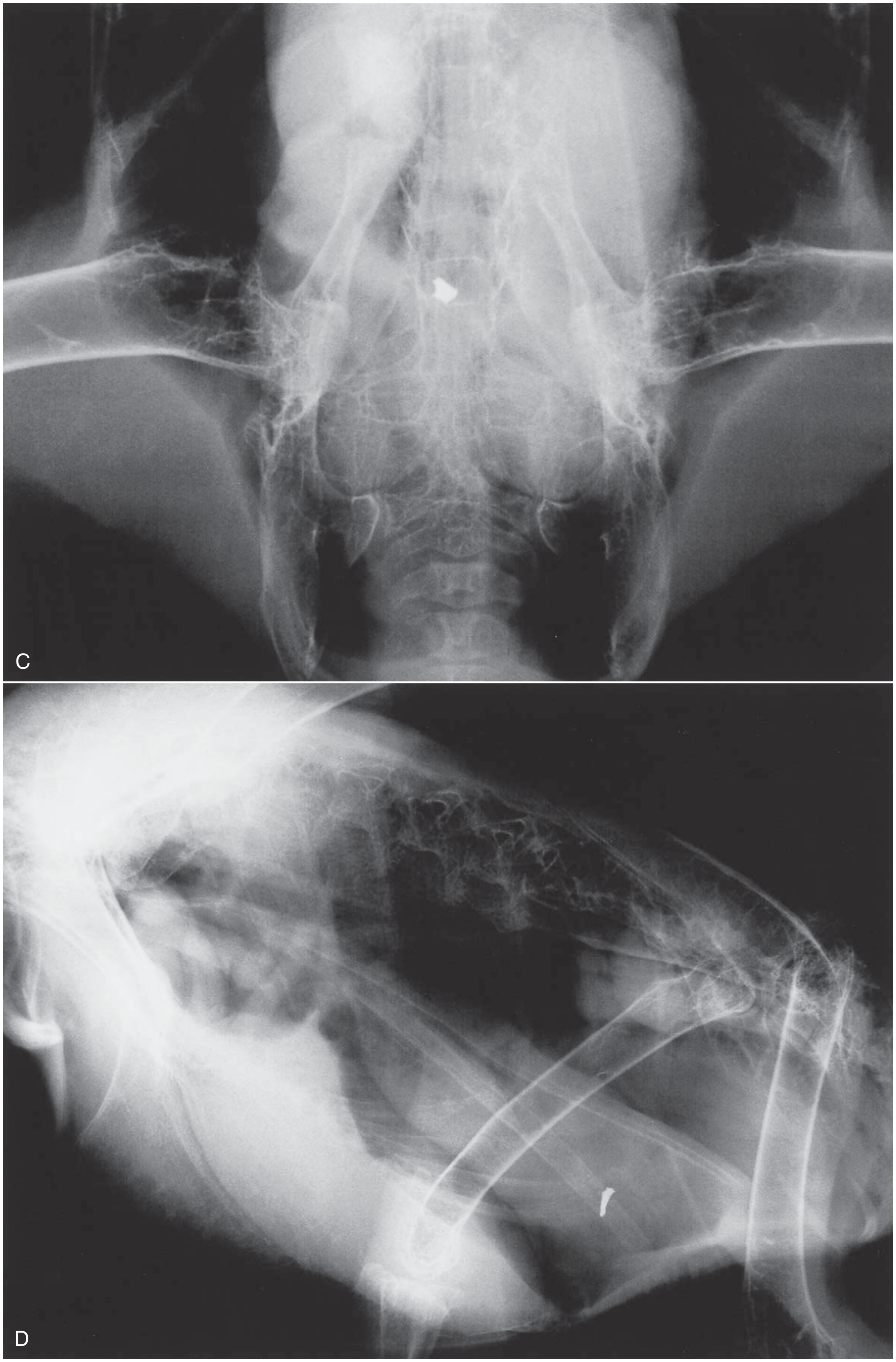

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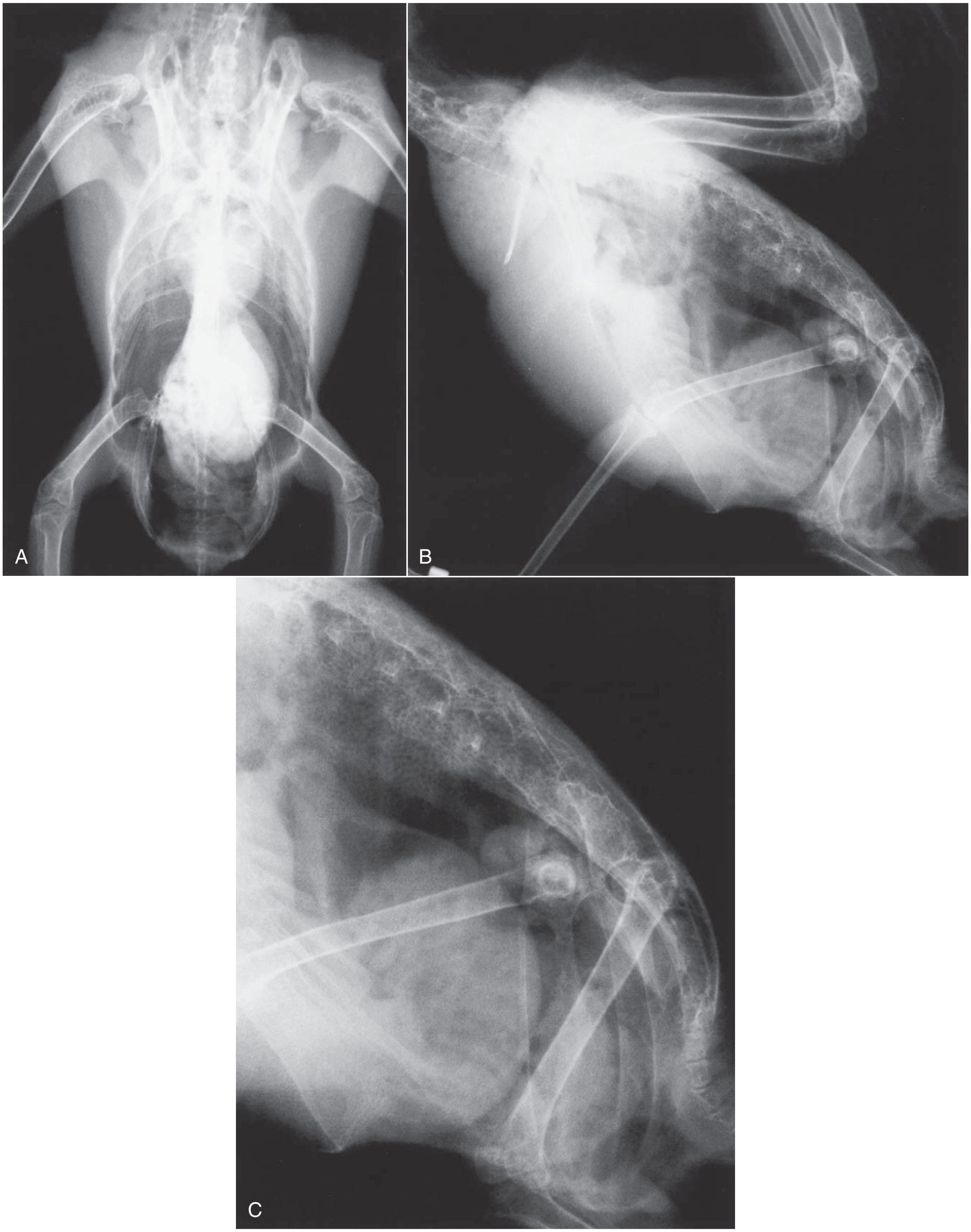

Figure 20-31 • A, Ventrodorsal, lateral **(B),** and lateral close-up **(C)** views of the torso of an Amazon parrot with suspected gastric impaction show enlargement of the ventriculus with what appears to be food.

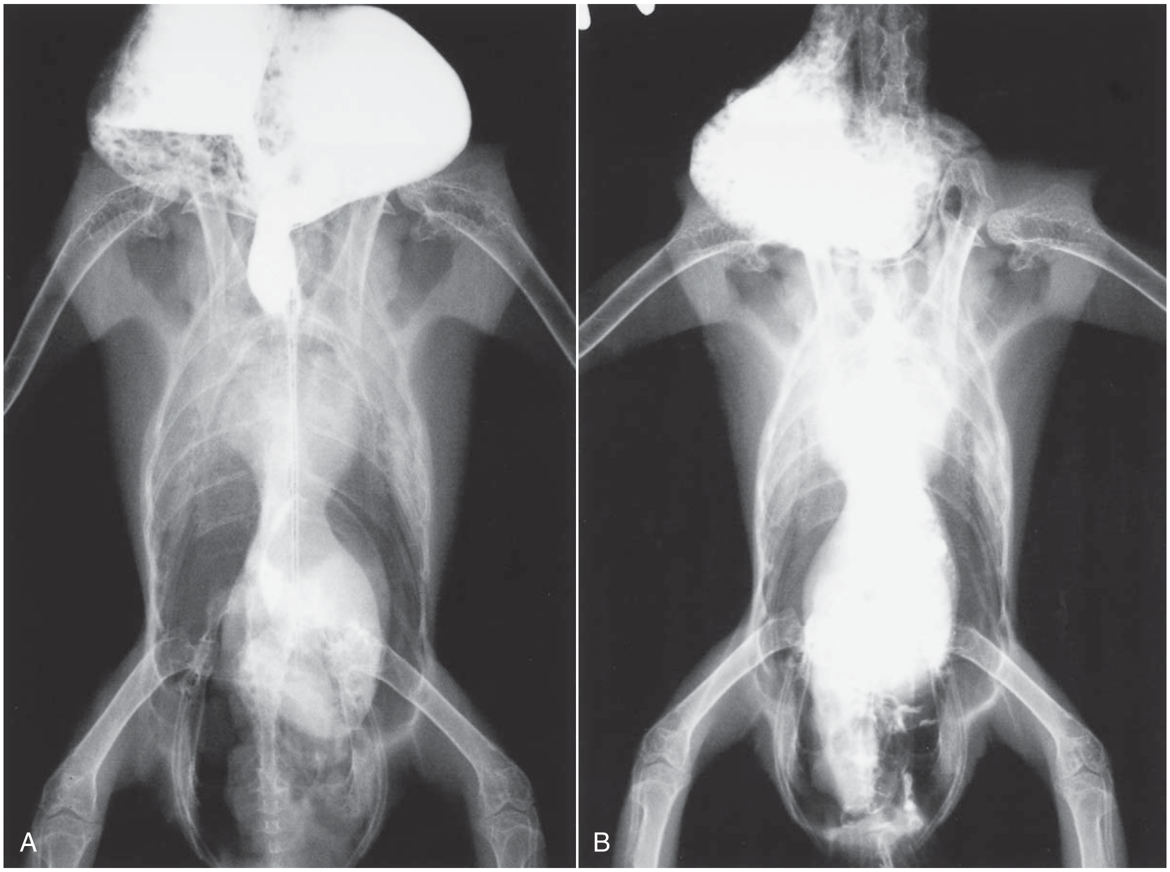

Figure 20-32 • A, Immediate and 30-minute **(B)** ventrodorsal views of the torso of an Amazon parrot after barium administration initially show normal accumulation of contrast solution in the crop and, later, barium in the esophagus and ventriculus, partially outlining the food mass.

Ovaries

The dominant left ovary is situated just ahead of the left kidney and attended by a single, highly undulant oviduct that travels caudally, eventually forming the uterus and culminating in the vagina.

Eggs

Radiographic detection of an egg typically occurs once it has reached the uterus where shell formation occurs. Depending on its degree of calcification, the egg may occasionally be identified in some species while in the magnum, the portion of the oviduct just before the uterus.

Testes

The paired testes are located on either side of the abdomen, adjacent to the cranial pole of the kidney immediately caudal to the adrenal gland. Based on a limited number of dissections and ultrasound examinations, I have found the position, as well as the orientation, of the testes quite variable, as is the case with the adrenal glands.

THE SPINE

Spinal Trauma

Often sought but rarely found characterizes the majority of avian spinal surveys in cases of suspected trauma. As a rule, the more one progresses caudally, the more difficult it becomes to clearly see and thus accurately assess the individual vertebrae. Immature birds are even harder to diagnose. Chapter 16 includes an example of a displaced spinal fracture in an immature Merlin.

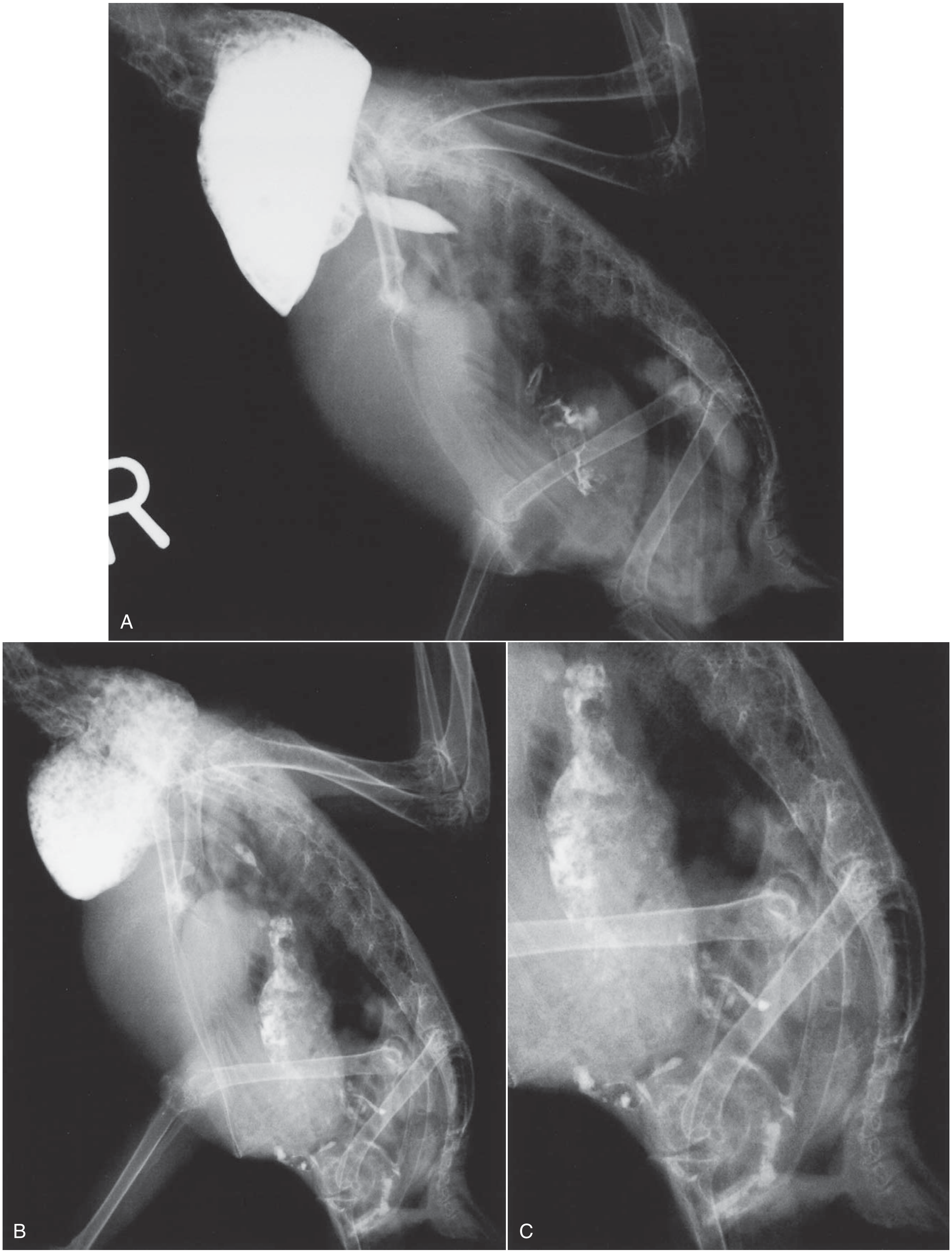

Figure 20-33 • A, Immediate, 30-minute **(B),** and 30-minute close-up **(C)** lateral views of the torso of an Amazon parrot after barium administration. Initially, most of the contrast solution accumulates in the crop but eventually moves into the esophagus and then into the ventriculus, where it begins to permeate the food mass.

Figure 20-34 • A, Lateral and ventrodorsal **(B)** views of a crow with an air gun pellet lodged in its left kidney. The left tibia was shattered by the bird's fall from a tree after being shot, not by the pellet **(C).**

SECTION II

The Mammals

Chapter 21

Guinea Pigs

Guinea pigs, or *cavies*, as they are sometimes called, come in a great variety of colors and hair coats and are among the most docile of the small cage pets (Figures 21-1 through 21-3). *Pigs*, as they are sometimes affectionately termed, are classified as rodents and have a life expectancy of 4 to 5 years.

RADIOGRAPHY

When bringing a guinea pig into the radiology area, it is best to bring the animal in a cage or carrier and preferably covered, especially when dogs and cats are present (Figure 21-4). Once the exposure has been set and the radiographers are ready, the pig should be gently removed from its cage and well secured in preparation for being radiographed (Figure 21-5).

Many guinea pigs, particularly when they are ill, can be radiographed while crouched on a cassette—at least for the dorsoventral (DV) projection (Figure 21-6). A lateral image can also be obtained from the same position by using a horizontal x-ray beam. For a particularly squirmy pig, a clean, loose-fitting stockinet can be placed over the limbs and torso, using a tongue depressor to make any needed positional adjustments before exposure (Figure 21-7). Otherwise, conventional positioning can be employed, with or without the aid of chemical restraint.

SONOGRAPHY

The most difficult things about performing ultrasound examinations on guinea pigs and other small rodents are their diminutive size and reluctance to remain still. I prefer to scan these animals as shown in Figure 21-8, where the pig is held snuggly in the lap of an assistant in the upright position, with the animal's feet and rump supported by a second person. If assistance is unavailable, I often conduct a brief examination with the pig positioned in my lap, in which case I must set the controls of the ultrasound machine before beginning the examination.

Figure 21-1 • Owner keeps pet guinea pig bundled up against winter's cold.

Figure 21-2 • Shorthaired, uniformly colored pet guinea pig being secured by radiographer before being radiographed.

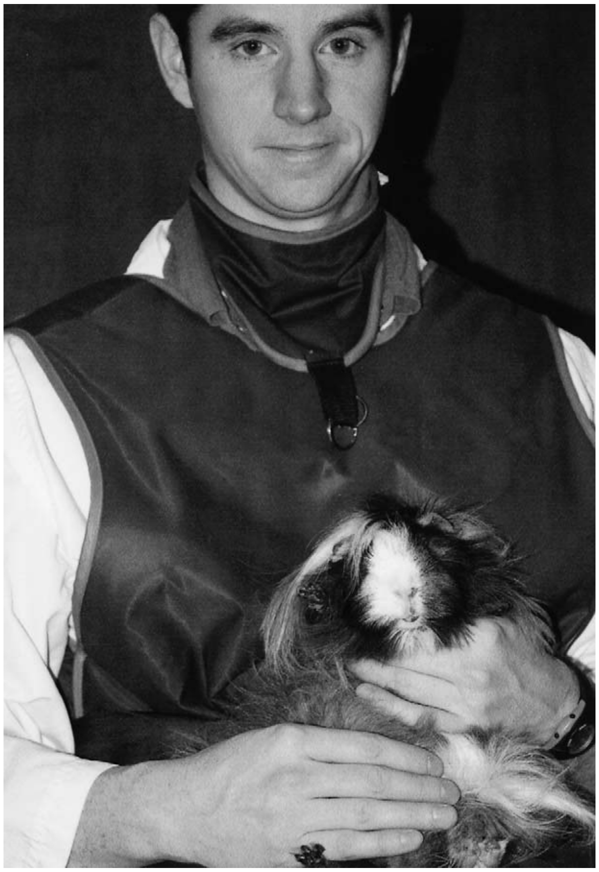

Figure 21-3 • Longhaired, multicolored pet guinea pig posed for the camera before being radiographed.

Figure 21-4 • Students bring a guinea pig to the Radiology Department with the cage covered by a towel, hoping to lessen the animal's apprehension in a strange environment.

Figure 21-5 • Veterinarian safely secures guinea pig with both hands after removing the animal from its cage just before being radiographed.

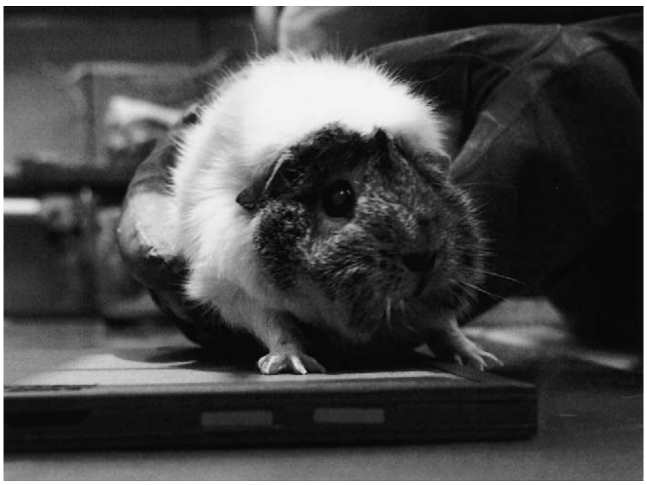

Figure 21-6 • Most guinea pigs will remain motionless atop a cassette long enough to be radiographed.

Figure 21-7 • **A,** Radiographers first position the guinea pig laterally on the x-ray cassette, then using a wooden tongue depressor, *gently* isolate its injured limb in preparation for the exposure **(B)**.

Figure 21-8 • Ultrasound can be performed on a restless guinea pig with the animal positioned in the lap of an assistant, as the second assistant secures the animal's hind legs.

NORMAL RADIOGRAPHIC ANATOMY

Little sets the guinea pig apart from the rest of the small rodents, although this class of mammals does have distinguishing morphological features.

Skull

The skull of the guinea pig, as with other rodents, is perhaps its most distinguishing radiographic feature. Viewed from a lateral perspective, the skull appears flattened dorsally, with the relatively small cranium blending almost imperceptibly with the elongated face, which terminates in a pronounced rostral hook (Figure 21-9). When combined with the upward swept lower incisors and the large interdental gap, the profiled jaws resemble a surgical towel clamp.

The ventrodorsal (VD) projection of the pig's skull is characterized by an elongated face, which appears deceptively wide thanks to its large, flared zygomas. The large thick mandible forms a distinctive V-shaped opacity rostrally, accentuated laterally by the hornlike angular processes of the mandible (Figure 21-10).

Thorax

Diagnostically, the thorax is by far the most challenging region in the guinea pig. First, the thoracic cavity is disproportionally small when compared with the much wider and longer abdomen. As seen in both standard radiographic projections (Figure 21-11), the visible portion of the thorax comprises only about one-sixth of the total length of the torso.

Second, the thoracic viscera typically appear vague, the result of the normally poor or at best mediocre contrast between the heart and lung. Thoracic superimposition by one or both forelimbs makes accurate analysis and interpretation even more difficult (Figure 21-12). In some animals, it is impossible to identify the aorta or caudal vena cava, much less the pulmonary arteries and veins.

The cranial mediastinum is often invisible as such, and even the thoracic portion of the trachea may be difficult to identify as a discrete structure. The diaphragm is better seen in the lateral than in the VD projection. The single biggest problem in rodent radiology, which includes radiology of guinea pigs, is *accurate* thoracic diagnosis.

Abdomen

The abdomen fills the great majority of the trunk of the guinea pig and in most instances is visually dominated by its largest gas-filled viscera: the stomach and cecum. The bowel mass, which is made up of the small intestine and the caudal portion of the colon, makes up the rest of the gaseous background (Figure 21-13).

Figure 21-9 • Lateral view of guinea pig's skull shows tonglike appearance of the rostral facial region that characterizes most rodents.

Figure 21-10 • Ventrodorsal projection of what at first appears to be a pair of skulls, one superimposed on the other. But closer inspection reveals the "second skull" to be an extremely dense mandible.

The liver is the easiest solid abdominal organ to identify, principally because of the contrasting lung and stomach that lie on either side in the lateral view and cranially and caudally in the VD view. The kidneys may or may not be identifiable, depending mainly on the presence or absence of surrounding gas; this is also true of the urinary bladder.

Limbs

The limbs of guinea pigs, like those of their relatives, are small compared with the size of their trunks and can be somewhat difficult to physically isolate when being imaged unless the animal is drugged or unconscious and the legs are taped to the cassette. If manual restraint is used, a tongue depressor, which is radiographically transparent, can be used to draw a pig's leg away from its body and held while being radiographed (Figure 21-14).

INJURIES

As with the other small cage pets seen in our hospital, most of the injuries received by guinea pigs are the result of attacks by cats and dogs, which often reside in the same household. Guinea pigs are also subject to attack by strange dogs and cats when taken outside the home for a "walk."

Guinea pigs are often injured accidentally by their owners, sometimes quite seriously (Figure 21-15). In addition to the usual extremital fractures, typically caused by being stepped on or having a leg caught in a closing door, guinea pigs are also subject to crush injuries, particularly to the chest, and some of these injuries can be extremely serious.

DISEASES

In our practice, the two most common reasons for obtaining a medical imaging consultation in a guinea pig are suspected bloat and urinary tract calculi. Less often, consultation for pneumonia, gastrointestinal obstruction, or nonspecific abdominal masses is sought. Most such examinations are predominantly radiographic, although there are the occasional contrast studies and ultrasound examinations. I have yet to identify extreme ovarian enlargement because of cysts, but marked unilateral and bilateral enlargement have been reported.

Guinea pigs also suffer from a wide variety of joint diseases, many of which are symmetrical and result in marked structural alteration to the affected joints. For the most part these are predominantly *generative* forms of arthritis (new bone deposited on preexisting bone), at least as viewed from a radiological perspective.

Bloated Stomach

Bloat is a gaseous distention of some part of the gastrointestinal system (but most often the stomach) and can have a variety of adverse effects including colic, obstruction, and dyspnea.

Colic often accompanies overdistention of the stomach or bowel secondary to inappropriate stimulation of the autonomic nervous system. Marked gastrointestinal distention, particularly of the stomach, can lead to secondary compression, kinking, or twisting of the cardia or pylorus, leading to obstruction.

Distention of the stomach, or cecum, places pressure on the diaphragm, making it physically more difficult to breathe, as well as making it *feel* more difficult to breathe. Gastric distention may also produce varying amounts of regional venous compression, which causes anoxia of the stomach wall, predisposing to rupture if not alleviated.

Radiographically, a bloated stomach is usually characterized by gaseous distention, typically in the left cranial half of the abdomen. When air and gas are present together, the stomach content appears a medium rather than a dark shade of gray (Figure 21-16). In some instances, the stomach may become so large that it reaches caudally all the way to the pelvis and can resemble cecal enlargement (Figure 21-17).

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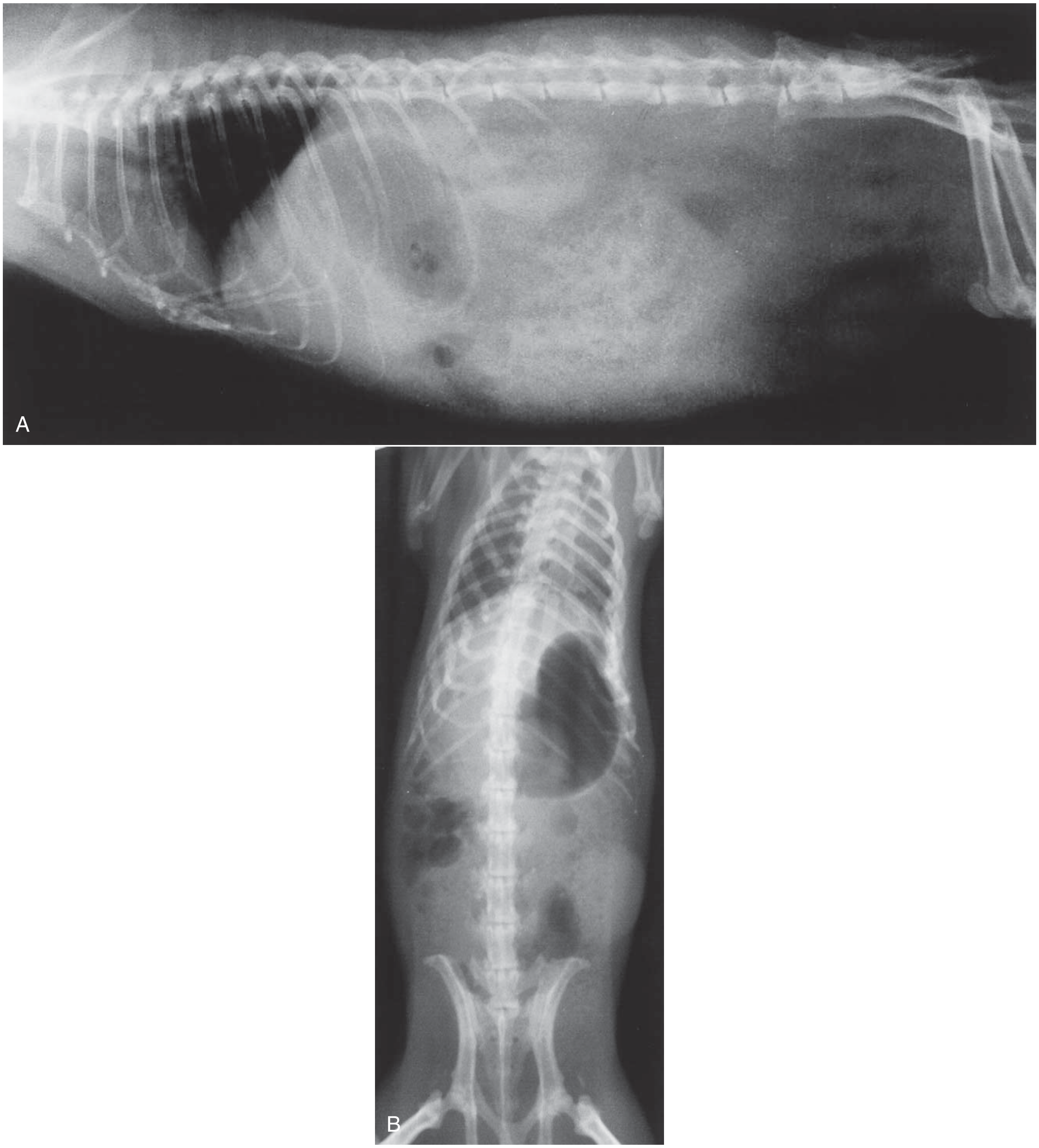

Figure 21-11 • A, Full-length lateral and ventrodorsal **(B)** views of a healthy guinea pig show the thorax to be much shorter than the abdomen, making the former more difficult to assess radiographically.

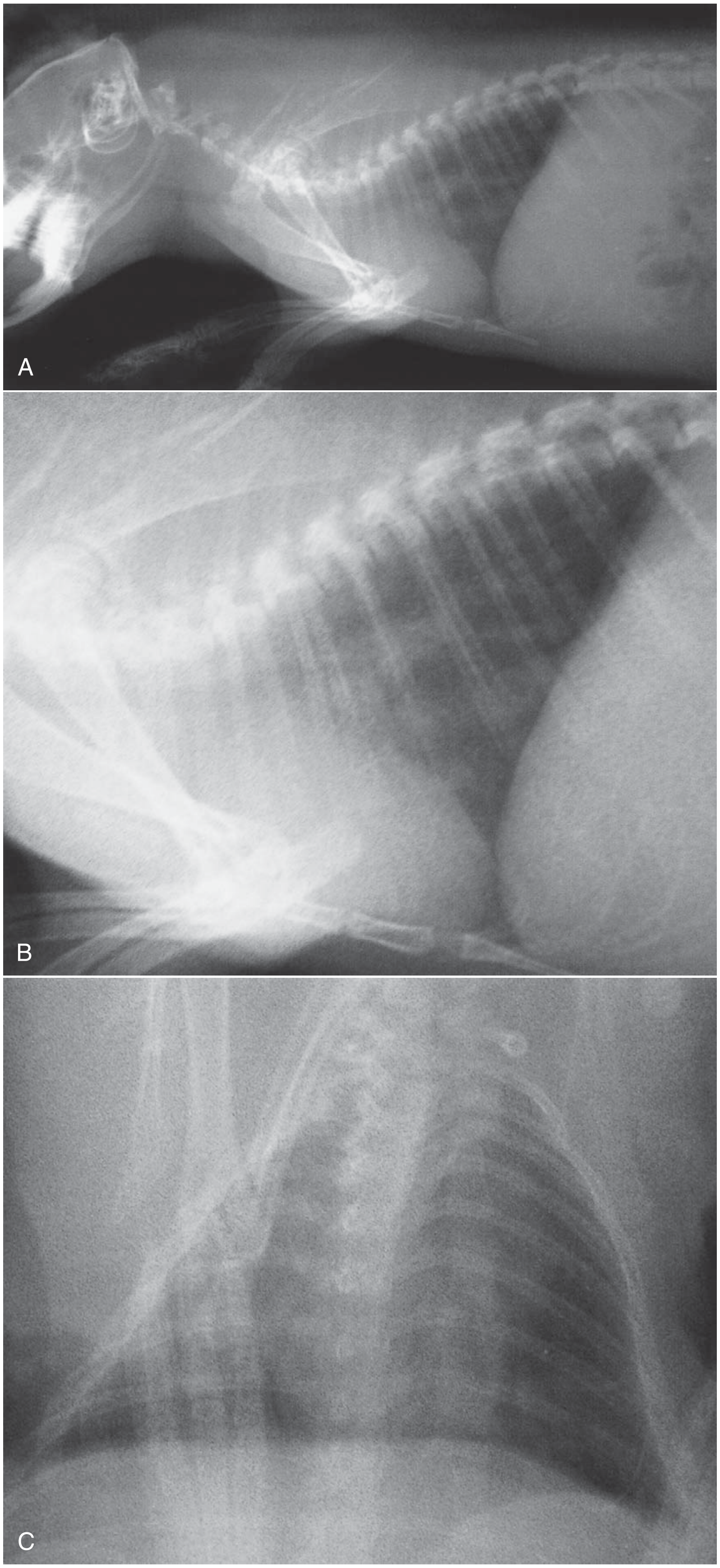

Figure 21-12 • A, Lateral screening view of the throat, neck, and chest, and close-up lateral **(B)** and ventrodorsal **(C)** views of a guinea pig recently attacked by a cat show mediocre intrathoracic contrast, exacerbated by the superimposition of both upper forelimbs on the cranial half of the thorax. No injuries were identified.

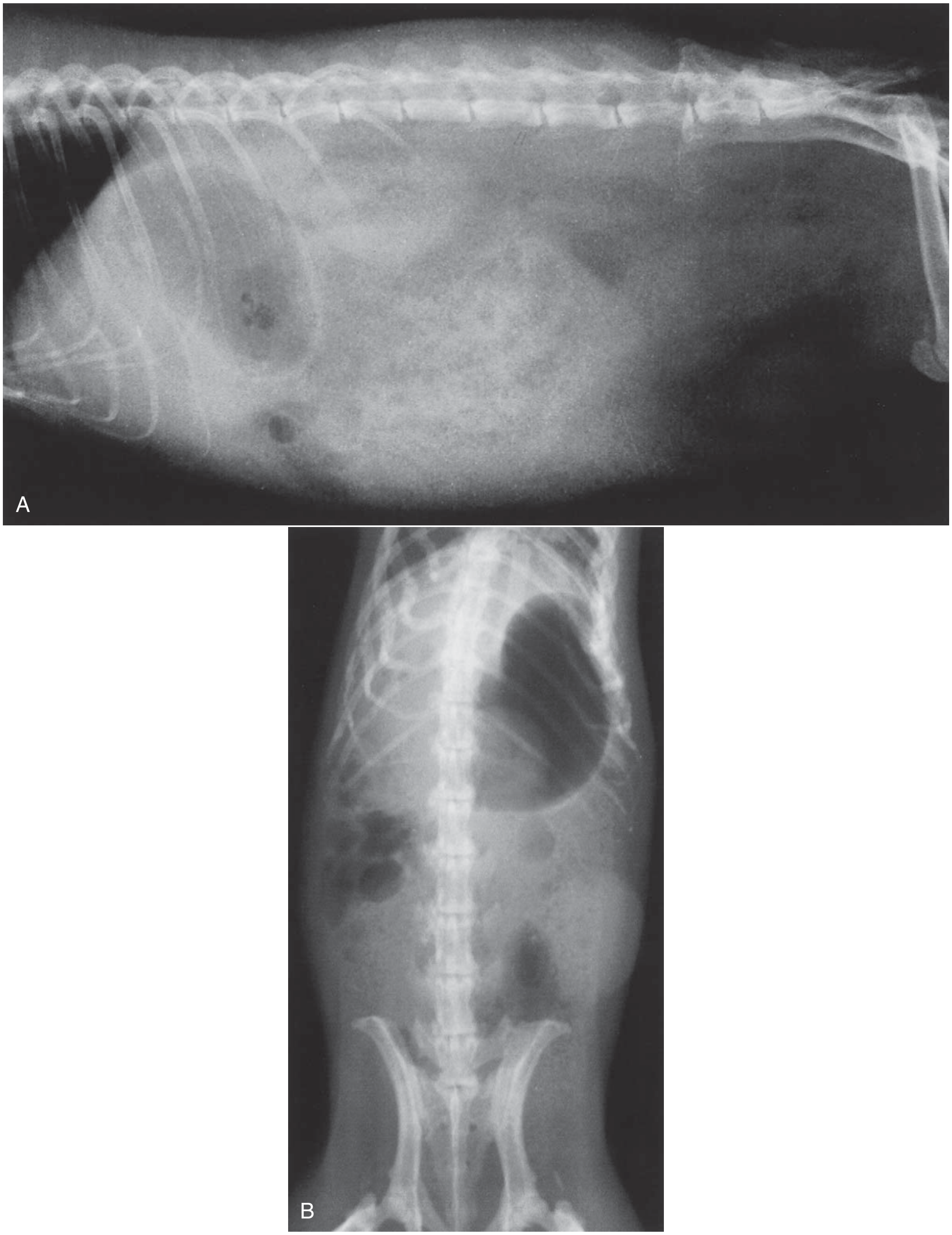

Figure 21-13 • A, Close-up lateral and ventrodorsal **(B)** views of the abdomen of a healthy guinea pig.

Figure 21-14 • Close-up view of the right humeral joint of a guinea pig with a suspected fracture. The pig's torso has been rotated away from the shoulder to avoid superimposition of the rib cage, and the extended position of the limb maintained with a tongue depressor.

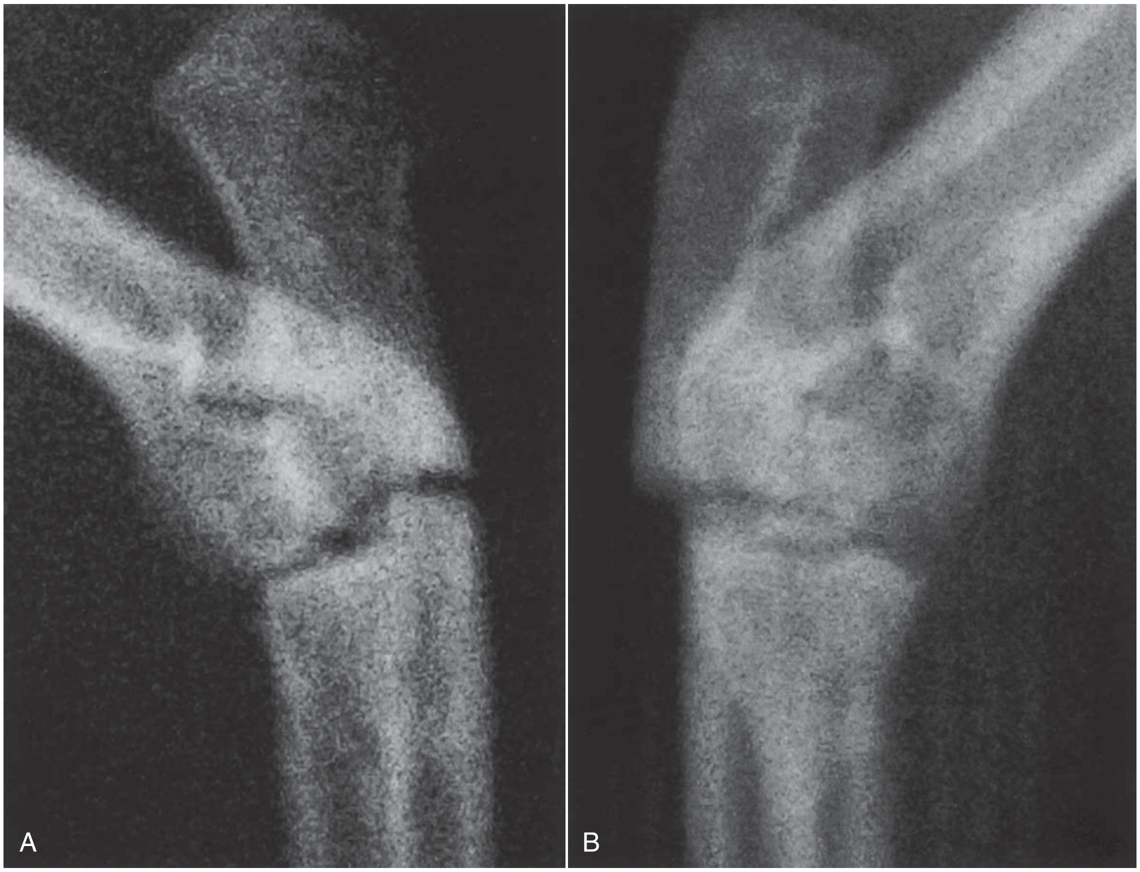

Figure 21-15 • Close-up views of the right **(A)** and left **(B)** elbows of a guinea pig accidentally stepped on by its owner, resulting in *bilateral* fracture-dislocations.

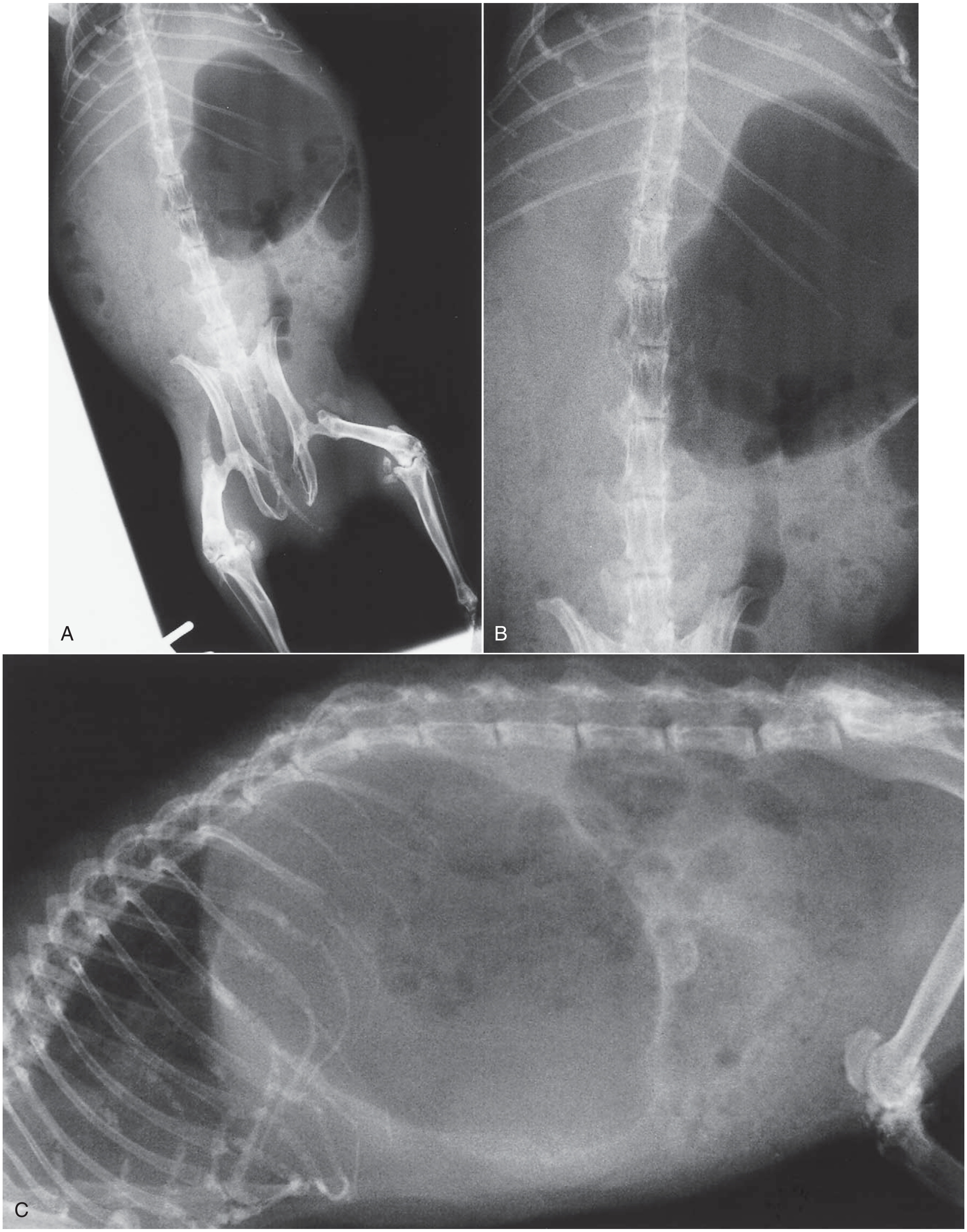

Figure 21-16 • A, Ventrodorsal, close-up ventrodorsal **(B),** and lateral **(C)** views of a moderately distended, air- and fluid-filled stomach in a bloated guinea pig.

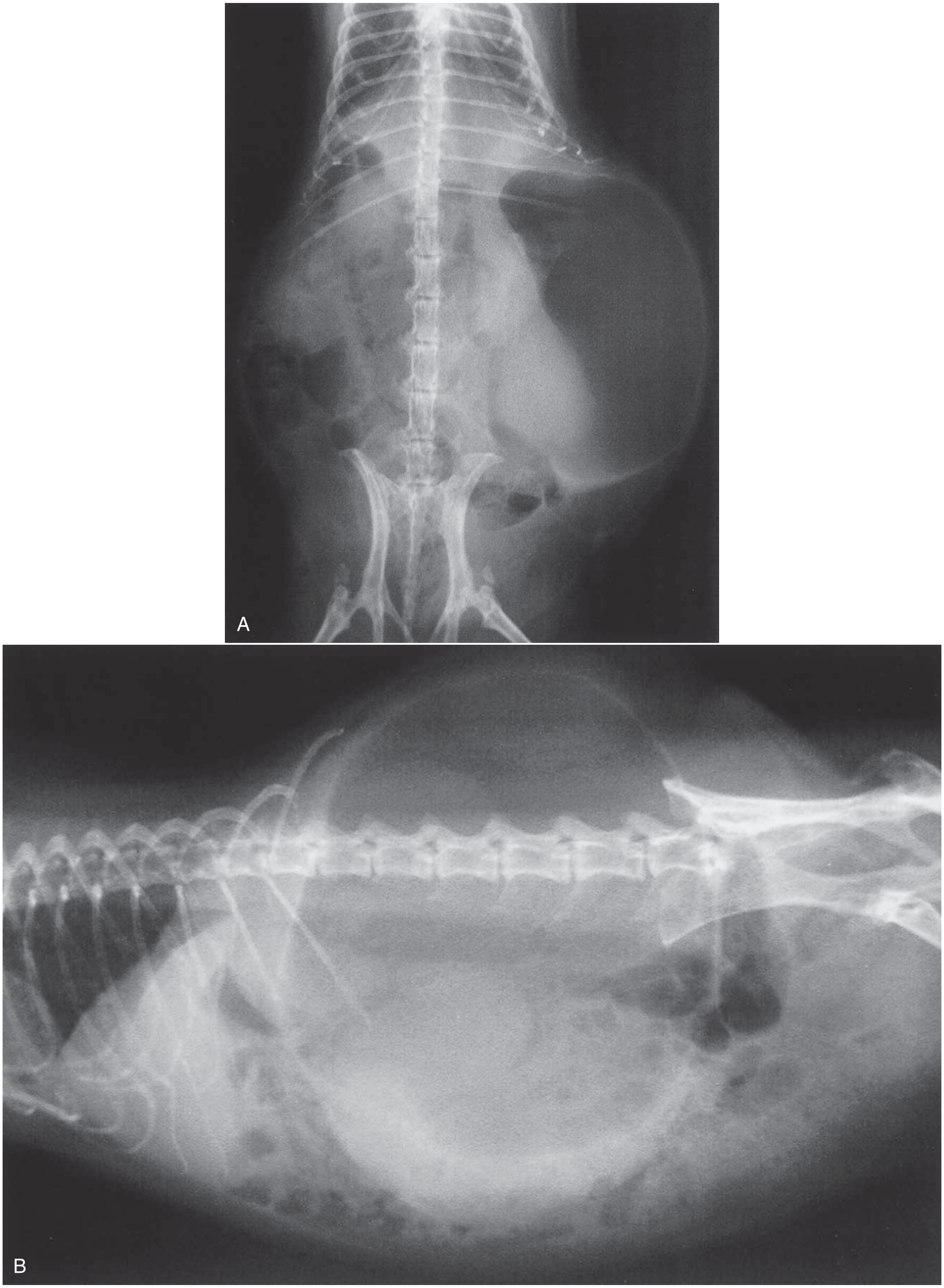

Figure 21-17 • A, Ventrodorsal and lateral **(B)** views of a bloated guinea pig as indicated by a severely distended stomach that reaches nearly to the pelvis.

Sometimes, a straightforward case of bloat is actually a more serious problem. For example, the stomach may become distended with fluid and air as a result of atony secondary to a gastric ulcer or abscess (Figure 21-18). Peritonitis can have a similar effect on the stomach, as well as the bowel. Large amounts of gas often accumulate in the stomachs of dyspneic guinea pigs, causing forward pressure on the diaphragm and making it even harder to breathe.

Cecum. Cecal enlargement, or by inference cecal impaction, can be associated with a variety of sizes, shapes, and interior densities, most of which force the rest of the adjacent abdominal viscera forward into the

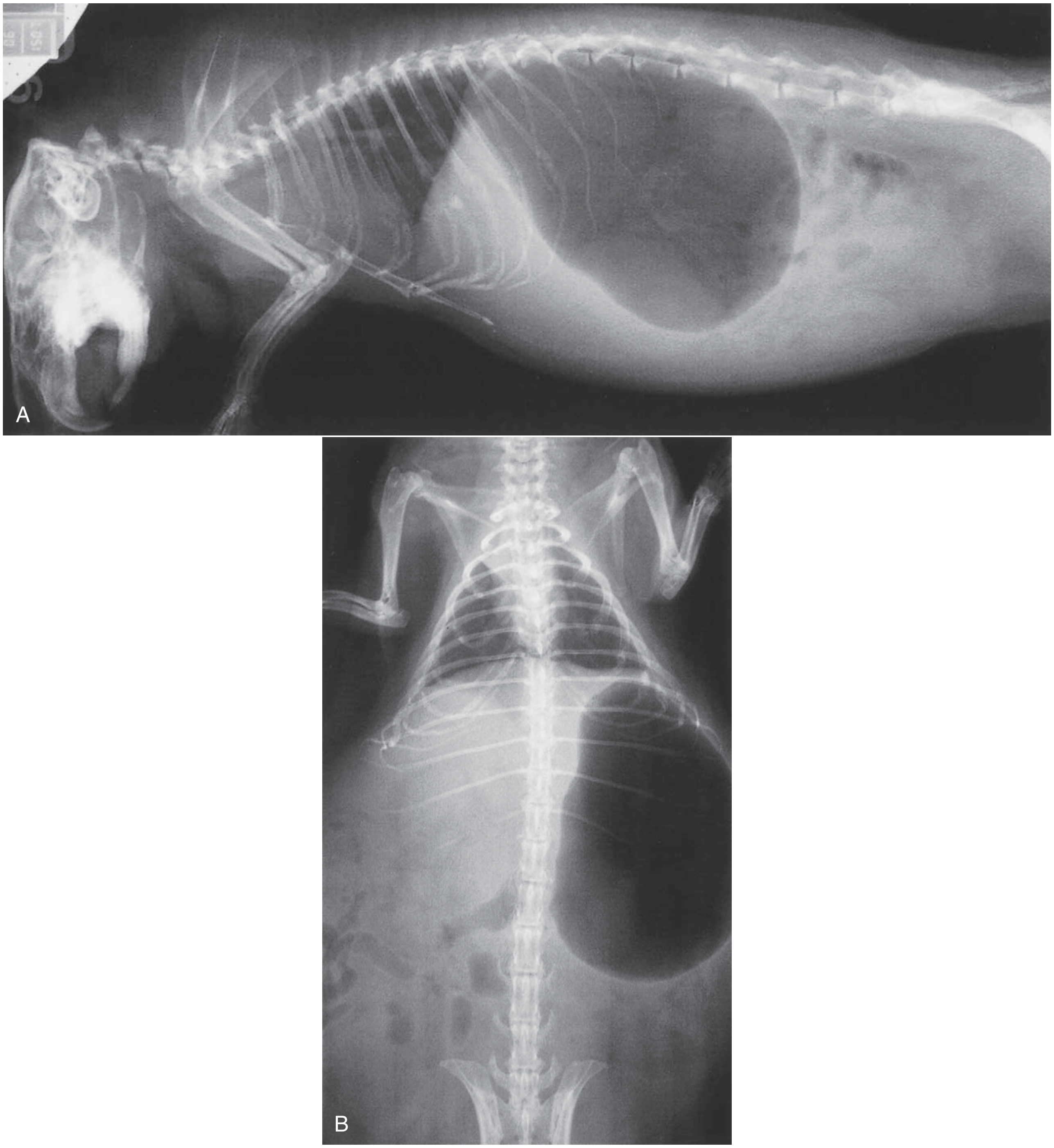

Figure 21-18 • A, Lateral and ventrodorsal **(B)** views of the torso of a guinea pig with a confirmed gastric abscess show moderate to severe gaseous distention of the stomach, flattening and cranial displacement of the diaphragm (inferring increased abdominal pressure), and a cranial mediastinal mass (nature undetermined).

cranial half of the abdomen (Figure 21-19). Depending on the amount of abdominal detail and the nature of the cecal content, it may be impossible to differentiate a large fluid-filled cecum from a solid mass such as a tumor. A *mass effect*, for example, a gravid uterus, can lead to a similar kind of diagnostic uncertainty.

Bladder Stones (Cystic Calculi)

Cystic calculi, or as they are more commonly termed *bladder stones*, are frequently encountered in guinea pigs and can usually be diagnosed radiographically, provided the stones are sufficiently large and dense and the image is high quality (Figure 21-20). Occasionally, dystrophic calcification occurs in the wall of the bladder and resembles calculi. Where there is a question regarding the possible nature of such densities, sonography can be used to establish whether the densities move or change position while being scanned. If they do, they are stones.

Urethral Calculi

Urethral calculi are identified less often than cystic calculi, usually because they have been overlooked. Obviously, a bladder stone can pass into the urethra, provided it is not too large, with or without accompanying *urethral colic*. Urethral calculi are invariably best seen in high-quality images of the caudal abdomen (Figure 21-21).

Lameness. At first, the term *lameness* may seem foolish, or even laughable, given how difficult it may be to conduct anything even approaching a standard lameness examination in a guinea pig (Figure 21-22). However, it is quite common for owners to describe their guinea pigs as being lame (or limping, not walking right, or dragging a leg). So based on what appears to be a clear owner preference, lameness seems to have a genuine currency and legitimacy and therefore can be used without apology or reservation.

Fracture and Soft Tissue Injury

As mentioned previously, many fractures in guinea pigs, perhaps even the majority of such injuries, have been inadvertently inflicted by their owners. Serious injuries, such as fracture and dislocation, are often suspected at or near the time of their occurrence but not always. The undetected or unappreciated fracture can also be a problem, especially in previously owned animals acquired from a shelter.

But there is far more to limb injury than just fracture or dislocation, as most readers can attest to through personal experience. For example, a torn nail, a puncture or cut, or a bad bruise or hematoma is capable of causing an observable lameness, albeit one that is usually short-lived compared with a fracture.

Sprains and Strains

A stretched or torn tendon *(strain)* or ligament *(sprain)* can sometimes be as painful and disabling as a fracture and can cause an equally profound lameness. While such injuries may be inferred, especially in the absence of a radiographically demonstrable fracture or

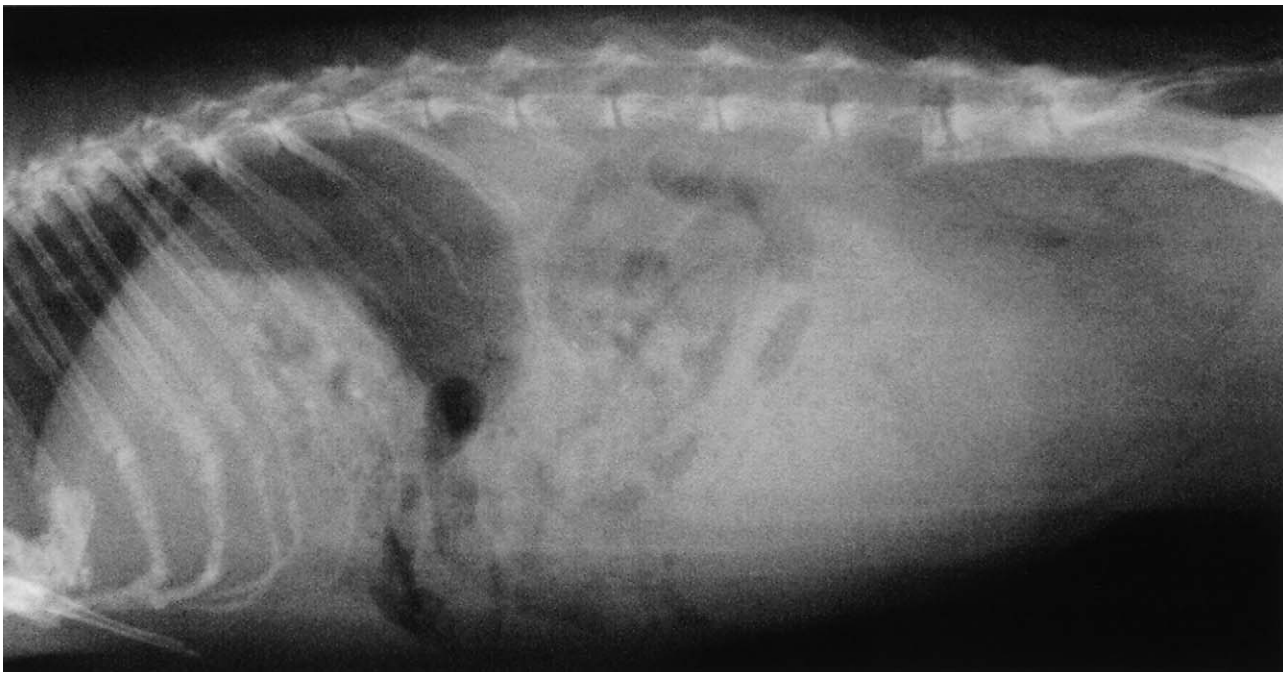

Figure 21-19 • Lateral view of the torso of a guinea pig with an impacted cecum shows a caudal abdominal mass or mass effect being created by organomegaly, most likely the cecum. The unusual appearance of the stomach is the result of cranial displacement by the enlarged cecum.

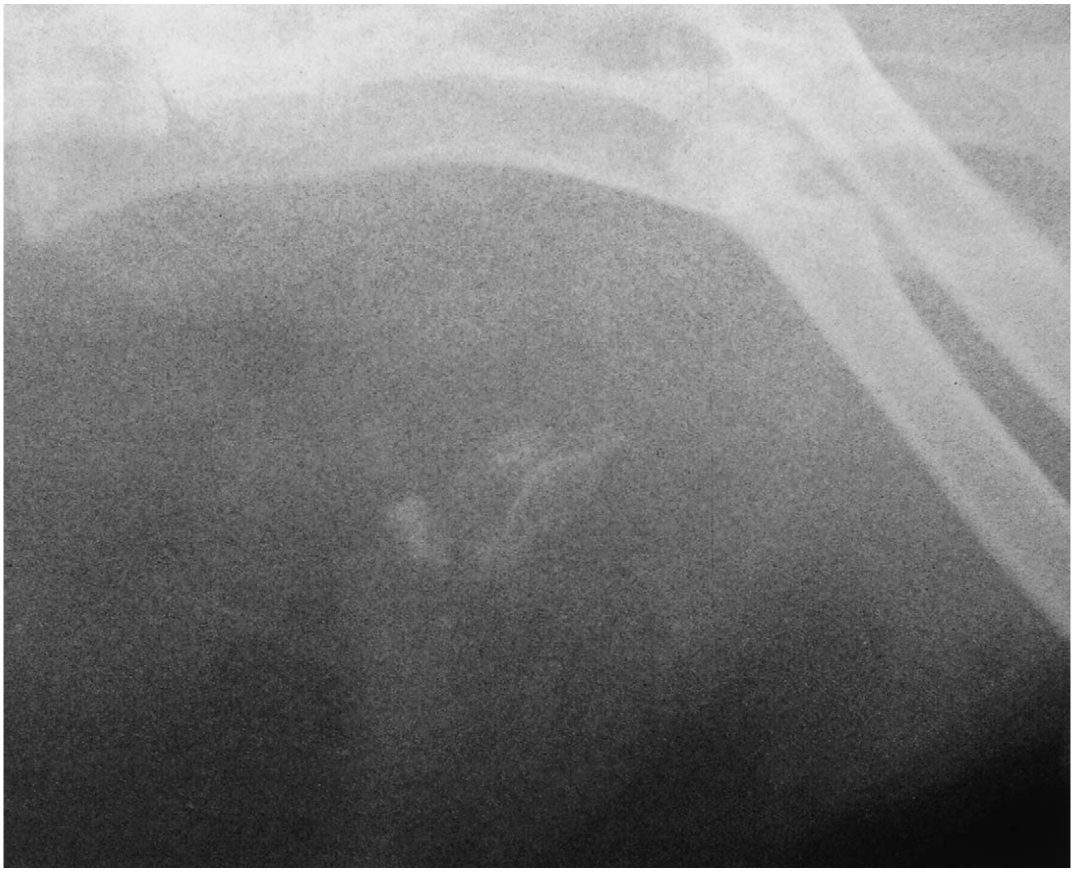

Figure 21-20 • Close-up view of the caudal abdomen of a guinea pig shows a small cluster of variably shaped, medium-sized bladder stones.

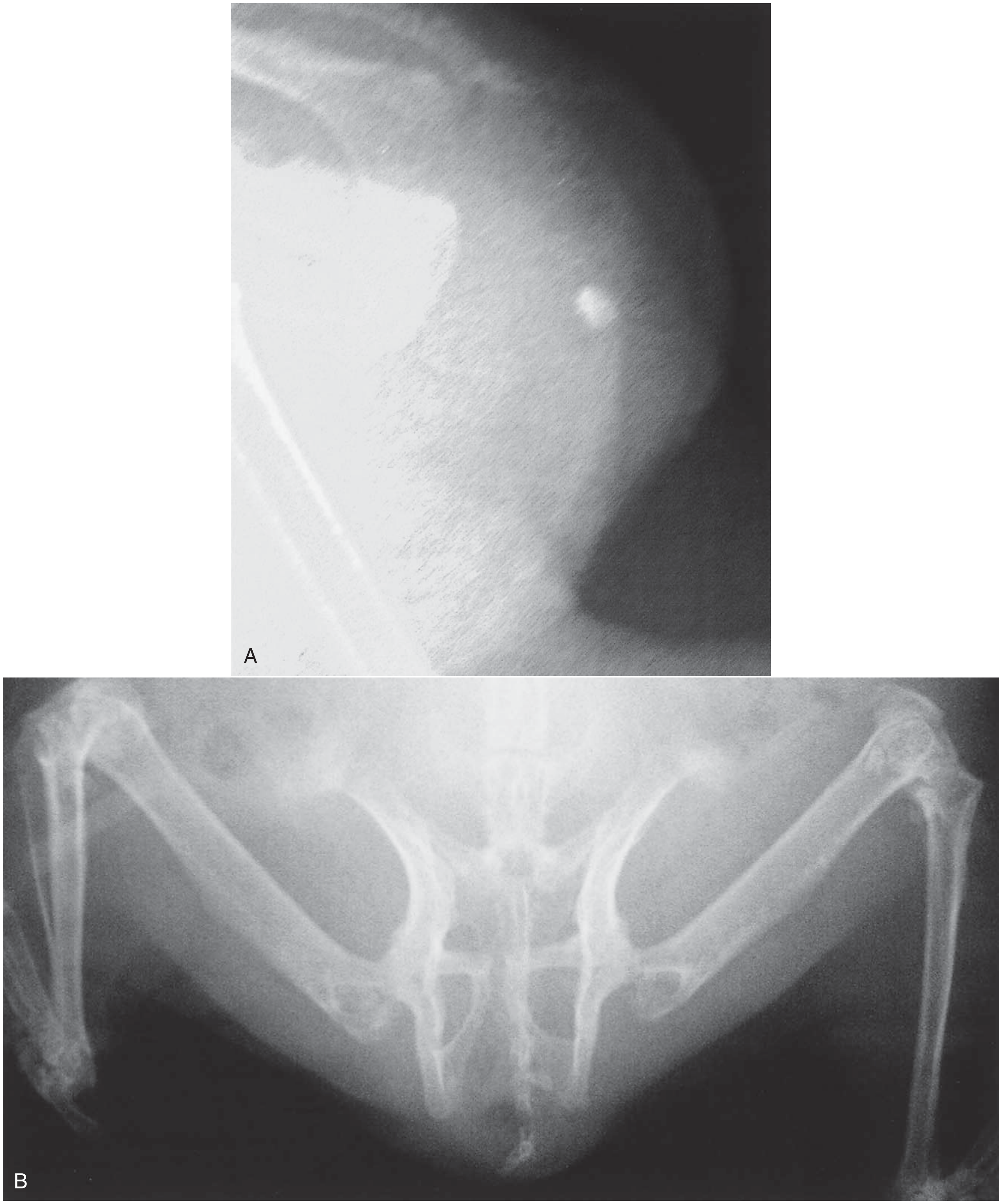

Figure 21-21 • A, Close-up lateral and ventrodorsal **(B)** views of a guinea pig show a urethral calculus caudal to the ischial arch. Note that it is far easier to identify the stone in the lateral view where there is no pelvic superimposition, compared with the ventrodorsal projection where the calculus is almost completely hidden by the tail.

Figure 21-22 • Veterinarian closely observes guinea pig that has been described as being lame by its owner.

dislocation, they usually produce little more than a nonspecific localized or regional swelling. In the case of a moderate *(second-degree)* or severe *(third-degree)* sprain, it may be possible to palpate a dislocation, but this usually requires a strong analgesic or sedative to examine the animal humanely.

I have identified by ultrasound an intramuscular hematoma causing a compartment syndrome in a young puppy that had sustained a severe crush injury. This injury is yet another means by which a non–weight-bearing lameness might occur in a traumatized guinea pig and then identified without radiographic evidence of injury.

Osteoarthritis

Traumatic Osteoarthritis. Osteoarthritis in guinea pigs, or any of the small mammalian cage pets, is often the result of a previous injury, particularly articular fractures and serious sprain injuries that are associated with dislocation. Proximal femoral growth plate fractures are notorious in this regard, with some chronic injuries so radically changing the appearance of the joint that it becomes nearly unrecognizable (Figure 21-23).

Nontraumatic Osteoarthritis. Guinea pigs can also develop osteoarthritis for which there is no obvious explanation. The stifle seems particularly prone to this type of disease (Figures 21-24 and 21-25), which in some respects resembles the radiographic appearance of *chondromatosis* that often affects the stifles of older cats.

Infection

Hematogenous infections, most of which are presumed, typically occur in immature and young adult guinea pigs, usually in the peripheral appendicular joints. Less frequently, infections, including abscesses, occur in the cranial mediastinum, lung, peritoneal cavity, and individual organs, including the liver and stomach.

Although these infections begin by causing one or more swollen joints (in the case of skeletal lesions) and thus can be recognized radiographically as being intraarticular, they soon spill into the extraarticular tissues, masking the initial nidus. Because the periosteum covering the tarsal (and carpal) bones is the relatively primitive fibrous type, it is slow to react; for example, it takes a month or more in most instances, unlike the periosteum covering the long bones, which typically responds in a few days after being stimulated.

Thus, if interior bone destruction is seen, especially when accompanied by one or more widened cartilage spaces, the infection probably did not begin recently (Figure 21-26). An exception to this is some types of penetrating wound in which the bone or joint has been inoculated directly by one or more bacteria.

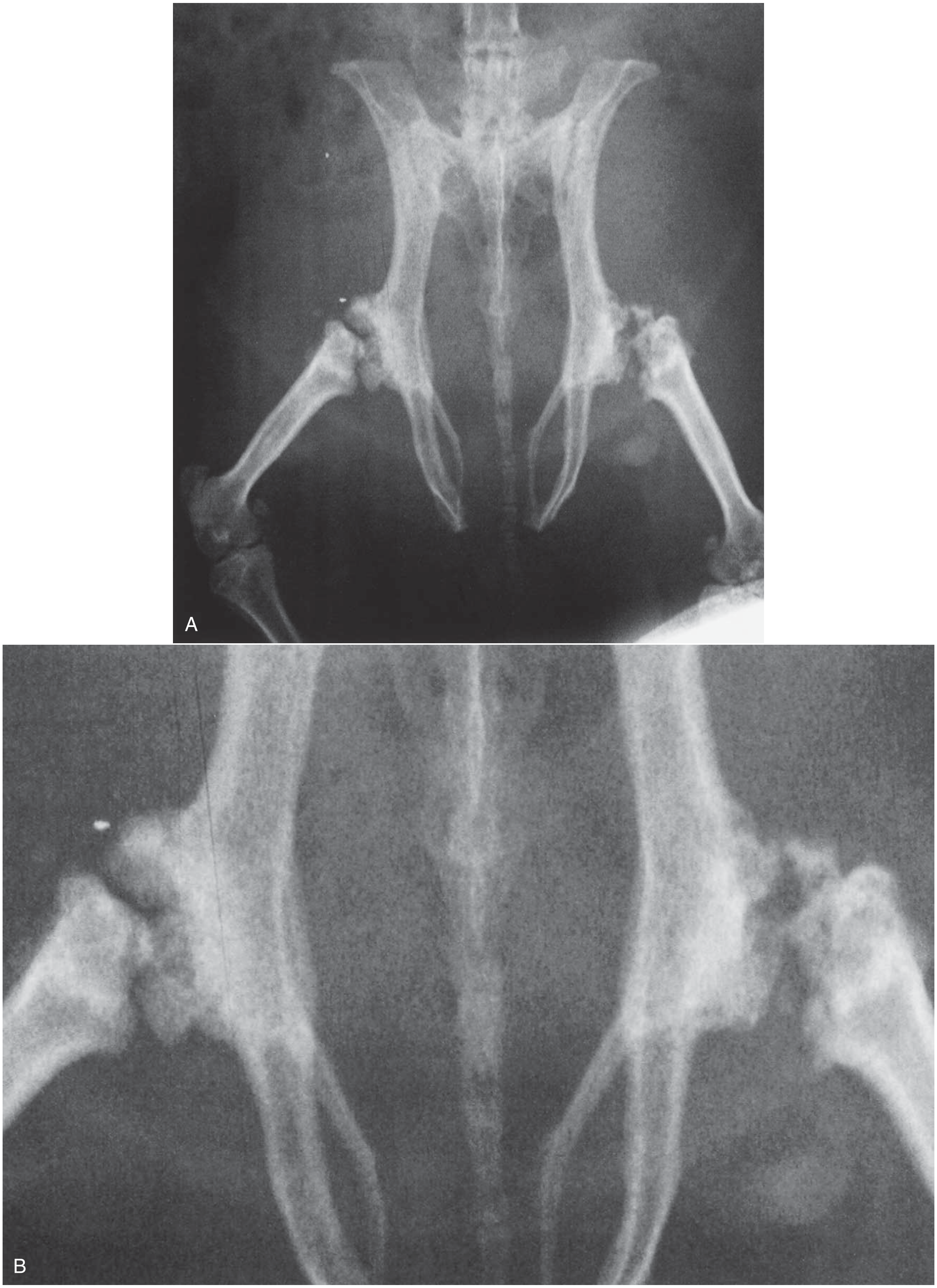

Figure 21-23 • A, Orientation and close-up ventrodorsal **(B)** views of the pelvis and hips of a guinea pig with old bilateral femoral growth plate fractures that have caused severe secondary osteoarthritis. A normal pelvis and hips are provided for comparison **(C).**

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Figure 21-23, cont'd • For legend see p. 253.

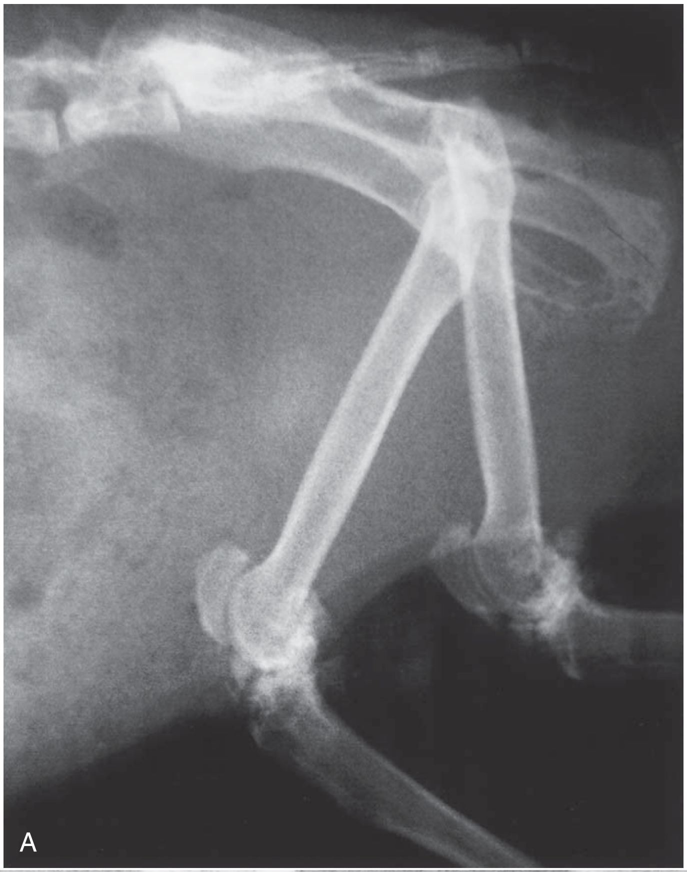

Figure 21-24 • A, Orientation and close-up lateral **(B)** views of a guinea pig show severe bilateral osteoarthritis with extensive "islands" of periarticular new bone resembling chondromatosis. A normal lateral oblique projection is provided for comparison **(C).**

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Figure 21-24, cont'd • For legend see p. 255.

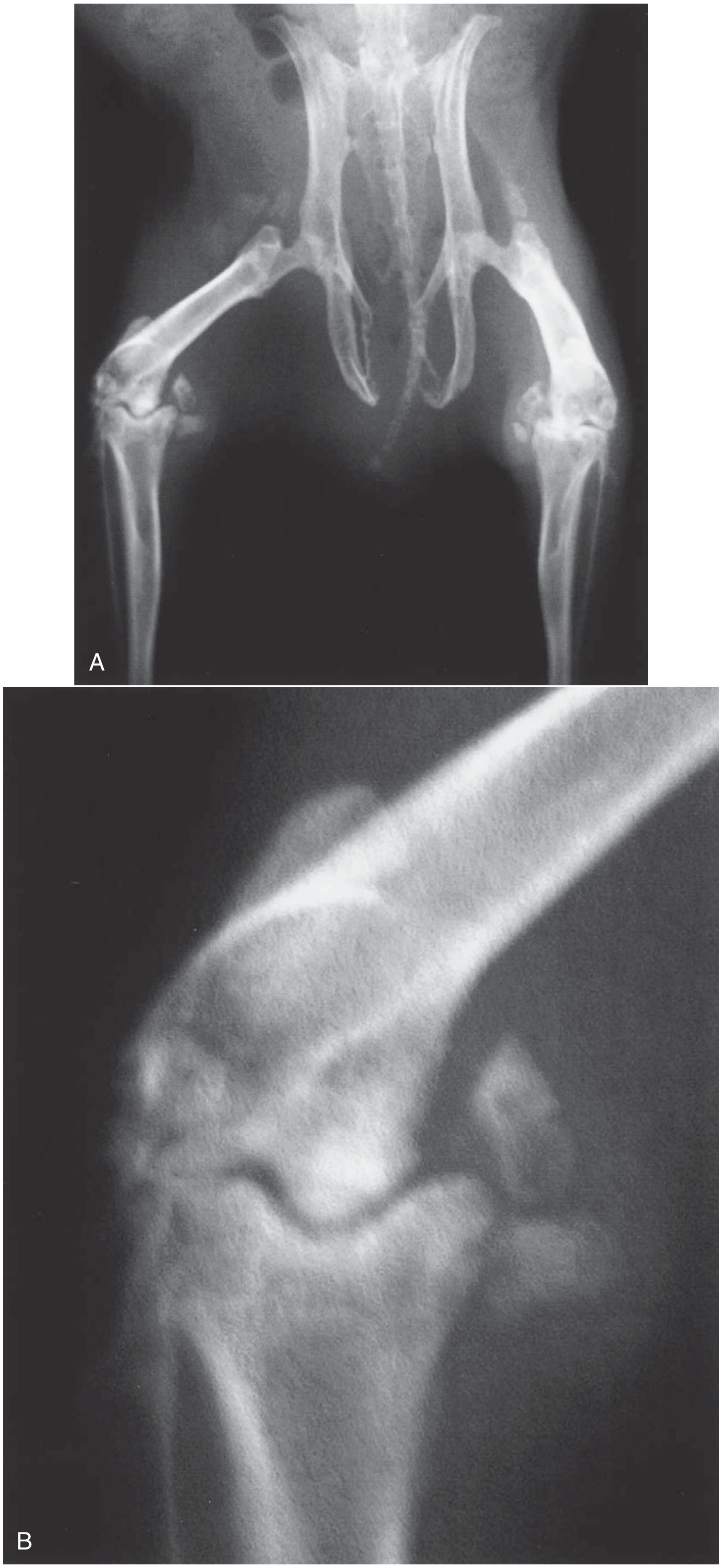

Figure 21-25 • A, Orientation and right **(B)** and left close-up **(C)** ventrodorsal views of the stifles of the guinea pig shown in Figure 21-24 show partial dislocation, collapse of the cartilage space, subchondral sclerosis, and discrete formation of periarticular new bone.

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Figure 21-25, cont'd • For legend see p. 257.

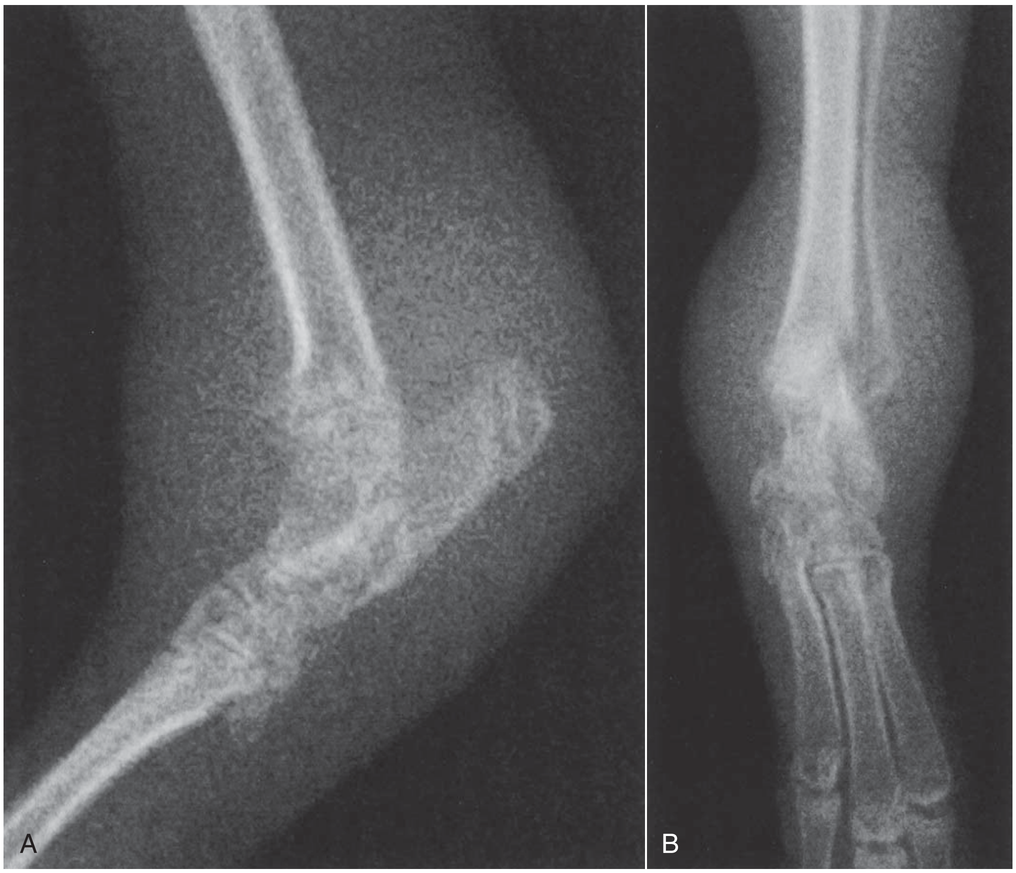

Figure 21-26 • A, Close-up lateral and dorsoplantar **(B)** views of the infected tarsus of an immature guinea pig with an unspecified bacteremia. Note the extensive interior destruction of the distal intertarsal joint, generalized loss of cartilage spaces, and large extraarticular swelling centered over the tarsocrural joint.

Chapter 22

Hamsters

RADIOGRAPHY

We see comparatively few hamsters in our practice, perhaps 2 to 3 dozen a year, and only a few of these are radiographed. Hamsters are particularly energetic and disinclined to be handled by strangers, making radiographic restraint quite difficult. If chemical or gas restraint is inadvisable, some measure of control can be achieved by briefly placing the animal in stockinet, pinching the ends closed to prevent escape, positioning as desired, and making the exposure (Figures 22-1 and 22-2).

The obvious drawbacks to this strategy are that positioning will necessarily be inexact and superimposition of the limbs on the torso inevitable (Figure 22-3). These problems are exacerbated when the animal is placed on its back, which alarms most small rodents, causing them to redouble their efforts to escape. For this reason, we prefer the dorsoventral (DV) projection to the ventrodorsal view. The lateral position is less problematic as concerns restraint but does force one to assess the cranioventral thorax and caudal abdomen through the superimposed fore and hind limbs (Figures 22-4 and 22-5).

A hamster may also be radiographed while in a cardboard container, for example, a shoebox (Figure 22-6). An animal that is ill and depressed will often remain motionless, at least long enough for an exposure or two; however, the position assumed by the hamster may be imperfect (Figure 22-7).

A more active animal can usually be kept reasonably still by surrounding it with soft foam blocks within the box that are configured to resemble a mini-corral. This usually results in a better DV projection than what can be achieved by box confinement alone (Figure 22-8).

Clearly, the best positional quality is achieved when the animal is unconscious, which can be achieved using anesthetic gas administered by mask (Figure 22-9).

NORMAL RADIOGRAPHIC ANATOMY

The radiographic anatomy of the hamster is similar to that of the rat and guinea pig; the principal difference is in the skull, which is relatively shorter, wider, and rounder. The narrow, tapered trunk of the hamster closely resembles that of the rat.

Figure 22-1 • A restraint stockinet is placed around an active hamster just before being radiographed.

Figure 22-2 • A demonstrator shows how a hamster is temporarily placed fully within a stockinet, the ends of which are then pinched off to prevent escape, and the animal radiographed. Under such circumstances, the animal remains captive for only a few seconds and then is returned to its cage.

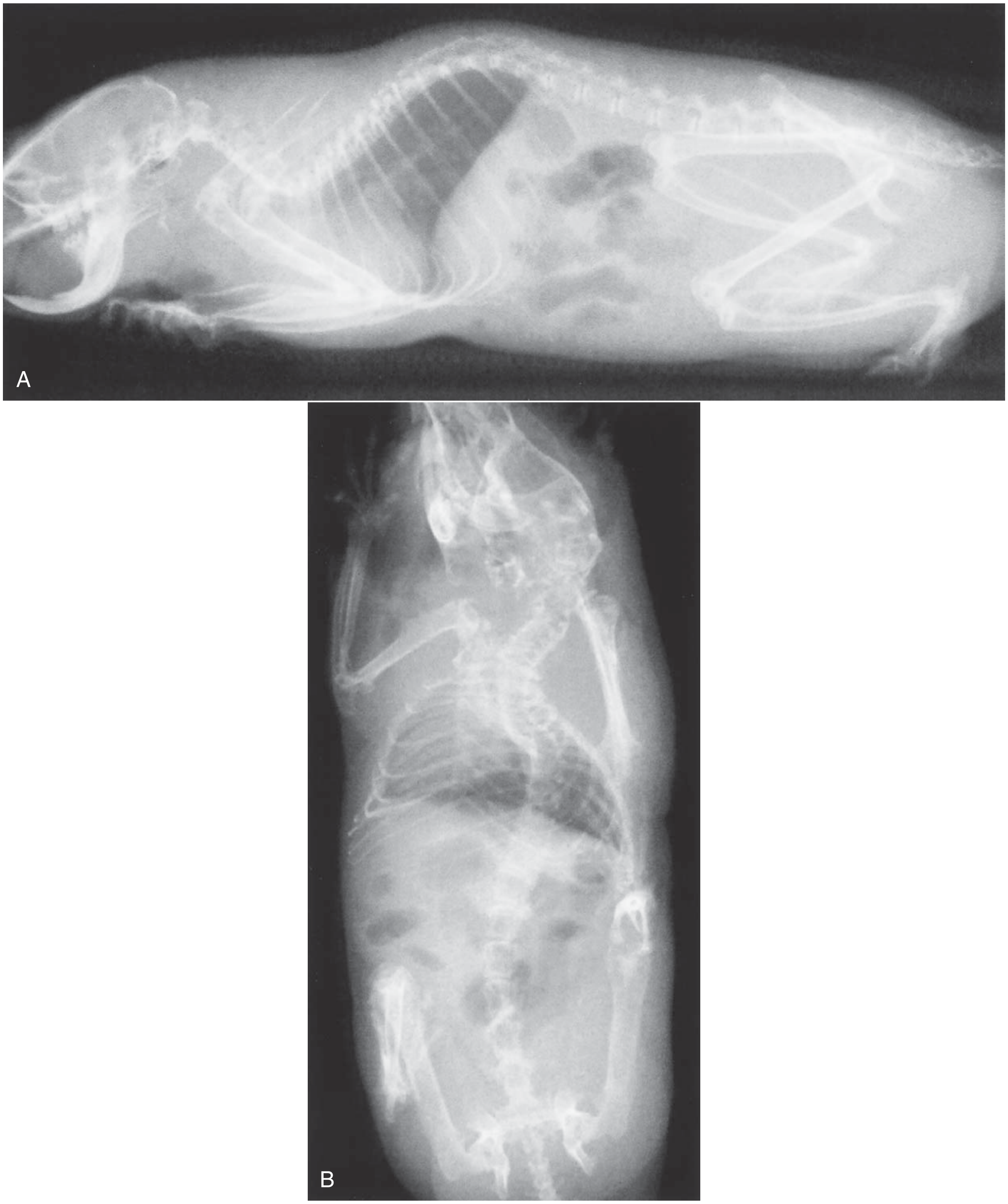

Figure 22-3 • **A,** Whole-body lateral and dorsoventral **(B)** views of a hamster incased in restraint stockinet. Superimposition of the limbs on the torso is unavoidable using this method.

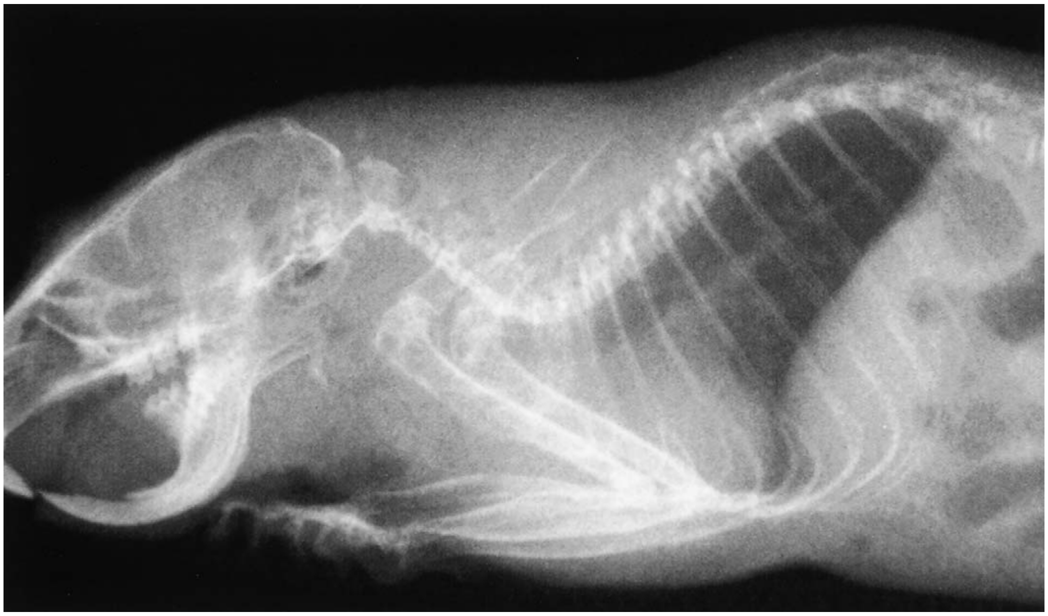

Figure 22-4 • Close-up lateral view of the thorax of a fully conscious hamster imaged with a horizontal x-ray beam and within a restraint stockinet shows little of the cranial thorax because of forelimb superimposition.

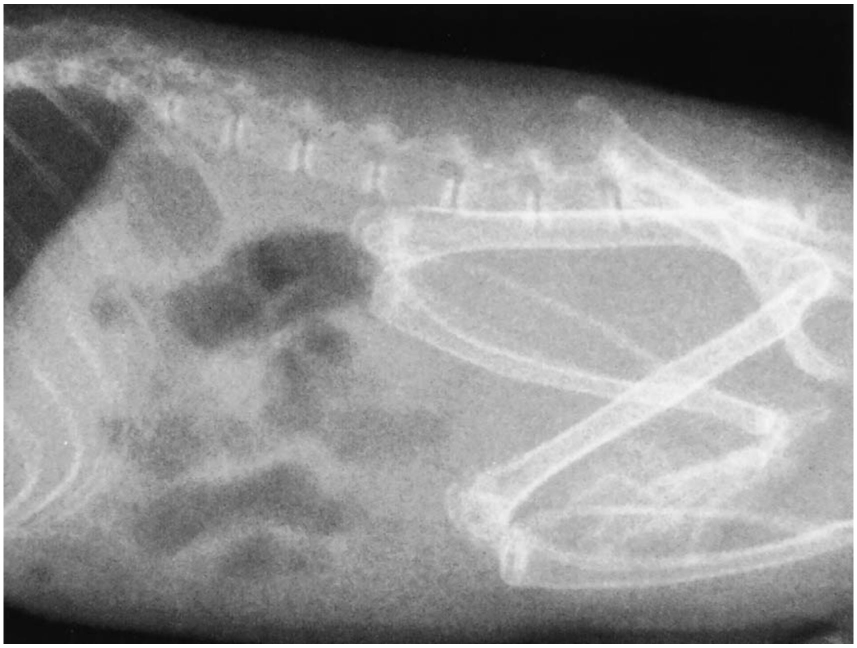

Figure 22-5 • Close-up lateral view of the abdomen of a fully conscious hamster imaged with a horizontal x-ray beam and within a restraint stockinet shows little of the caudal abdomen because of hind limb superimposition.

Figure 22-6 • Hamster peers out from the corner of its box before being radiographed.

Figure 22-8 • An active (and aggressive) hamster radiographed while in its box is also being further confined by a corral of foam pads. Although the image is not perfect, it does reveal a large abdominal mass (or alternatively, a mass effect), ascites, and decreased lung capacity secondary to diaphragmatic compression.

Figure 22-7 • A whole-body radiograph of a hamster confined only by its box while being radiographed frequently results in a nonstandard image, which may be difficult to evaluate.

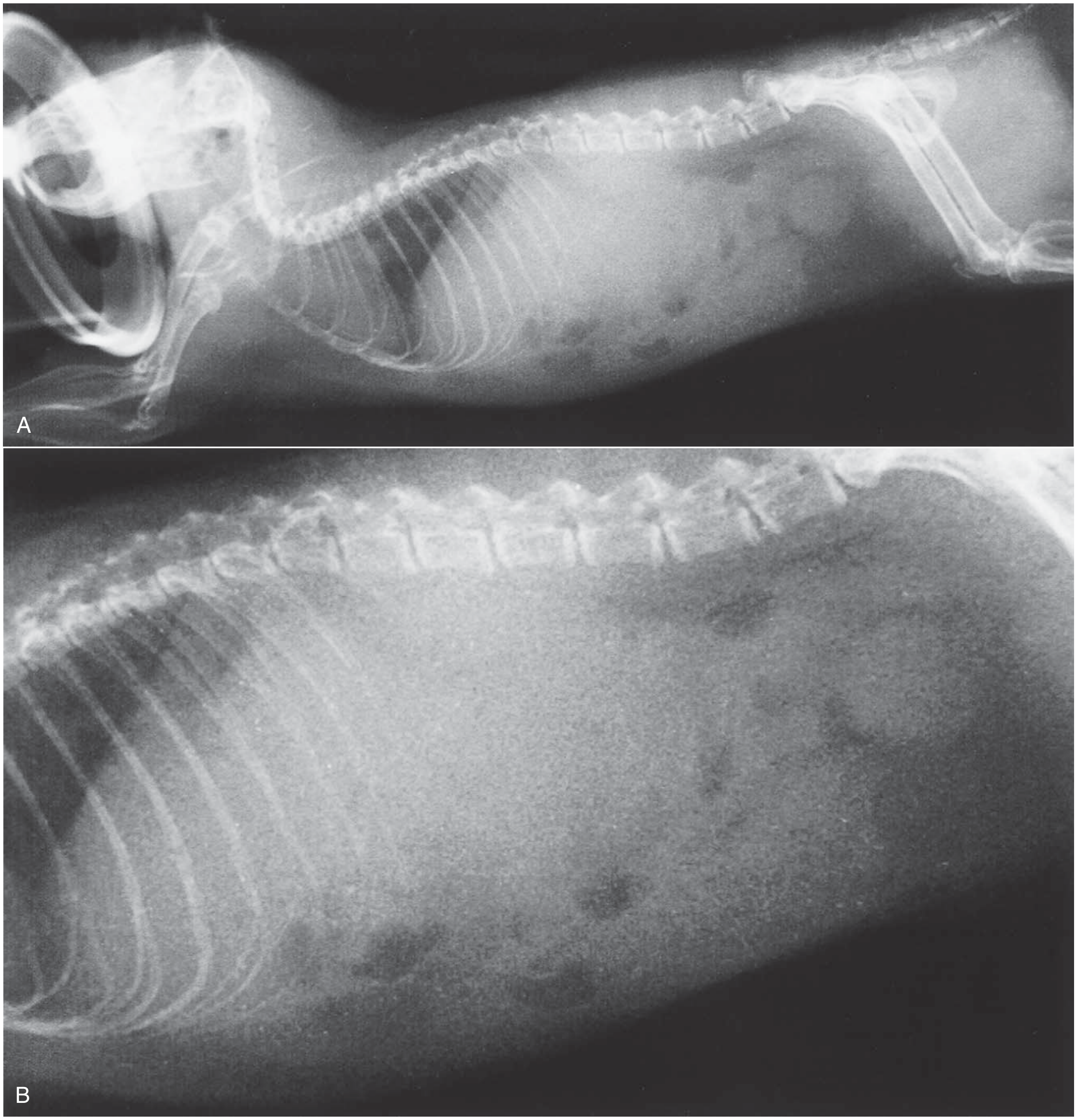

Figure 22-9 • A, Orientation and close-up lateral **(B)** plus orientation **(C)** and close-up ventrodorsal **(D)** whole-body views of a hamster with a cranial abdominal mass as indicated by an *abnormal bowel distribution pattern*.

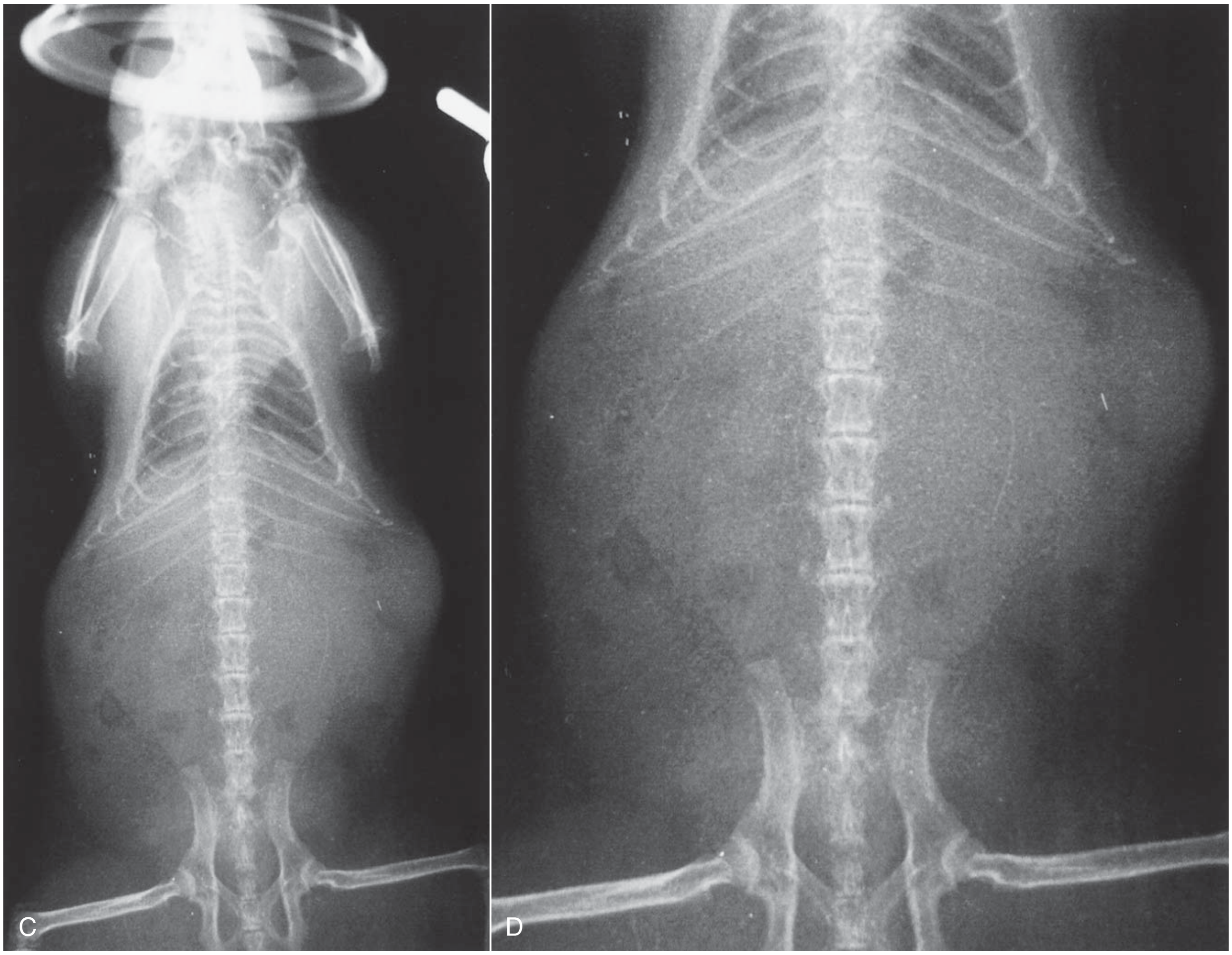

Figure 22-9, cont'd • For legend see opposite page.

Chapter 23

Rats

INJURIES

Most injuries to rats and other pet rodents are the result of being accidentally stepped on. Crush injuries occur occasionally and can be quite serious, especially if the chest or diaphragm is involved. Attacks by other pets, particularly cats and small dogs, can be fatal.

THORACIC DISEASE

Cardiopulmonary Disease and Related Interpretive Difficulty

We probably do more cardiopulmonary examinations on pet rats than any other rodent, and these are studies that I often find difficult to interpret. In the ventrodorsal (VD) view, I sometimes have difficulty deciding if the heart is enlarged or simply projected in a nonstandard manner because of obliquity, making it seem abnormal (Figure 23-1). In the lateral view, I often find it hard or impossible to clearly see the cranial border of the heart, making it impossible to accurately measure heart length (Figure 23-2). Apparently, this is common, as evidenced by other authors publishing normal lateral radiographs of rats with color overlays marking the otherwise obscure cranial and caudal heart borders.

Another interpretive problem with thoracic radiology in rats (and most other small mammals) relates to the gas anesthesia often used for restraint. Specifically, the lowermost lung in an anesthetized animal gradually collapses, while its contralateral lung expands, a process termed *postural atelectasis*. The resulting inflationary imbalance causes the heart to shift toward the partially collapsed half of the lung, which is termed *mediastinal shift*, or more precisely, a *cardiac shift* (Figure 23-3).

In the process of being displaced from the center of the thorax to either the right or left side, the heart also rotates on its vertical axis, further altering the appearance of the cardiac silhouette. Under the described conditions, it can be very difficult to distinguish lung consolidation from collapse, in the normally vague cranioventral region of the thorax.

There are other interpretive difficulties as well. For example, in the VD view the width of the cranial mediastinum can be up to four times greater than the cranial mediastinum of a cat. Also, in the VD view, the right half of the heart often appears overly large and conical, appearing to lie abnormally close to the right chest wall, especially if there is right-sided obliquity.

When the gastrointestinal tract is distended with ingesta, the diaphragm is forced forward, and typically assumes a near-vertical position as seen previously in Figure 23-2. This creates the *illusion* of an enlarged heart because of the less visible background lung; this phenomenon is also known as an *increased cardiac-thoracic ratio*.

Mediastinal Disease

Rats can develop mediastinal disease, which most often takes the form of a cranial mediastinal mass. The majority of these are malignant tumors, and some of these tumors may become as large as the heart, making it difficult to distinguish between the two. The visual impression of two heartlike objects in the thorax has been termed the *double heart sign* (Figure 23-4). In such situations, the heart can usually be distinguished from the contiguous mass by following the trachea in the dorsoventral projection, which should terminate at the level of the heart base.

Abdominal Disease

Abdominal Distention. Rats, like other small pet rodents, regularly develop abdominal distention, which is not a disease but may indicate the presence of one. Most instances of abdominal distention are

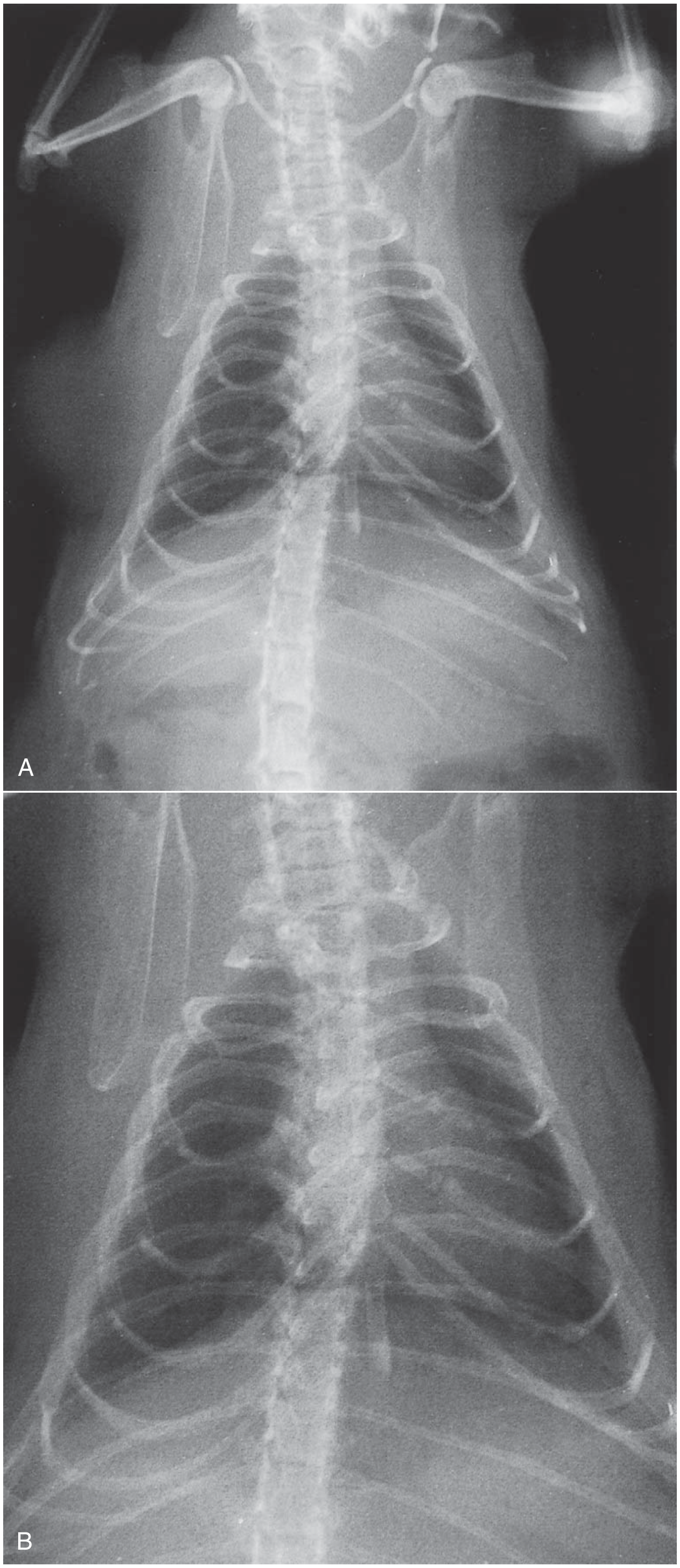

Figure 23-1 • A, Orientation and close-up **(B)** dorsoventral views of the thorax of a pet rat show apparent cardiomegaly with left-sided emphasis, an illusion caused by oblique positioning. Note the injury to the left elbow and the lipoma on the right chest wall.

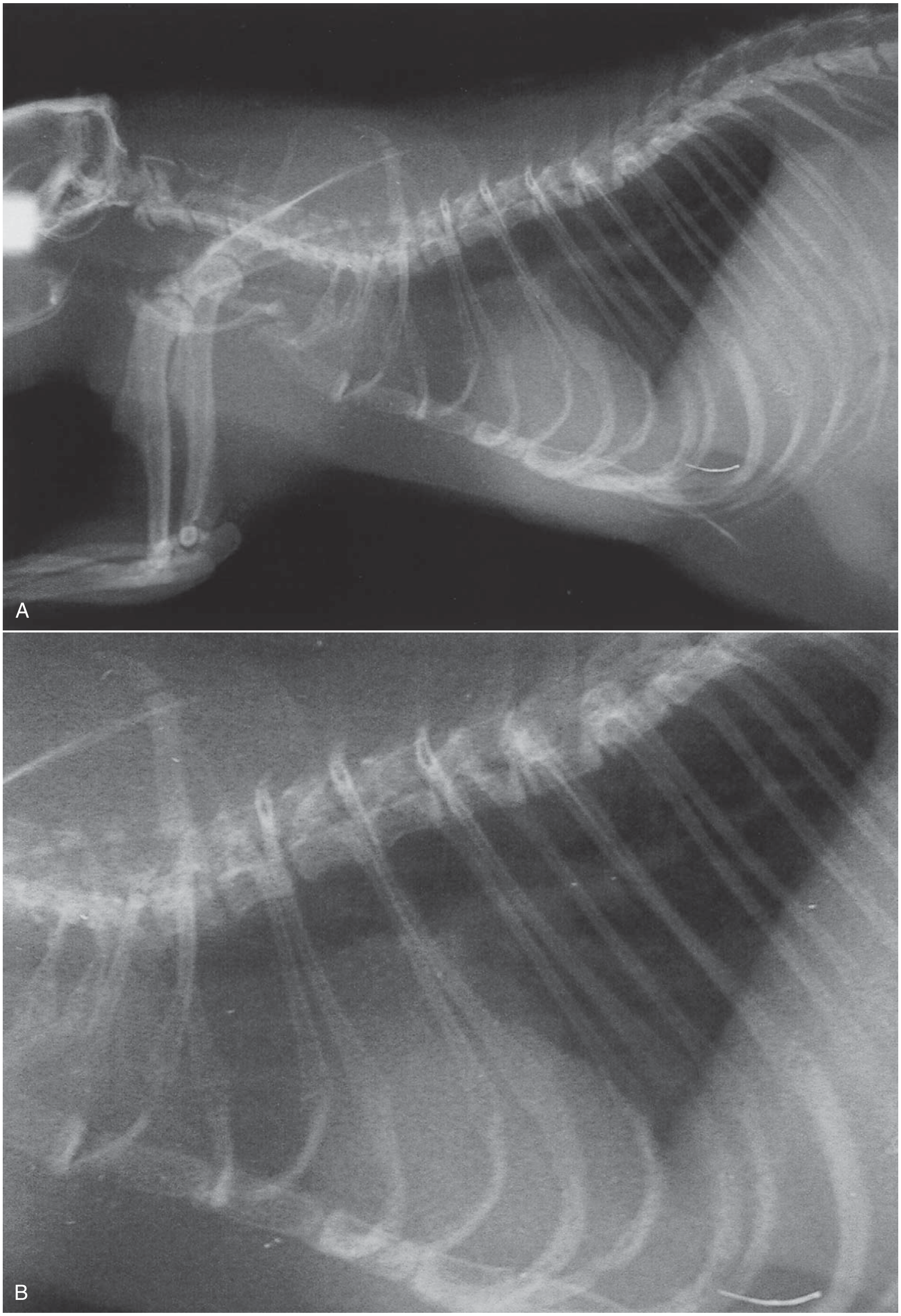

Figure 23-2 • A, Orientation and close-up **(B)** lateral views of the rat shown in the previous figure show the flasklike shape and vague cranial and dorsal borders that characterize the hearts of most small rodents such as the rat. Note that because of obliquity the vertebral bodies have been projected on the upper part of the lung, creating the misimpression of an abnormally tall heart (also termed *increased apicobasilar dimension*).

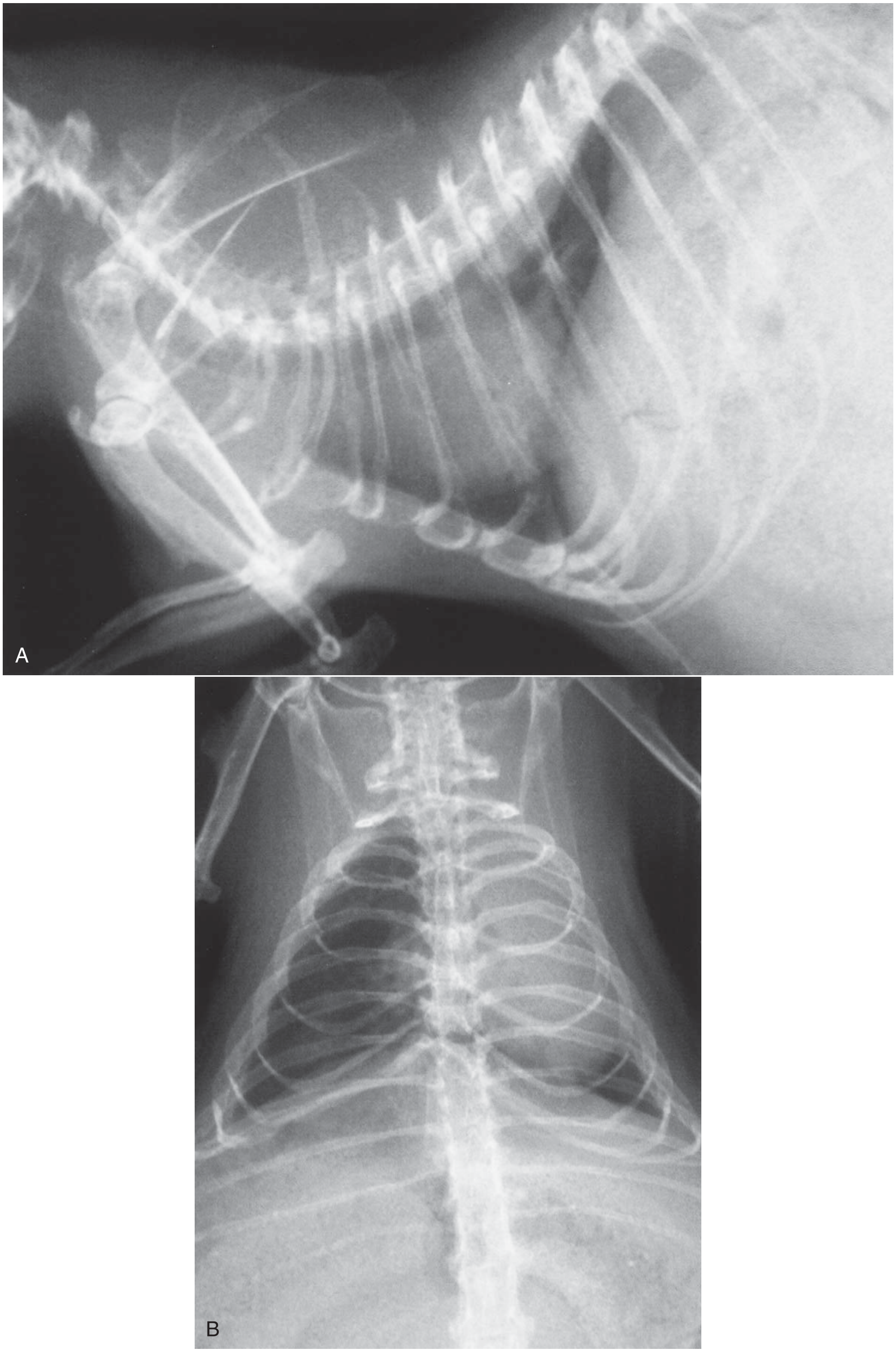

Figure 23-3 • A, Close-up lateral and dorsoventral **(B)** thoracic radiographs of an unconscious pet rat show a pronounced left cardiac shift because of left-sided postural atelectasis resulting from prolonged left lateral recumbency while anesthetized. Other false disease indicators related to postural atelectasis include (1) decreased lung volume implying atelectasis, (2) retraction of the caudal lobes from the chest wall simulating pleural fluid, and (3) a heart that appears to be raised off the sternum suggesting a pneumothorax.

Figure 23-4 • Close-up dorsoventral view of the thorax of a dyspneic rat shows an immense mass filling much of the thorax, making it appear as if the animal has a pair of hearts *(double heart sign)*. The lesion proved to be a cancerous tumor that originated in the cranial mediastinum. With respect to differential diagnosis, a primary lung tumor would have a similar appearance.

transient, lasting only a day or two, and often reflect little more than constipation. Cecal or cecocolic impaction is a concern (Figure 23-5), which can be more persistent, and may be associated with colic. Alternatively, abdominal distention can be an indicator of serious underlying disease such as intestinal blockage, liver disorder, cancer, or ascites.

Abdominal Tumors

Abdominal tumors may affect any organ, solid or hollow, in addition to the peritoneum. A peripherally situated abdominal tumor is sometimes visible from the exterior as a lump or distortion in the abdominal wall (Figure 23-6), but this is exceptional. Radiographic detection depends almost entirely on a combination of organ enlargement and/or disfigurement and to a lesser extent on displacement. Localized calcification is present infrequently, and although suggestive of malignancy, especially of the adrenal gland, offers no assurance of the existence of such a process (Figure 23-7).

Where a lump or subcutaneous mass is evident, a lead marker on the overlying skin usually proves helpful in establishing a radiographic relationship (Figure 23-8). Likewise, holding or otherwise securing a palpable mass while ultrasound is performed often speeds and simplifies the process of sonographic identification.

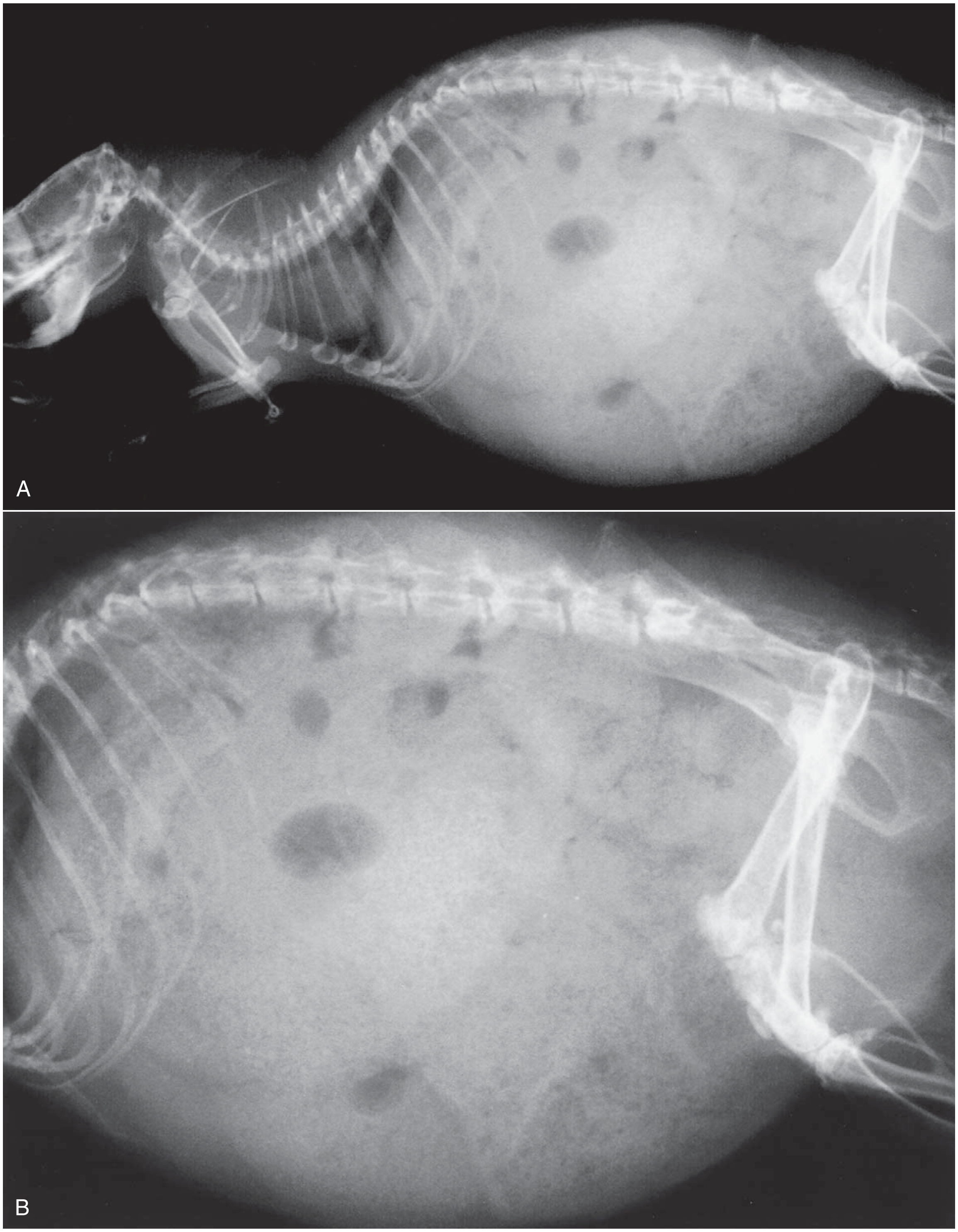

Figure 23-5 • A, Lateral, close-up lateral **(B),** dorsoventral **(C),** and close-up dorsoventral **(D)** views of the abdomen of a pet rat with intestinal impaction show the cecum and descending colon distended with high-density stool.

Continued

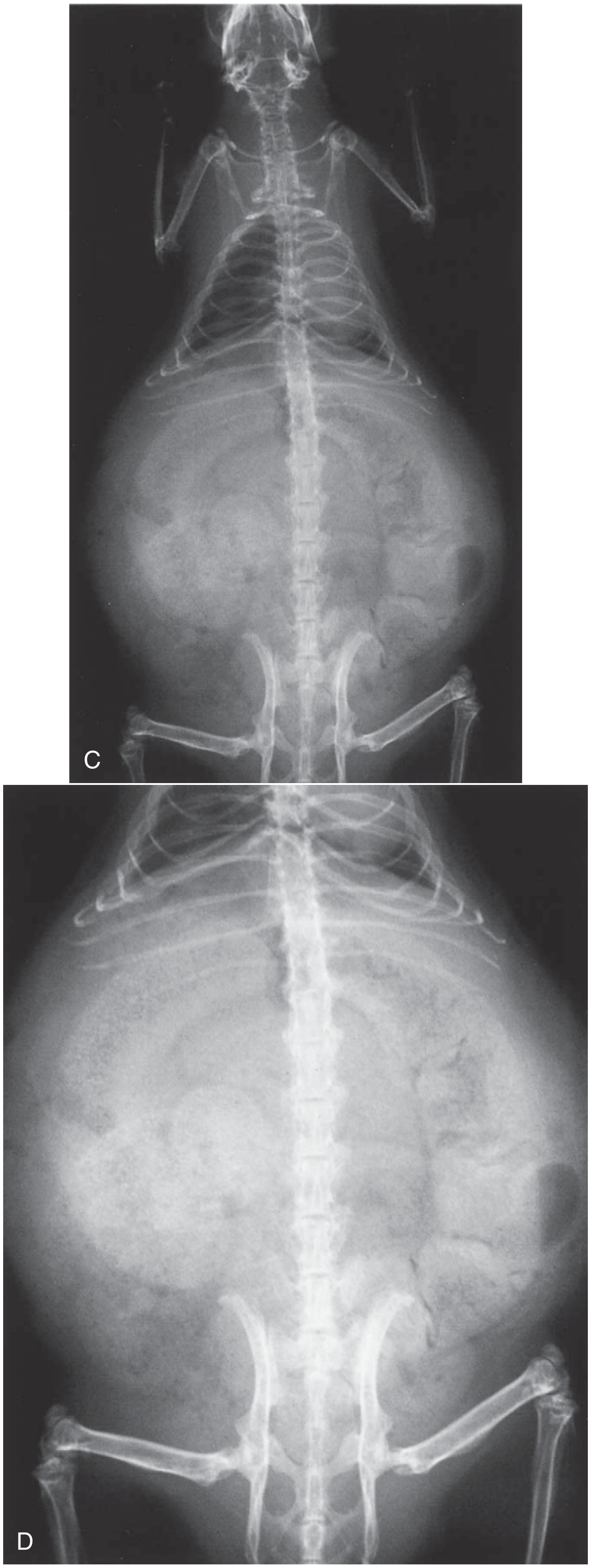

Figure 23-5, cont'd • For legend see p. 271.

Figure 23-6 • A hairless pet rat shown here in the dorsoventral position breathing an anesthetic gas before being imaged has a visible swelling over the left paralumbar fossa, subsequently confirmed as a malignant pararenal tumor.

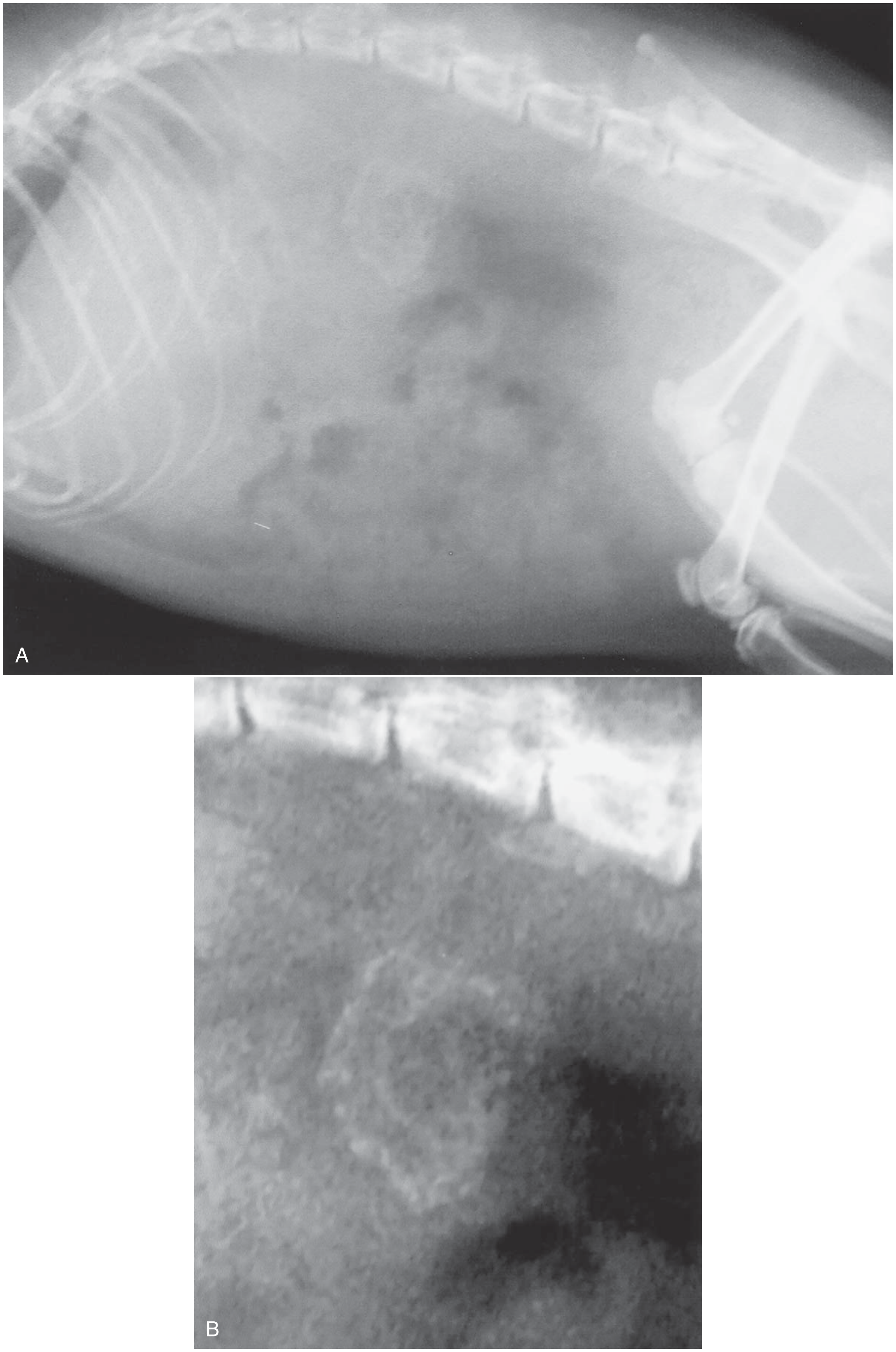

Figure 23-7 • A, Lateral and close-up lateral **(B)** views of the abdomen of a pet rat with a partially calcified mass suspected of being an adrenal tumor.

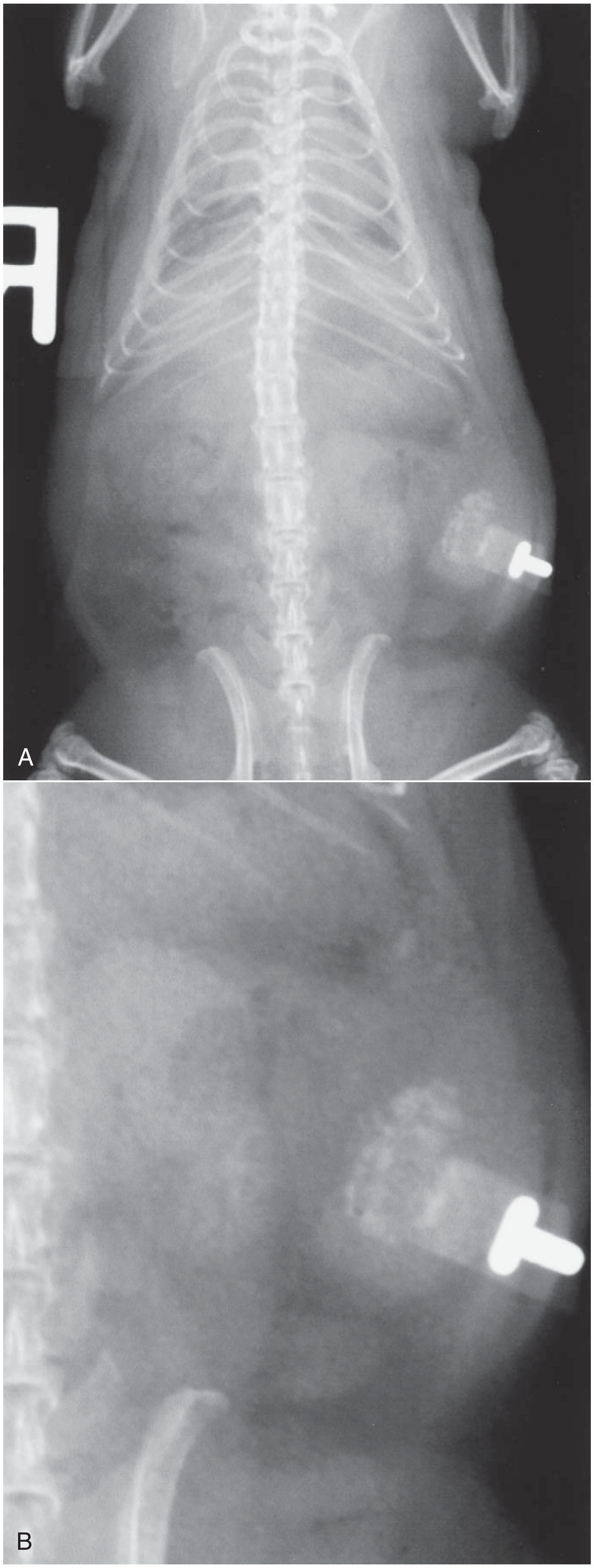

Figure 23-8 • A, Dorsoventral view of the torso and ultraclose dorsoventral projection of the left paralumbar fossa **(B)** show an oval-shaped area of calcification superimposed on the caudal half of the left kidney. A metallic marker *(T)* has been placed on the overlying skin surface to facilitate radiographic identification.

Chapter 24

Chinchillas, Degus, and Gophers

CHINCHILLAS

Radiography

Chinchillas, like guinea pigs, are extremely docile (Figure 24-1). Many can be radiographed with minimal restraint. More active animals can be easily imaged (Figure 24-2) after first receiving a small dose of anesthetic gas (Figure 24-3).

Normal Radiographic Anatomy

Radiographically, the chinchilla is distinguished by its enormous tympanic bullae (Figure 24-4), which are 4 to 5 times larger than other comparably sized rodents, such as the rat, hamster, and guinea pig. Chinchillas also possess large muscular hind limbs, which are more than twice as long as their forelimbs, and thus require more penetrating radiation to image adequately.

The radiographic visibility of the chinchilla's heart is generally better than that of the smaller pet rodents, such as mice, rats, and hamsters, especially the cranial border. As with most small rodents the chinchilla's heart appears relatively large compared with the size of its lung, falsely conveying the impression of enlargement (Figure 24-5).

When full, the digestive tract of the chinchilla is usually dominated by either the stomach or cecum (Figure 24-6). The ability to differentiate between these two possibilities can be diagnostically important, for example, with bloating. Chinchillas have a large, extensively haustrated colon, which a practiced eye can detect on plain films, but detection generally requires barium for any sort of detailed inspection. The important thing is not to mistake the wrinkled appearance of the normal colon for some sort of disease.

Injuries

Chinchillas, like other small rodents, are susceptible to injury by their owners. The most common of these is stepping on the chinchilla, which often results in one or more fractures (Figure 24-7).

DEGUS AND GOPHERS

We occasionally radiograph degus (Figure 24-8) and gophers (Figure 24-9) but have yet to accumulate a significant amount of clinical material, imaging or otherwise, to warrant even a superficial discussion of their ailments. However, it is worthwhile to show pictures of them, if for no more than recognition purposes.

Figure 24-1 • Chinchilla is briefly inspected by a veterinarian and student assistant before being masked down for radiography.

Figure 24-2 • Chinchilla being positioned for radiography prior to exposure.

Figure 24-3 • Chinchilla breathing anesthetic gas from a mask in preparation for radiography.

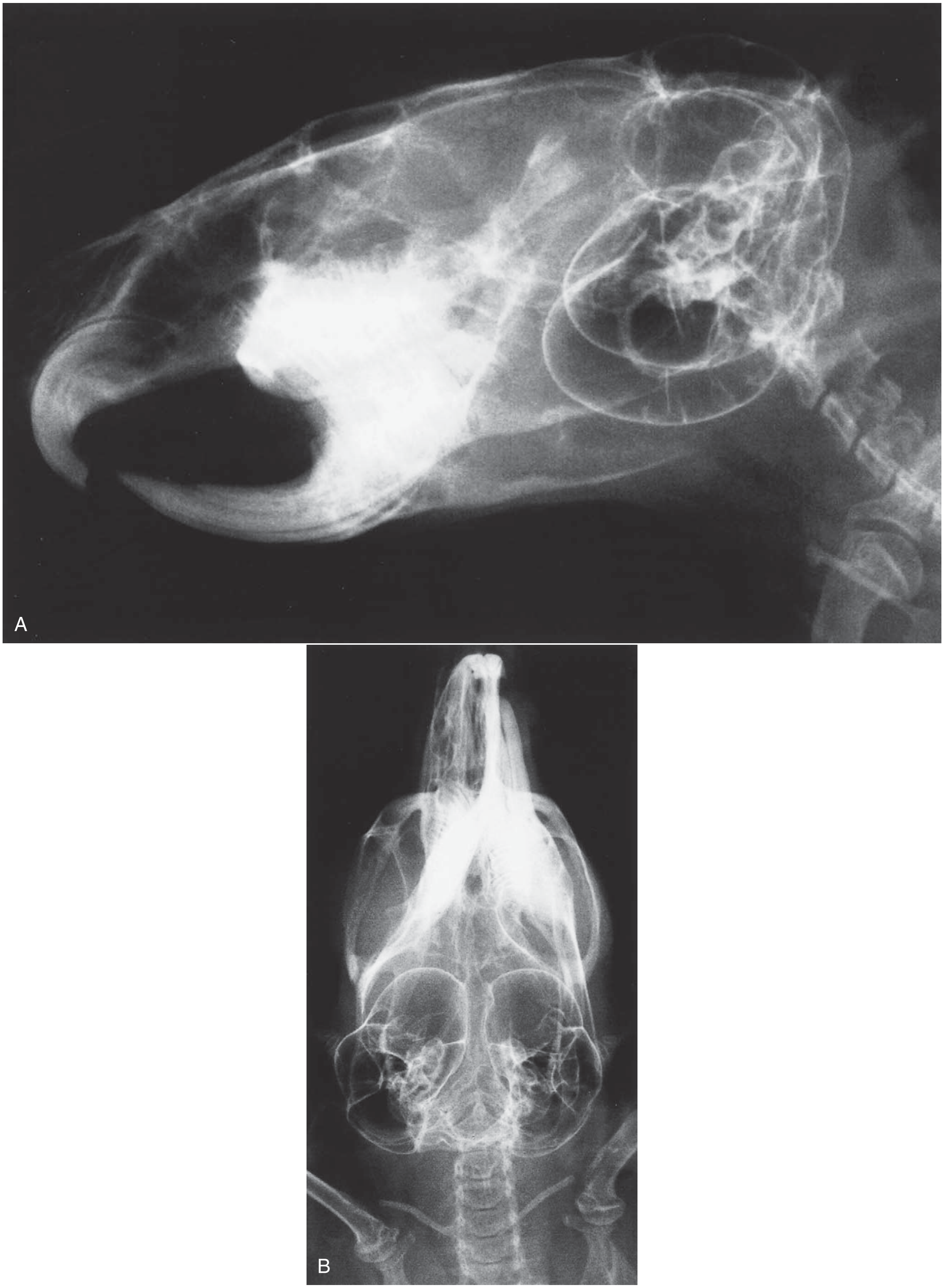

Figure 24-4 • A, Close-up lateral and dorsoventral **(B)** views of the skull of a chinchilla showing its extraordinarily large bullae.

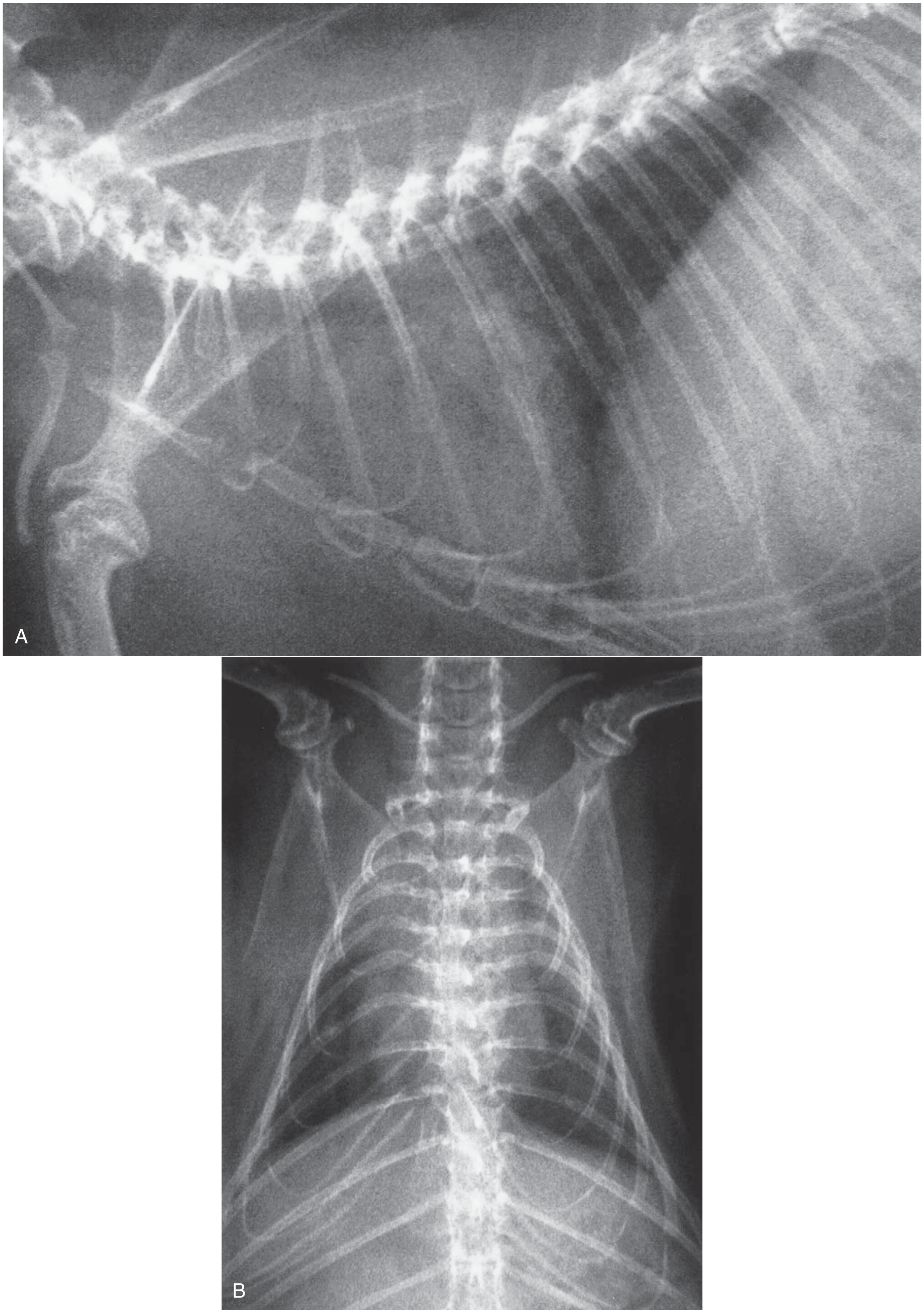

Figure 24-5 • A, Close-up lateral and dorsoventral **(B)** views of the thorax of a normal chinchilla. The apparently increased cardiothoracic ratio is normal in small rodents, including chinchillas.

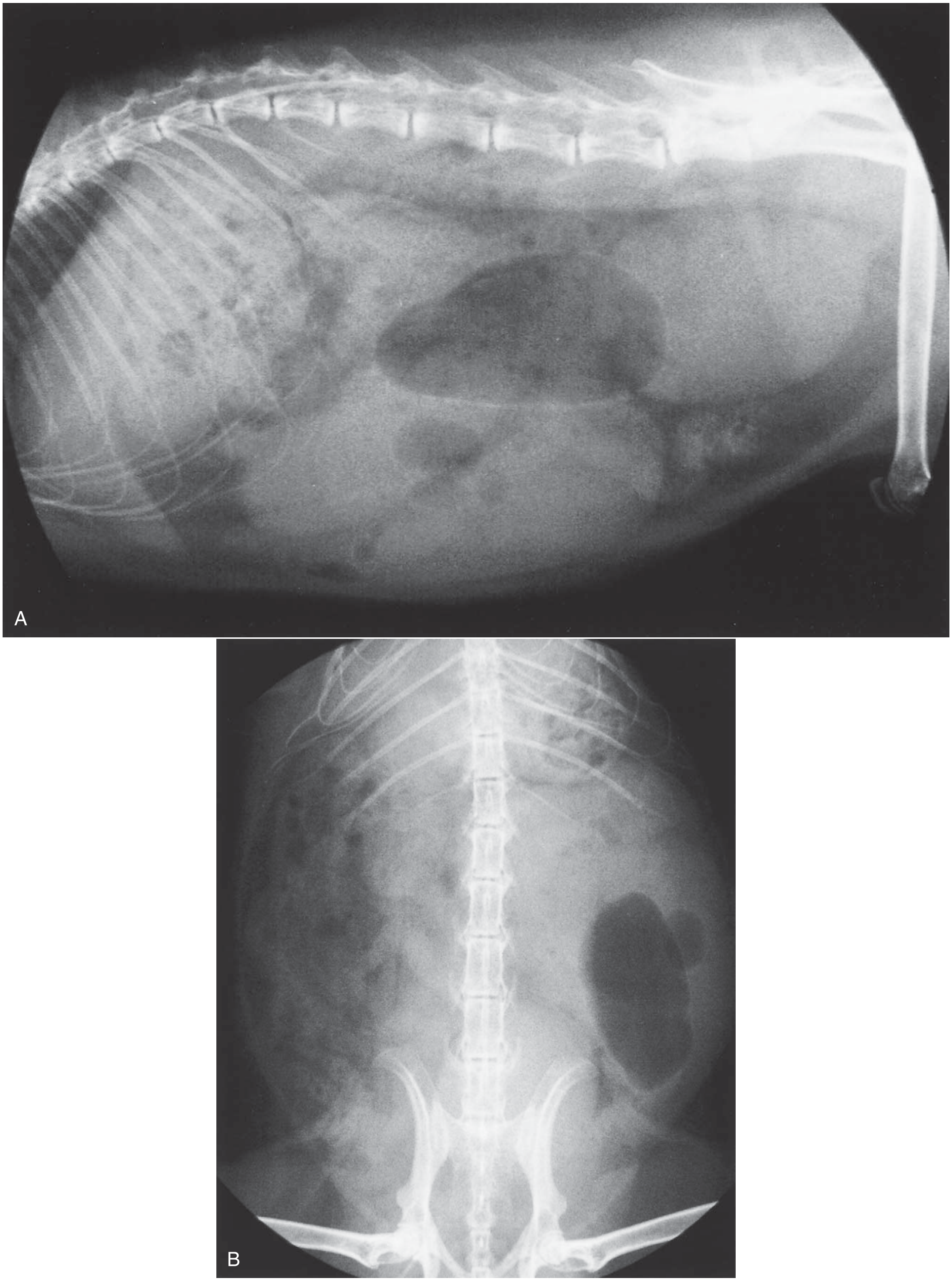

Figure 24-6 • A, Close-up lateral and dorsoventral **(B)** views of the abdomen, which is currently being dominated by the stool-filled cecum.

Figure 24-7 • Dorsoventral view of the midforelimbs and distal forelimbs of a chinchilla that was recently stepped on by its owner, breaking the distal radius and ulna bilaterally.

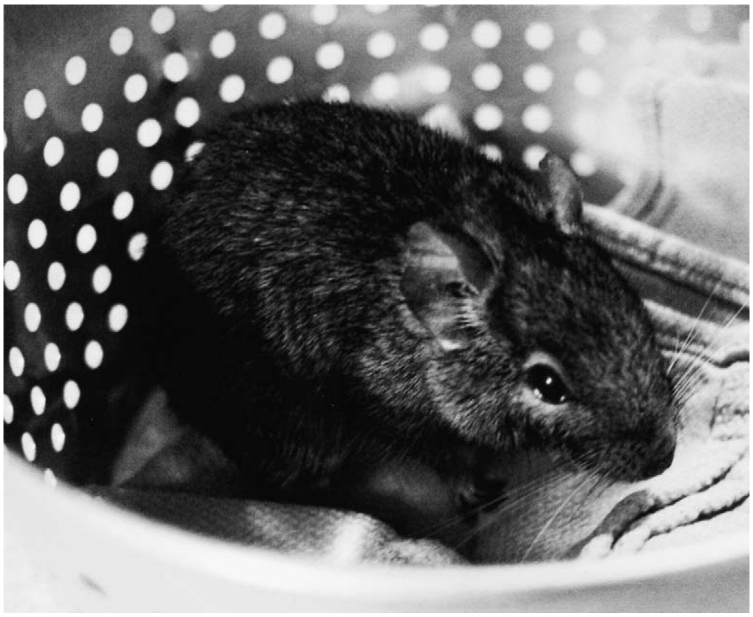

Figure 24-8 • A degu crouches in its cage awaiting being radiographed.

Figure 24-9 • A sedated gopher (Richardson's ground squirrel) being adjusted on an x-ray cassette before imaging.

Chapter 25

Hedgehogs

Hedgehogs are unique among mammalian cage pets in two principal ways: (1) the dorsal half of their body is covered by a thick coat of long protective spines (Figure 25-1), and (2) when threatened, hedgehogs roll into a tight ball, exposing nothing but their formidable spines (Figure 25-2).

By comparison, the ventral half of the hedgehog body is only covered by a short coat of hair and is spineless. When viewed from the underside, a hedgehog is nearly unrecognizable (Figure 25-3).

RADIOGRAPHY

Nonchemical, Nongas Restraint

As with most small mammalian cage pets, hedgehogs can be radiographed with or without chemical or gas restraint. When poor condition, illness, or injury make anesthesia unacceptably risky, hedgehogs can be radiographed without direct manual restraint by placing them in an adjustable corral constructed of individual foam panels (Figure 25-4). A wooden spatula, which is radiographically transparent, is used to keep the animal still during the exposure (Figure 25-5). By moving the x-ray tube from its usual vertical position into a horizontal, cross-table position, it is possible to obtain both dorsoventral and lateral projections without moving the animal.

Gas Anesthesia

Alternatively, an anesthetic gas administered by mask is used to restrain a hedgehog while it is being radiographed (Figure 25-6). Typically, the animal arrives in radiology fully conscious, is masked down, radiographed, and then recovers while still in radiology. The entire process can often be done within 10 minutes.

NORMAL RADIOGRAPHIC ANATOMY

The skull and teeth of a hedgehog differ decidedly (Figure 25-7) from those of the preceding small mammals because the hedgehog is an insectivore (insect eater) while the others are Rodentia, or gnawing mammals.

The torso of a hedgehog is encased by a thick layer of fat, especially before beginning hibernation. This, along with their diminutive size, can make assessment of the thoracic interior quite difficult, with respect to evaluating the size and shape of the heart and evaluating the lung for abnormal density (Figure 25-8). Radiographic diagnosis is further compromised when the limbs are superimposed on the torso as they are in the lateral projection made with a horizontally directed x-ray beam (Figure 25-9).

INJURIES

Injuries sustained by hedgehogs are comparable to those that occur to other small mammalian cage pets, for example, bruises, cuts, fractures, sprains, and dislocations. Crush injuries, especially those to the chest, often prove fatal. Deep bite wounds to the head, throat, and neck are capable of causing very serious injuries and death caused by blood loss and resulting shock. A sudden, large volume pneumothorax is extremely difficult to treat and hard to effectively monitor.

ABDOMINAL DISEASE: A DIAGNOSTIC STRATEGY

Perhaps the single most effective strategy for diagnosing abdominal disease in small mammals such as hedgehogs is assessment of the *bowel distribution*

Text continued on p. 288.

Figure 25-1 • Undisturbed hedgehog seen from above shows its smallish head and protective spiny coat.

Figure 25-2 • Hedgehog seen from above withdraws its head and begins to assume its characteristic protective position in response to being handled.

Figure 25-3 • Unconscious hedgehog is held upright, exposing its unprotected, conventionally haired abdomen.

Figure 25-4 • Fully conscious hedgehog is placed in a snugly fitted, foam panel corral before being radiographed.

Figure 25-5 • After placement, the hedgehog is secured by a wooden paddle, and the cassette is positioned for a cross-table, whole-body radiograph.

Figure 25-6 • A hedgehog is masked down before being radiographed.

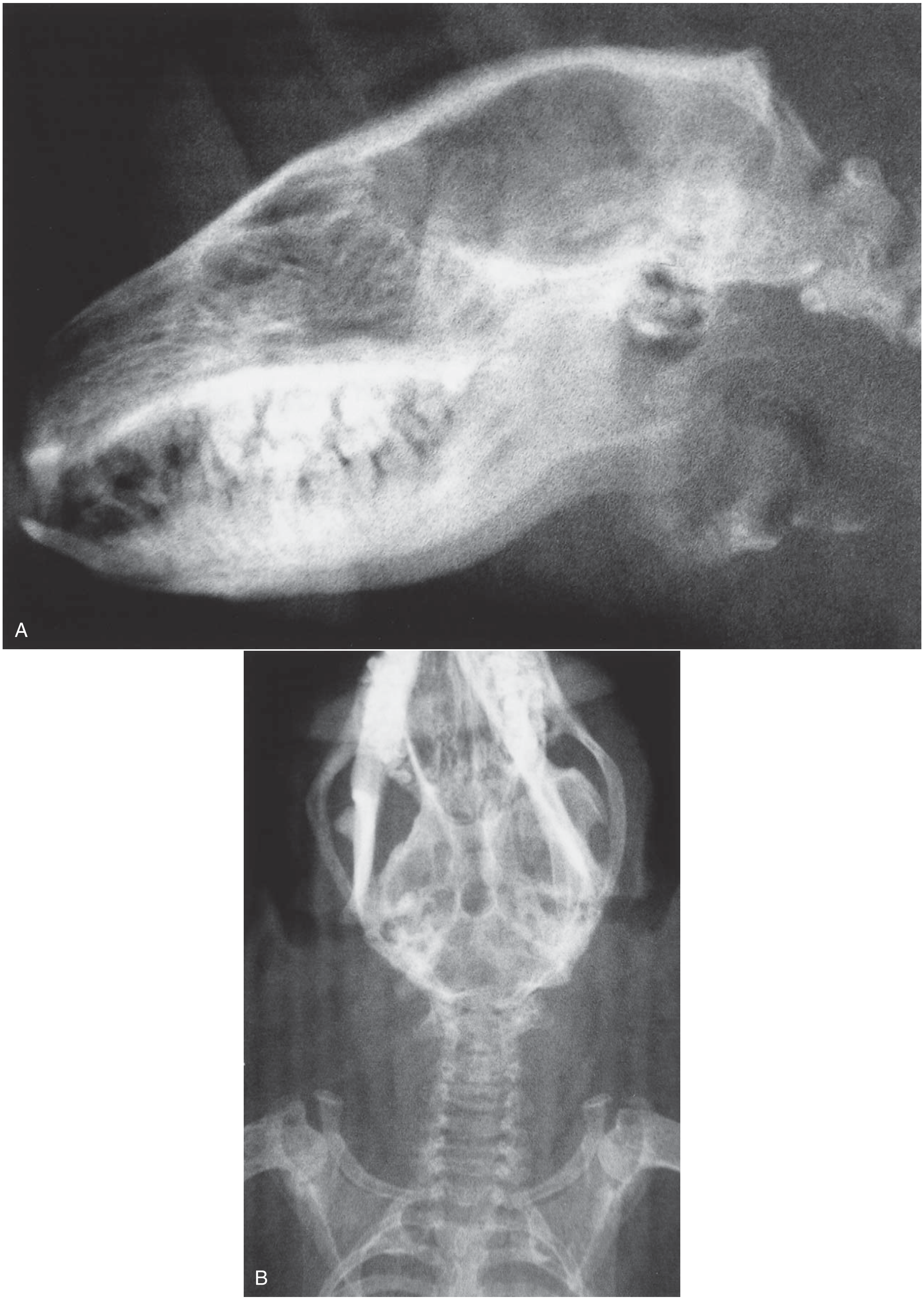

Figure 25-7 • Unlike the made-for-gnawing, tonglike incisors of rats, hamsters, guinea pigs, and other mammals, the teeth and jaws of hedgehogs are likely to appear more familiar to veterinarians because of their loose resemblance to those of a dog or cat as shown in close-up lateral **(A)** and dorsoventral **(B)** radiographs. Note the well-developed, inverted clavicular arch seen in the dorsoventral projection.

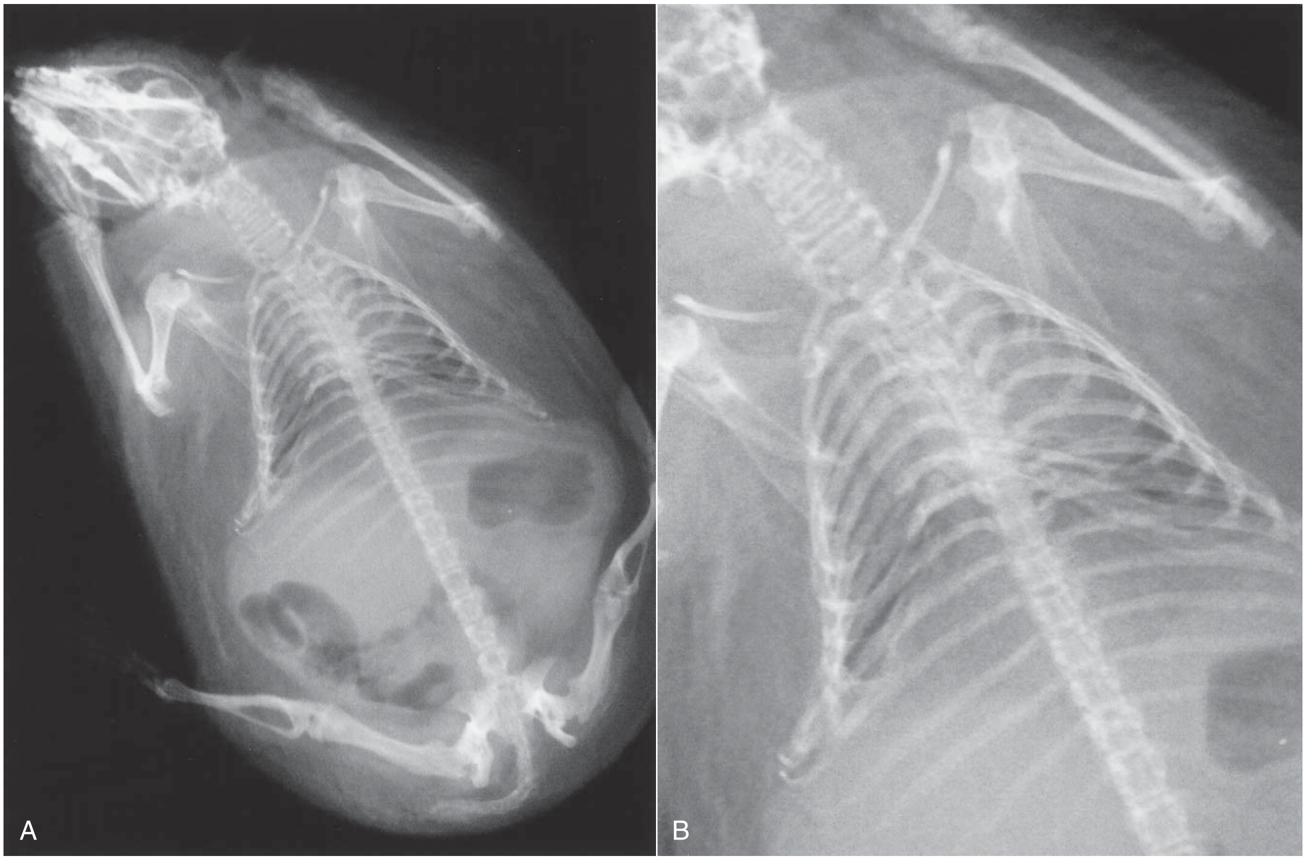

Figure 25-8 • Made almost invisible by a combination of a thick cloak of perithoracic fat and a poorly contrasting lung, the heart of this hedgehog is identifiable more by default than by definition as shown in orientation **(A)** and close-up **(B)** dorsoventral views.

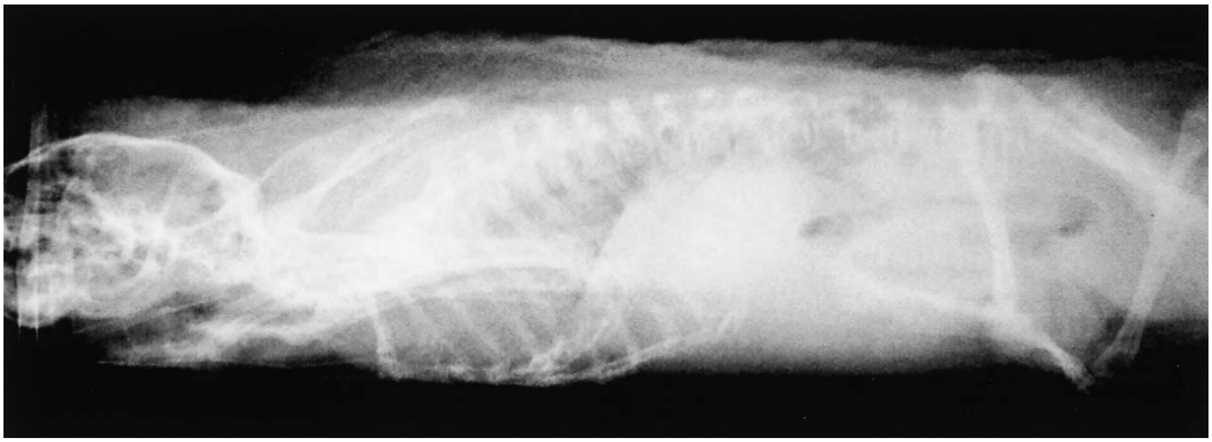

Figure 25-9 • Whole-body view of a fully conscious hedgehog, positioned in a foam panel enclosure and using a horizontal x-ray beam, illustrates the visual limitations caused by limb superimposition on the torso.

pattern. This method works as follows: because the stomach and portions of the bowel usually contain air, they are among the most visible of the abdominal organs. Although the positions of the various parts of the gastrointestinal tract are subject to change according to their content and surroundings, for example, an enlarged bladder will force the bowel mass cranially or a full stomach will force it caudally, they are generally distributed in an equitable fashion.

Therefore, if most of the intestine is found predominantly on one side or the other of the abdomen, the diagnostic implication is that something must be forcing it in that direction, for example, a mass. Likewise, if the stomach or bowel is displaced dorsally, then a ventrally situated mass becomes a distinct possibility; however, if the bowel mass appears ventrally displaced, then a dorsally located source warrants consideration.

Once a region of interest has been identified, based on an abnormal bowel distribution pattern, the organ or organs normally found in this location become the prime diagnostic suspects. Figures 25-10 through 25-12 illustrate this strategy.

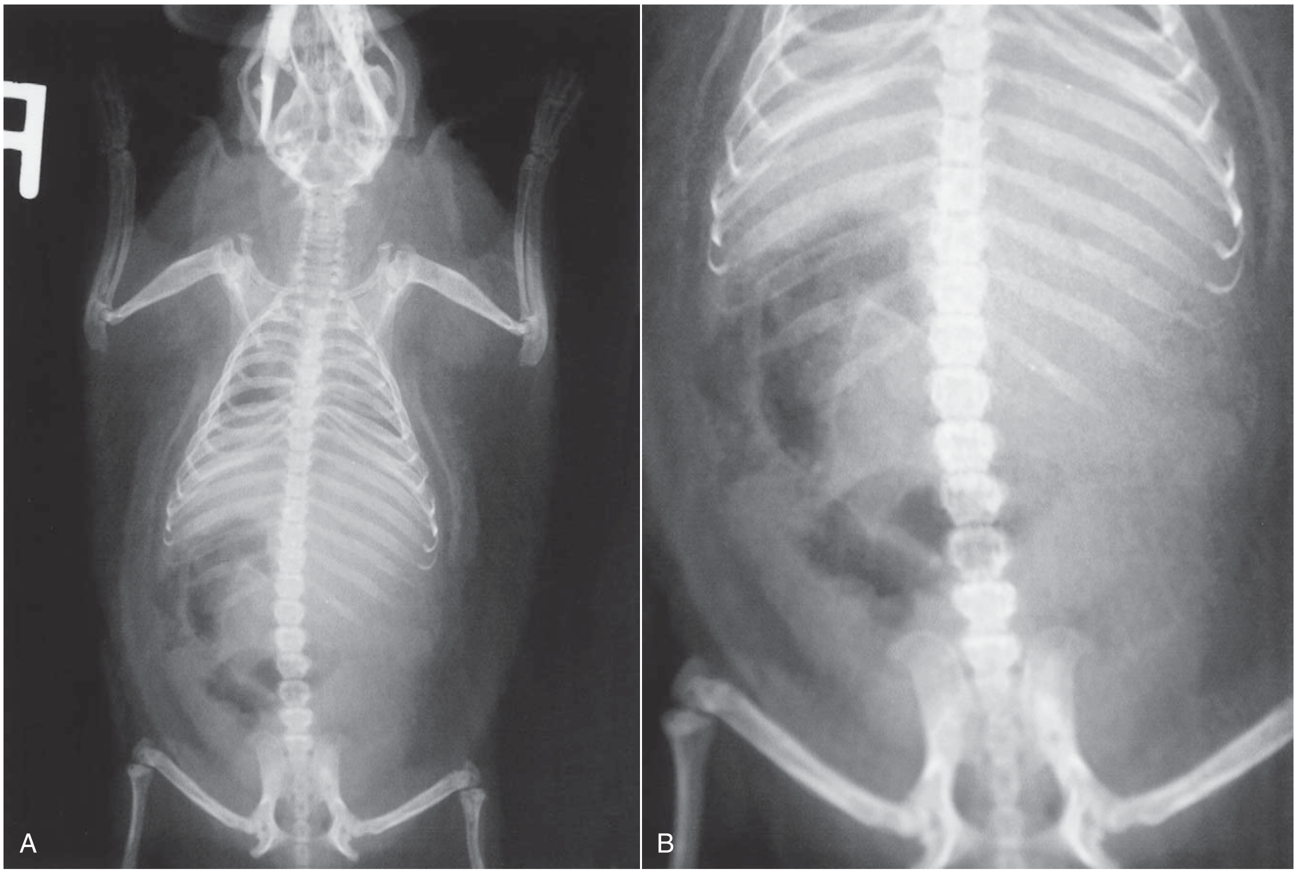

Figure 25-10 • A, Whole-body and close-up **(B)** dorsoventral abdominal views of a sick hedgehog show an abnormal bowel distribution pattern. Most of the identifiable gas-filled bowel is situated in the right half of the abdomen, suggesting a left-sided mass or mass effect.

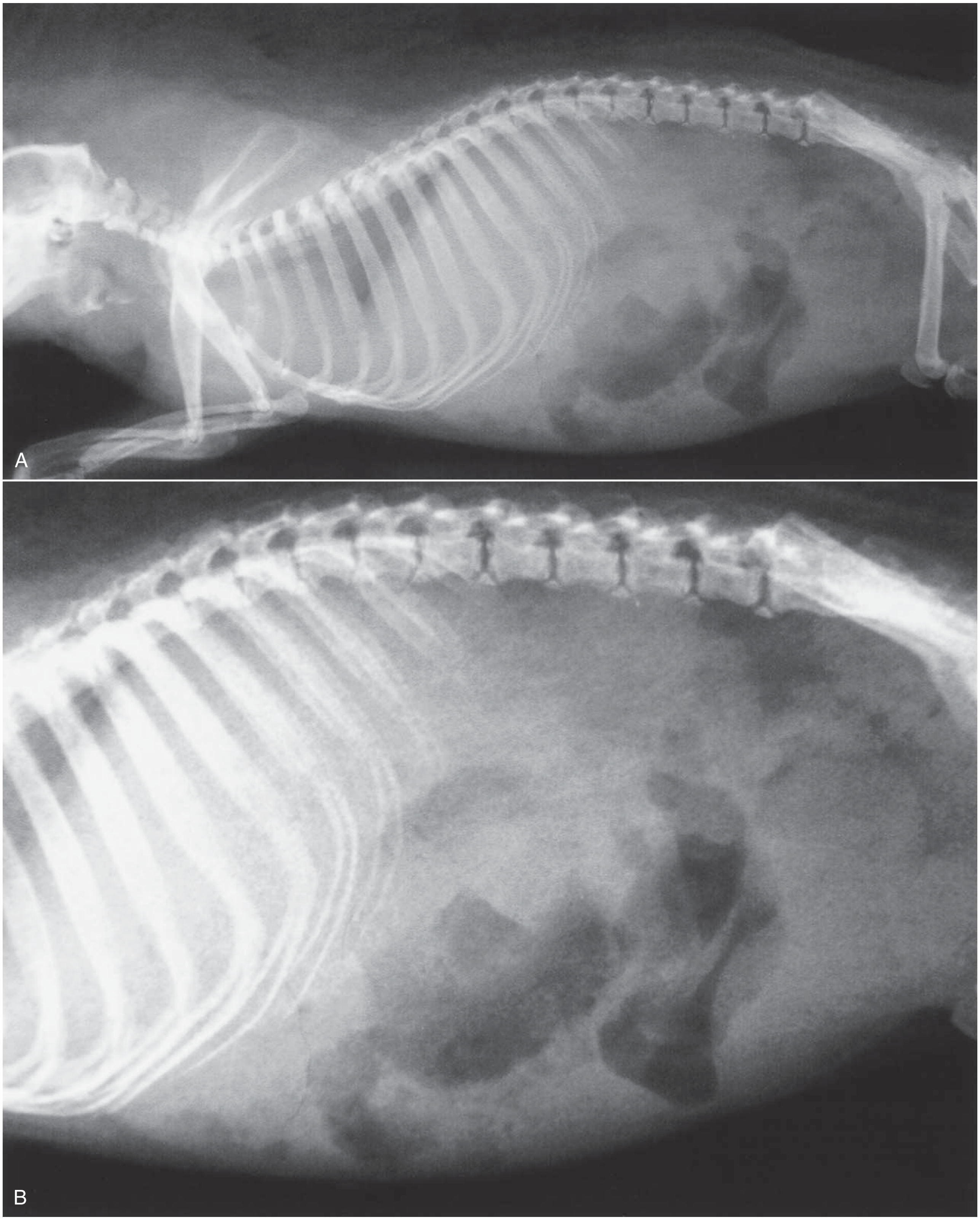

Figure 25-11 • A, Whole-body and close-up **(B)** lateral abdominal projections of a sick hedgehog show an abnormal bowel distribution pattern with most of the identifiable gas-filled bowel situated abnormally in the ventral half of the abdomen, which along with the previous images shown in Figure 25-10 suggest a left-sided, caudal ventral abdominal mass or mass effect—in this instance, an infected uterus.

Figure 25-12 • Close-up, caudal abdominal sonogram shows an enlarged, pus-filled uterus just above the urinary bladder.

C h a p t e r 26

Rabbits

Rabbits are docile creatures that make excellent, albeit sometimes short-lived, pets (Figure 26-1). Regrettably, many bunnies given to young children at Easter fail to reach their first birthdays. These pets become ill and eventually succumb to respiratory pasteurellosis, a disease related to many factors, including inadequate nutrition, overcrowded housing, and stress-related marketing practices.

RADIOGRAPHY

Most pet rabbits can be radiographed or viewed by ultrasound without chemical or gas restraint (Figure 26-2). Specialized, ported-lead mitts are ideally suited for manually restraining rabbits (Figure 26-3), although their protective flaps may inadvertently conceal portions of the desired field (Figure 26-4). However, force must be avoided when restraining sick rabbits, especially those with respiratory disease, because they are prone to cardiopulmonary arrest.

On the subject of restraining *pet* rabbits, I should point out that in over 30 years, I have never seen a rabbit injure itself while being transported to or from the Radiology Department, or during radiography. When I first began my career, I was warned repeatedly that the force of a rabbit's kick, while trying to escape the grip of the radiographer, for example, may be sufficient to break the animal's back, something I still have yet to witness. We handle most sick and injured rabbits as shown in Figure 26-5, which not only controls them but also relaxes the animal and makes it feel relatively secure.

NORMAL RADIOGRAPHIC ANATOMY

Skull

The skull of a rabbit resembles a somewhat asymmetrical egg (Figure 26-6). The upper incisors are long and curved, whereas the lower incisors are shoveled. The interdental spaces are quite large and together form a sizable gap between the jaws. The nasal cavity is voluminous and contains an elaborate system of conchae. The caudal half of the mandible is very large, extending well below the cranial portion. There are five upper and five lower cheek teeth, featuring lengthy and complex root systems.

The long and distinctive ears of rabbits can appear quite clearly on a skull radiograph (Figure 26-7), depending on the radiographic technique and the manner in which the animal is being positioned. When a cranial, facial, or jaw fracture is strongly suspected, it may appear in the form of a superimposed ear shadow.

Hips (Coxal Joints)

Immature Hip. The hips of an immature rabbit differ decidedly from those of dogs and cats, animals with which most veterinarians are most familiar. Specifically, the unfused femoral head of an immature rabbit appears to consist of two distinct elliptical pieces (Figure 26-8), instead of the single, hemispherical epiphysis found in companion animals. But in reality, the femoral head of a rabbit develops from only a single ossification center and only appears bipartite

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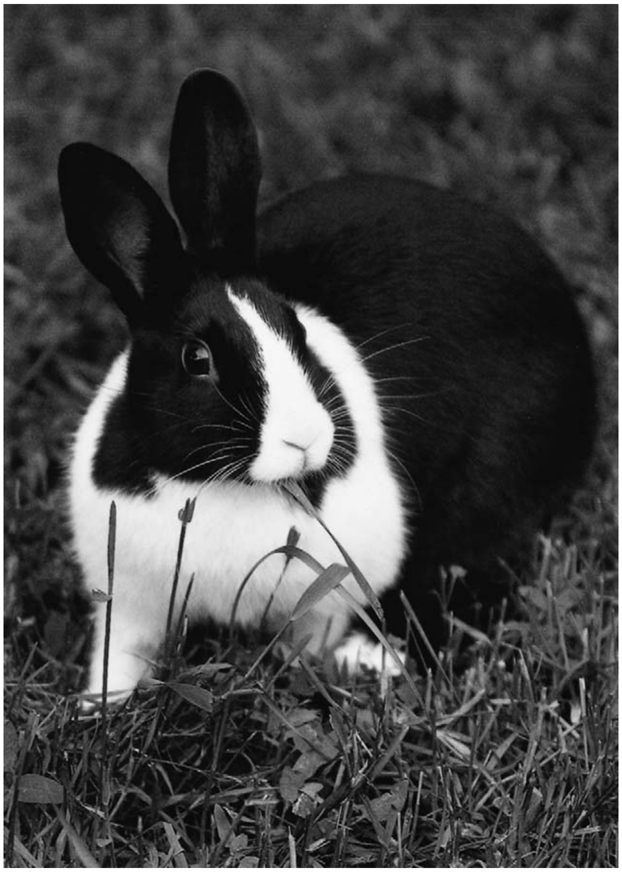

Figure 26-1 • "Princess Perfect," a bunny given to my neighbor's daughter as an Easter gift, explores my backyard after escaping from its enclosure.

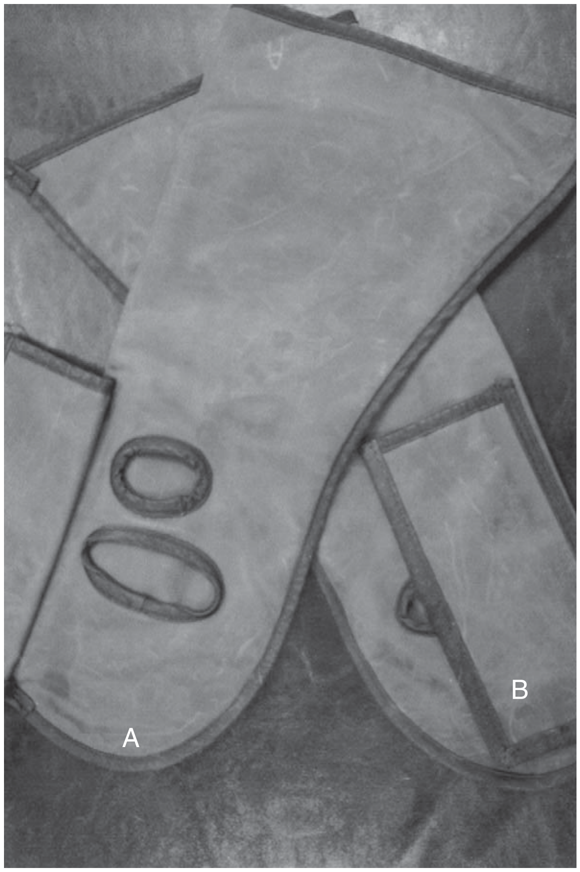

Figure 26-3 • Specialized, ported-lead mitts, shown in the open **(A)** and closed **(B)** positions, which are ideally suited for manually restraining rabbits when radiographed.

Figure 26-2 • Rabbit manually restrained for lateral thoracic radiograph.

Figure 26-4 • Whole body, ventrodorsal view of a rabbit in which portions of the cranial thorax have been inadvertently covered up by the flaps of the leaded gloves worn by the radiographer.

Figure 26-5 • Student radiographer secures and comforts an injured rabbit before a radiograph is made.

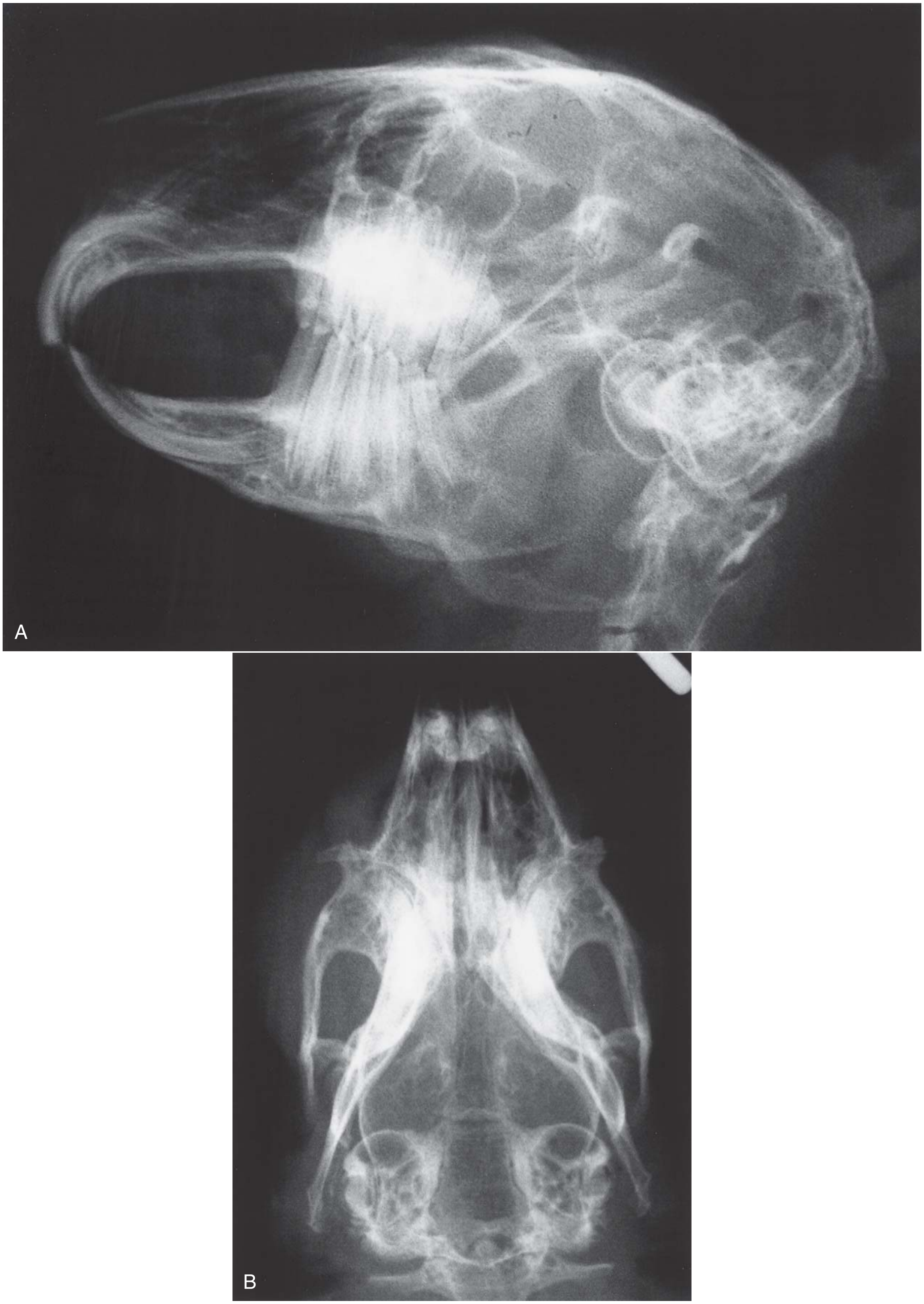

Figure 26-6 • A, Close-up lateral and ventrodorsal **(B)** views of a rabbit skull are characterized by the tonglike rostral facial region, the teeth centrally, and the cranium, bullae, and massive mandibular rami caudally.

Figure 26-7 • The ears of a rabbit, or more specifically their skinfolds and associated auricular cartilages, may mimic fractures when superimposed on the cranium, face, or jaws.

Figure 26-8 • Coxal joints of an immature rabbit show centrally peaked, proximal femoral growth plates that, along with deep femoral fossae, create the illusion of a bipartite femoral head. Note the open growth plate traversing the central acetabulum.

because of its undulant growth plate and deeply indented femoral fossa (Figure 26-9). The point is that this normal morphological variant must not be mistaken for a femoral head fracture.

Mature Hip. Generally, the hips of rabbits are deeply set in their sockets, an appearance accentuated by a large overhanging cranial acetabular lip, as seen in ventrodorsal (VD) projections (Figure 26-10). Because it is relatively easy to manipulate the hind limbs of a rabbit during radiography, overrotation often occurs, making it appear as if the femurs are bowed medially, a phenomenon termed *projectional curvature* (Figure 26-11).

Thorax

Immature Thorax. The immature rabbit thorax is characterized by an extremely wide cranial mediastinum, due in large part to the thymus (Figure 26-12). This normal organ and the fat that surrounds it must not be mistaken for a tumor such as a thymoma.

Mature Thorax. The thorax of a mature rabbit, especially a pet, is characterized by reduced contrast, which is most often the result of perithoracic fat combined with expiratory filming (Figure 26-13). This normal appearance may be misinterpreted as representing interstitial lung disease, which of course it is not. The cranial and precardiac portions of the mediastinum are usually vague in appearance, the result of localized fat

Figure 26-9 • Ultraclose view of the normal left hip of an immature rabbit.

Figure 26-10 • Close-up view of normal hips in a mature rabbit.

Figure 26-11 • Ventrodorsal view of the pelvis and hips of a normal rabbit shows apparent curvature of both femurs caused by excessive inward rotation of the limbs during radiography, indicated by the medial position of the patellas.

deposition and a pronounced relative narrowing of the thoracic inlet. I regularly receive such images with inquiries as to whether or not a cranial mediastinal mass is present, occasionally accompanied by fine-needle aspirates composed of fat.

Abdomen

The three principal influences on the radiographic appearance of a rabbit's abdomen are: (1) the stomach and its content (food, fluid, and gas), (2) the cecum and whether it is full or empty, and (3) the amount of intraabdominal fat and to a lesser extent, the amount of extraabdominal fat.

▮▮▮ FRACTURES AND OTHER INJURIES

Facial Injuries

Facial injuries in rabbits are largely confined to bruises, scrapes, and minor lacerations (Figure 26-14). Most serious crushing-type fractures prove fatal, either initially caused by shock and blood loss or a subsequent infection.

Extremital Fractures and Dislocations

Extremital fractures are usually the result of being stepped on, caught in a door, or some other form of momentary entrapment. Dislocations, with or without associated fracture, occur most often to the digits, usually as a result of catching a nail, for example, in its enclosure (Figure 26-15).

Pelvic Fractures

Pelvic fractures are typically caused by crush injuries such as a child falling or jumping on the pet rabbit. Such fractures usually occur in groups and often disrupt the weight-bearing ring, making it painful to stand and impossible to hop (Figure 26-16). These latter signs may be mistaken for a spinal cord injury.

When radiographing the pelvis of a rabbit (or any animal), the extended VD position is extremely painful because of related fragment distraction. Much of the pain associated with x-raying pelvic fractures can be reduced by placing the animal on a medium-density foam pad and by *not fully extending* the legs.

Osteoarthritis

Arthritis is caused either by excessive or abnormal joint motion, for example, an untreated or unsuccessfully treated third-degree sprain of the genual joint (Figure 26-17), or by developmental or acquired diseases leading to joint incongruity, as often results from hip dysplasia, osteochondritis, or an articular fracture.

▮▮▮ CHEST TRAUMA

Severe chest wall injury may or may not be heralded by swelling, puncture, or laceration. Large rents in the skin are usually accompanied by superficial and deep subcutaneous emphysema. If gas is felt beneath *intact* skin, then penetrating throat and neck injuries or the possibility of a pneumothorax should be suspected. If one or more displaced rib fractures are present, the *probability* of a pneumothorax or hemothorax becomes considerably greater, as does that of a diaphragmatic hernia.

Serious interior thoracic injuries are often accompanied by bleeding. Likewise, most diaphragmatic hernias lead to variable volumes of pleural fluid, usually a transudate resulting from abdominal organ displacement and related venous compression. When medium or large volumes of pleural fluid are present, the diaphragm, or more accurately the pulmonary-hepatic interface, is often obscure. Thus it is impossible to determine whether it is intact.

In such situations, I advise waiting for the fluid to be reabsorbed and then rechecking the diaphragm in a subsequent radiograph. In the event there is an

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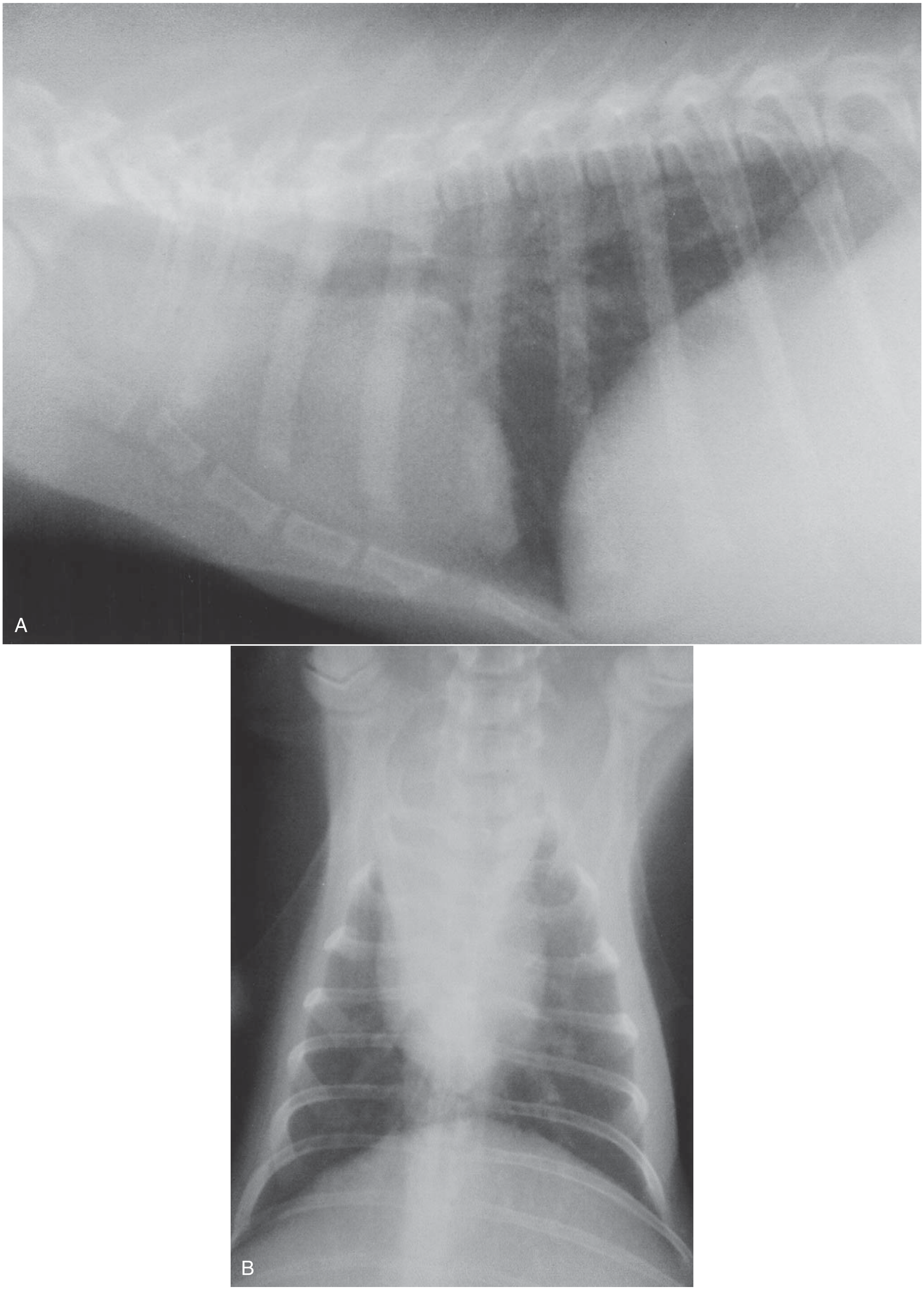

Figure 26-12 • A, Lateral and ventrodorsal **(B)** views of the thorax of a healthy 4-month-old rabbit. Note how the thymus and associated fat create a cranial mediastinal mass effect.

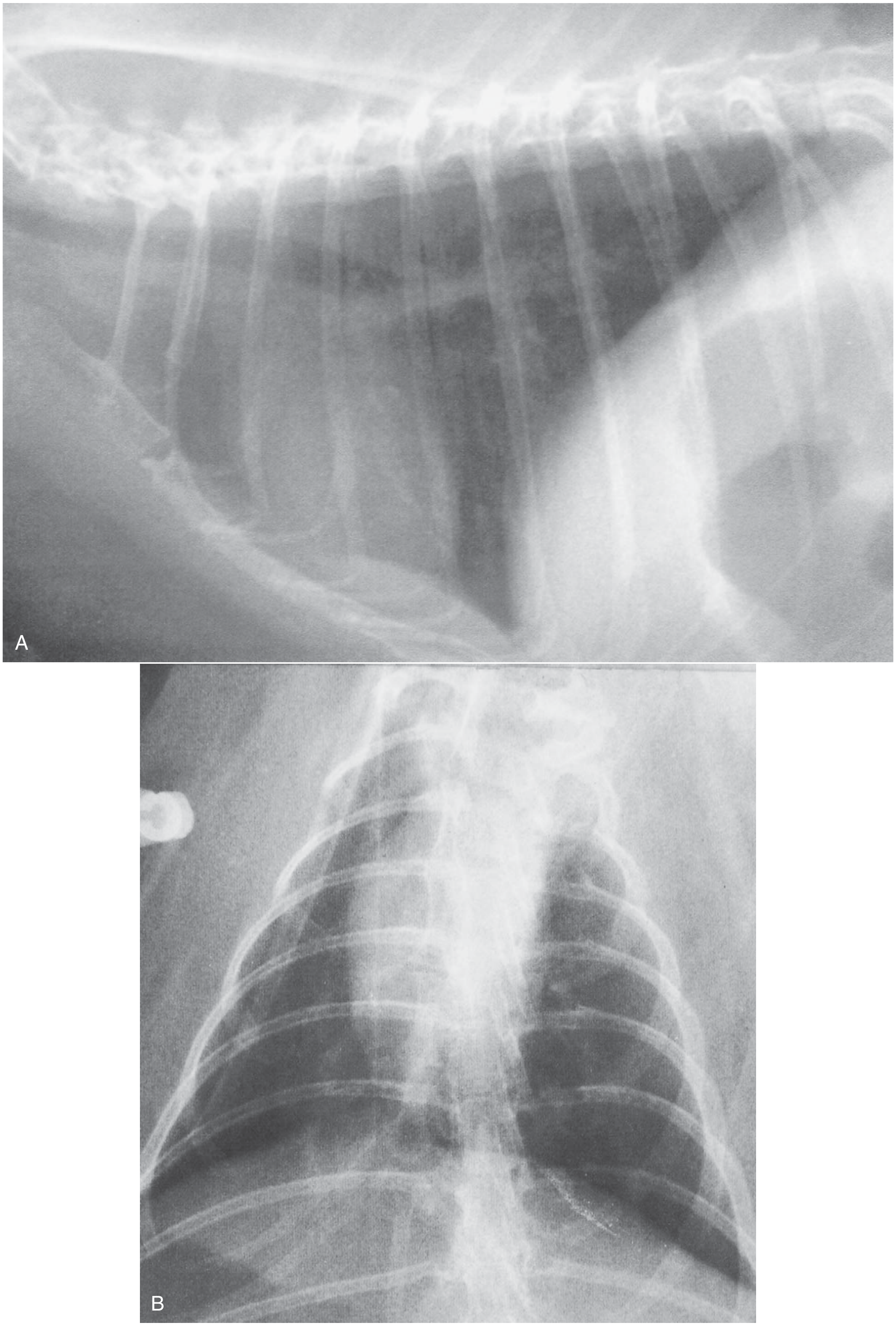

Figure 26-13 • A, Lateral and ventrodorsal **(B)** images of the thorax of a healthy adult rabbit show how perithoracic fat degrades both contrast and detail, mimicking interstitial lung disease such as pneumonia. Note how fat in the cranial mediastinum (a regular finding in pet rabbits) might be mistaken for a mediastinal mass by the inexperienced.

Figure 26-14 • Close-up view of the face of a recently mauled rabbit resembles a prize fighter after a hard bout: the left eye is swollen nearly shut, the bridge of the nose is scraped and puffy, and there is a cut nearby.

Figure 26-15 • Dorsoplantar view of the left hind paw of a rabbit shows a badly dislocated distal interphalangeal joint on the fifth digit.

Figure 26-16 • A, Orientation and close-up **(B)** partially flexed ventrodorsal views of a rabbit with multiple pelvic fractures: (1) left ilial neck and sacrum; (2) central pubis; (3) central, right, and left interior ischium. As a consequence of these fractures, the weight-bearing ring of the pelvis has been disrupted at multiple points, making standing or squatting painful and hopping impossible.

Figure 26-17 • A, Close-up lateral and craniocaudal **(B)** views of the arthritic right stifle of a rabbit that suffered a fracture-dislocation years earlier. Chronic-appearing bone deposition is seen over much of the surface of the distal femur, especially the medial trochlear ridge, including the adjacent soft tissue. The patella has undergone extensive remodeling, and there is a presumed enthesophyte embedded in the interior of the quadriceps tendon at its insertion on the base of the tibial tuberosity. **C,** Comparable lateral and craniocaudal **(D)** views of the normal opposite stifle are provided for comparison.

immediate need to know, a chest drain may be used to remove the fluid and the rabbit radiographed again. Postural radiography can be used under such circumstances; specifically, a lateral projection, using a horizontal x-ray beam, with the hind quarters elevated to move the fluid to the cranial portion of the chest cavity may result in better visualization of the diaphragm.

Occasionally, one or more large cranial vessels are ruptured and spill their contents in the mediastinal space. Confined by the interior pleura, the loculated blood behaves like a mass, displacing the heart caudally and potentially compressing the trachea (Figure 26-18).

INFECTIONS

Middle Ear, Facial, and Jaw Infections

Rarely, chronic middle ear infections can lead to bone formation in the normally air-filled bullae, in some instances completely opacifying the chamber. One or both ears may be affected (Figure 26-19). If both ears are affected, the heightened density may be judged normal because it is present on both sides. Thus the value of a normal comparison radiograph becomes obvious.

Occasionally, middle ear infections may spread from their point (or points) of origin to other parts of the head, such as the face and jaw, and as in the previous case, lead to large deposits of extensively mineralized tissue (Figure 26-20).

Clearly, both of these cases are not just obviously abnormal, they are visually spectacular. Although the viewer may not know the precise cause (or causes) of these changes, it is blatantly clear that the bullae are not normal. However, it is important to recognize that these are exceptional radiographic findings. The vast majority of rabbits with middle ear infections appear entirely normal: no wall thickening, no increased chamber density, and no mineralization. The radiographic reality is that most infected bullae, even those infected for months or even years, appear entirely normal when radiographed.

Lung Abscesses

Rabbits can develop some enormous lung abscesses, often the result of a chronic Pasteurella pneumonia. Some of these are solid, and others are cavitated, sometimes extensively. A typical lung abscess involves most or all of a single lung lobe, usually increasing its volume in the process. Those that involve the cranial or middle lobes typically displace the heart and trachea to the opposite side of the chest (Figure 26-21). Caudal lobe abscesses typically form *silhouette signs* (organ overlap) with the adjacent heart and diaphragm, as well as causing bronchial displacement (Figure 26-22). Affected rabbits often do not appear that ill.

Tumors

Lung Tumors. In the advanced stages of development when individual tumors are coalescing with their neighbors, it can be difficult or impossible to differentiate any individual lesions. Instead, the lung appears consolidated, much as it might with a severe pneumonia or abscess (Figure 26-23).

Abdominal Tumors. As with many secondary lung tumors, abdominal tumors are often associated with large volume transudates, which swell the abdomen, displace organs, and generally obscure the visceral content as shown in Figure 26-23. In such situations, ultrasound often reveals what is otherwise hidden in radiographs (Figure 26-24).

Some abdominal tumors, for example, uterine carcinomas, may become mineralized, making their radiographic detection quite straightforward (Figure 26-25).

Common Abdominal Disorders

The Normal Rabbit Abdomen. The principal influences on the appearance of the *normal* rabbit abdomen are (1) the amount of peritoneal fat and (2) the volume of air in the gastrointestinal tract. A large amount of fat can substantially degrade abdominal detail, often leading to the misimpression of peritoneal fluid. The visceral displacement caused by large abdominal fat accumulations *(fat depots)* can be particularly deceptive, creating the illusion of a mass, called a *mass effect*.

Fat Depots. Abdominal fat depots are situated beneath and behind the liver (sometimes referred to as falciform fat), around both kidneys, and about the urinary bladder. In a female, substantial amounts of fat surround the ovaries and uterus. The more fat there is in these locations, the less room there is for the adjacent viscera. Thus crowding occurs, which in turn leads to decreased abdominal detail, along with its attendant diagnostic implications.

Gastrointestinal Air Accumulations. Medium to large volumes of air, especially within the stomach, create a substantial mass effect that characteristically displaces the bowel mass caudally. As with large fat depots, this type of displacement crowds the intestine (including the cecum) into a smaller area of the peritoneal cavity, with a resultant increase in superimposition, greater overall regional density, and a commensurate reduction in visceral detail.

Hairballs

Hairballs are a fact of life where rabbits are concerned. Large amounts of hair in the stomach may interfere with emptying, leading to distention and discomfort.

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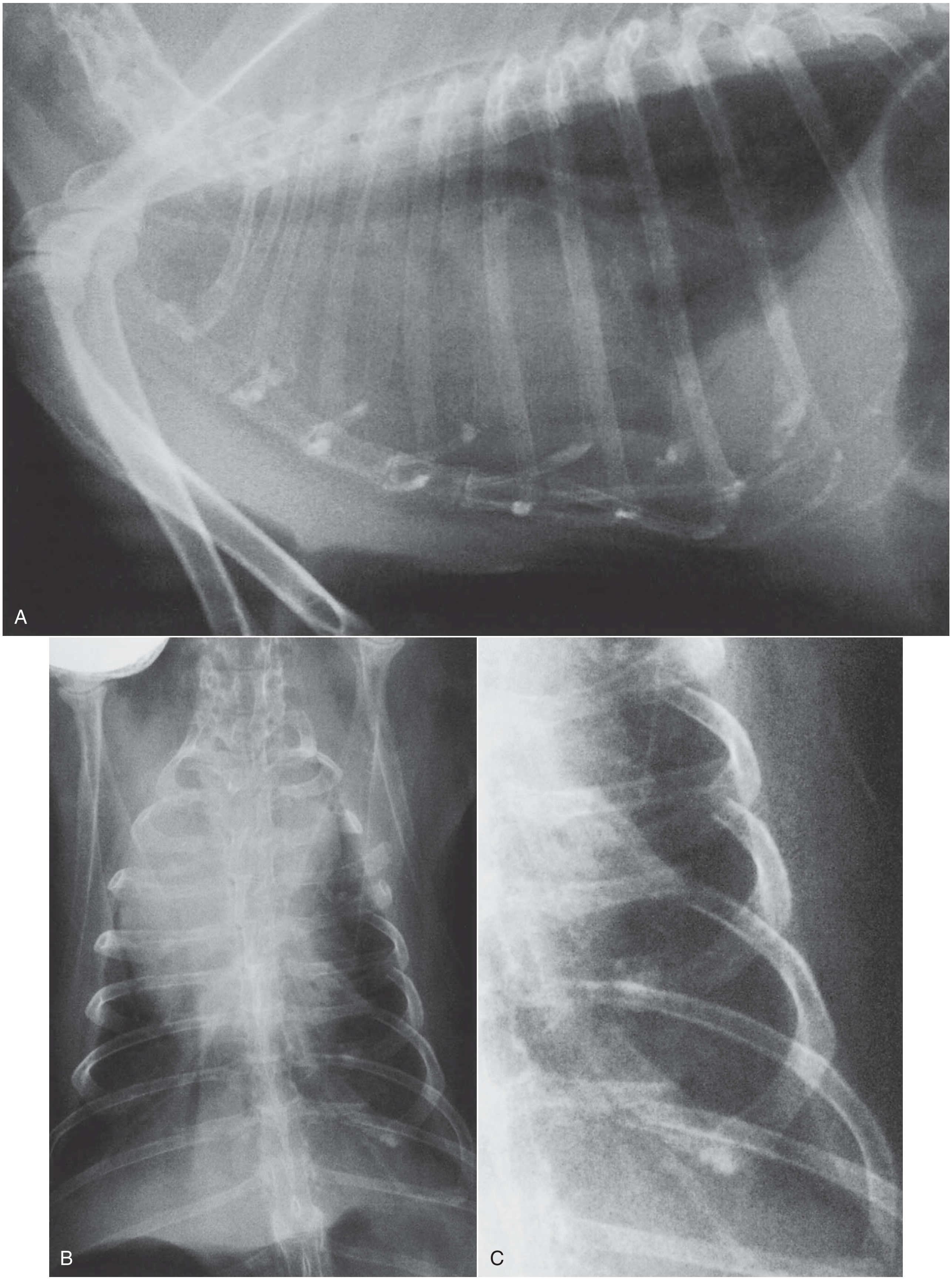

Figure 26-18 • A, Lateral, ventrodorsal **(B),** and close-up ventrodorsal **(C)** views of a rabbit with severe chest injuries, including (1) a cranial mediastinal mass effect (hematoma), displacing the heart caudally; (2) a left dorsolateral tracheal shift; (3) multiple displaced right lateral rib fractures; and (4) hemothorax that partially obscures the diaphragm.

Figure 26-19 • **A,** Ventrodorsal and close-up ventrodorsal **(B)** views of the skull of a rabbit with a severe bilateral, long-standing middle ear infection that has nearly opacified the normally lucent interior of the bullae.

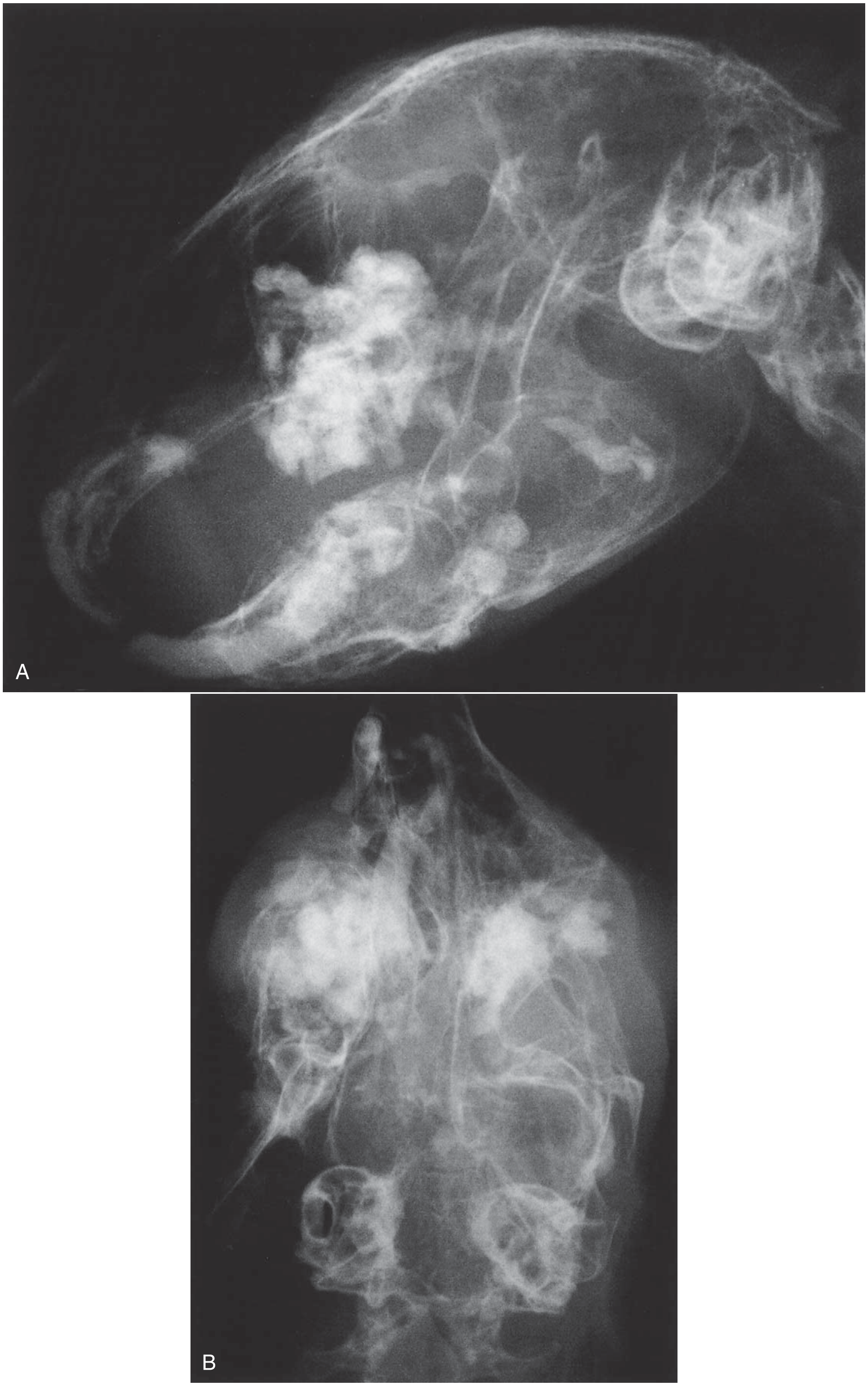

Figure 26-20 • A, Close-up lateral and ventrodorsal oblique **(B)** views of the infected skull of a rabbit showing new bone and dystrophic calcification in the bullae and surrounding the cheek teeth in both the upper and lower jaws.

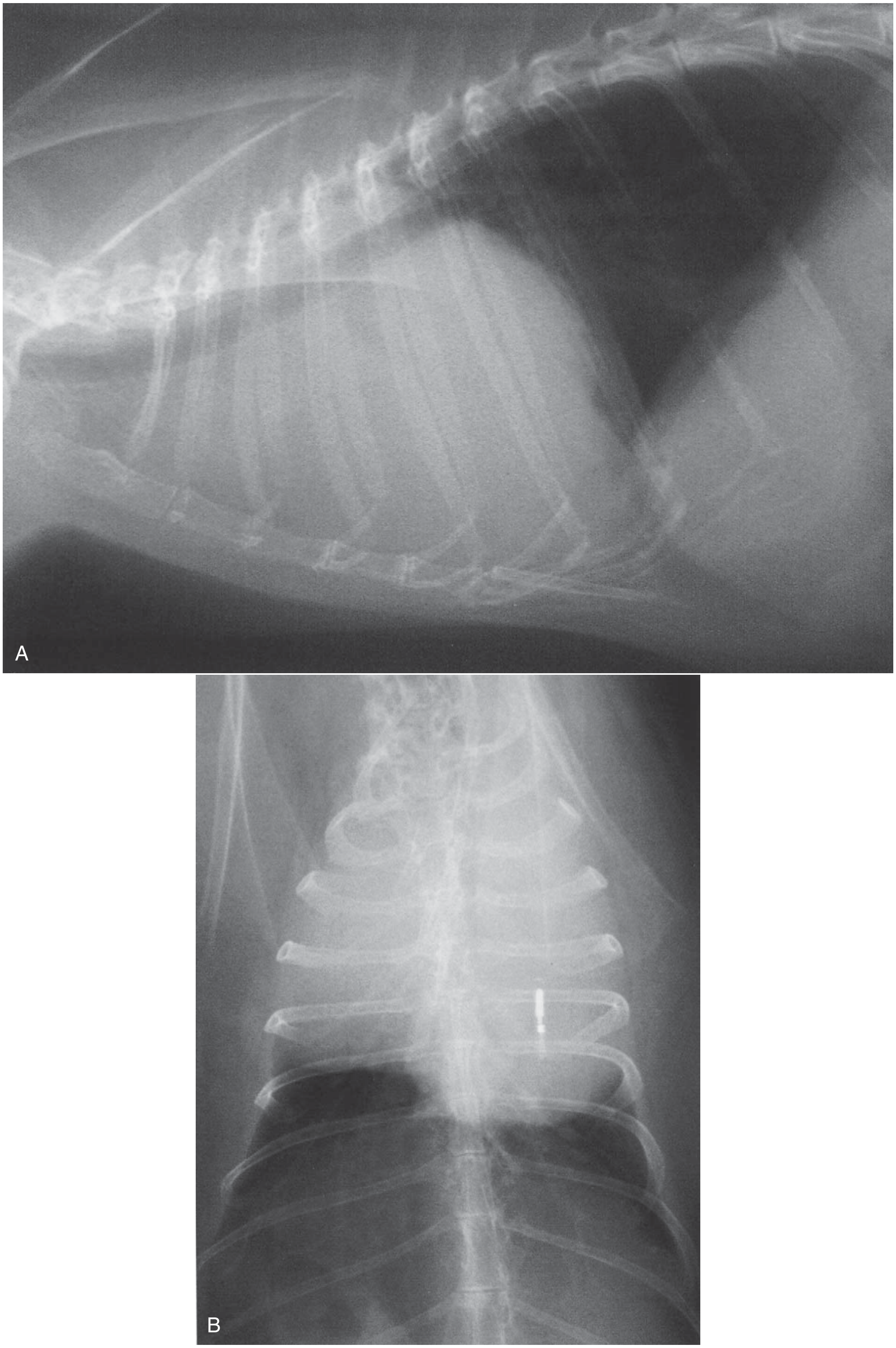

Figure 26-21 • A, Lateral and ventrodorsal **(B)** thoracic radiographs of a rabbit with an enormous right cranial lobe abscess that is displacing the heart and trachea in a dorsolateral direction. Note that in the lateral view the cardiopulmonary silhouetting, combined with the dorsal displacement of the trachea, creates the false impression of severe cardiomegaly.

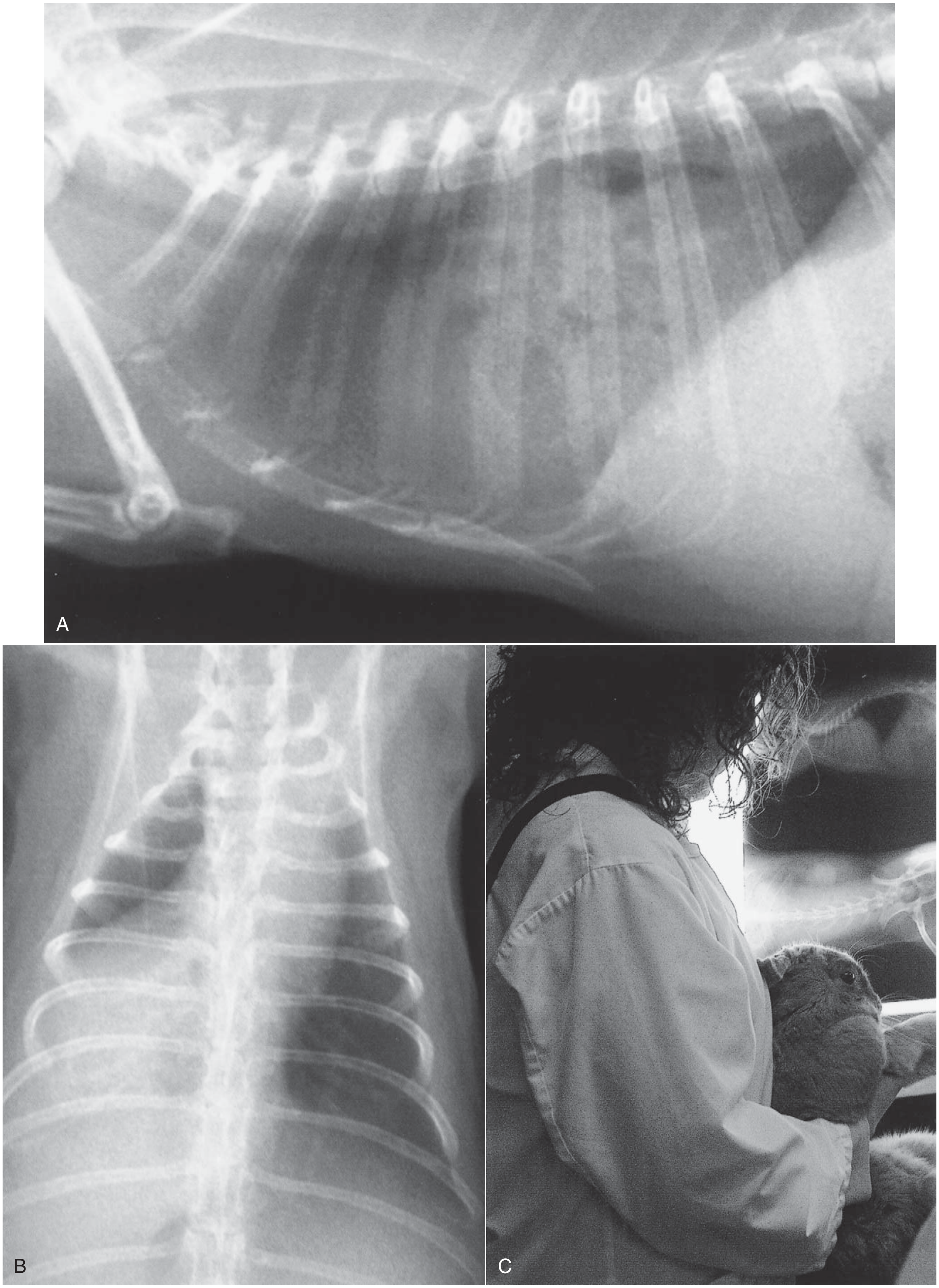

Figure 26-22 • A, Lateral and ventrodorsal **(B)** views of the thorax of a surprisingly healthy looking rabbit **(C)** show a well-demarcated density in the right caudal thorax interlaced with dilated and distorted bronchi, the result of an extensively abscessed, swollen right caudal lung lobe. Note how the diseased lung has merged with the adjacent portions of the heart and liver, including the diaphragm, which is normally indiscernible by radiographic means.

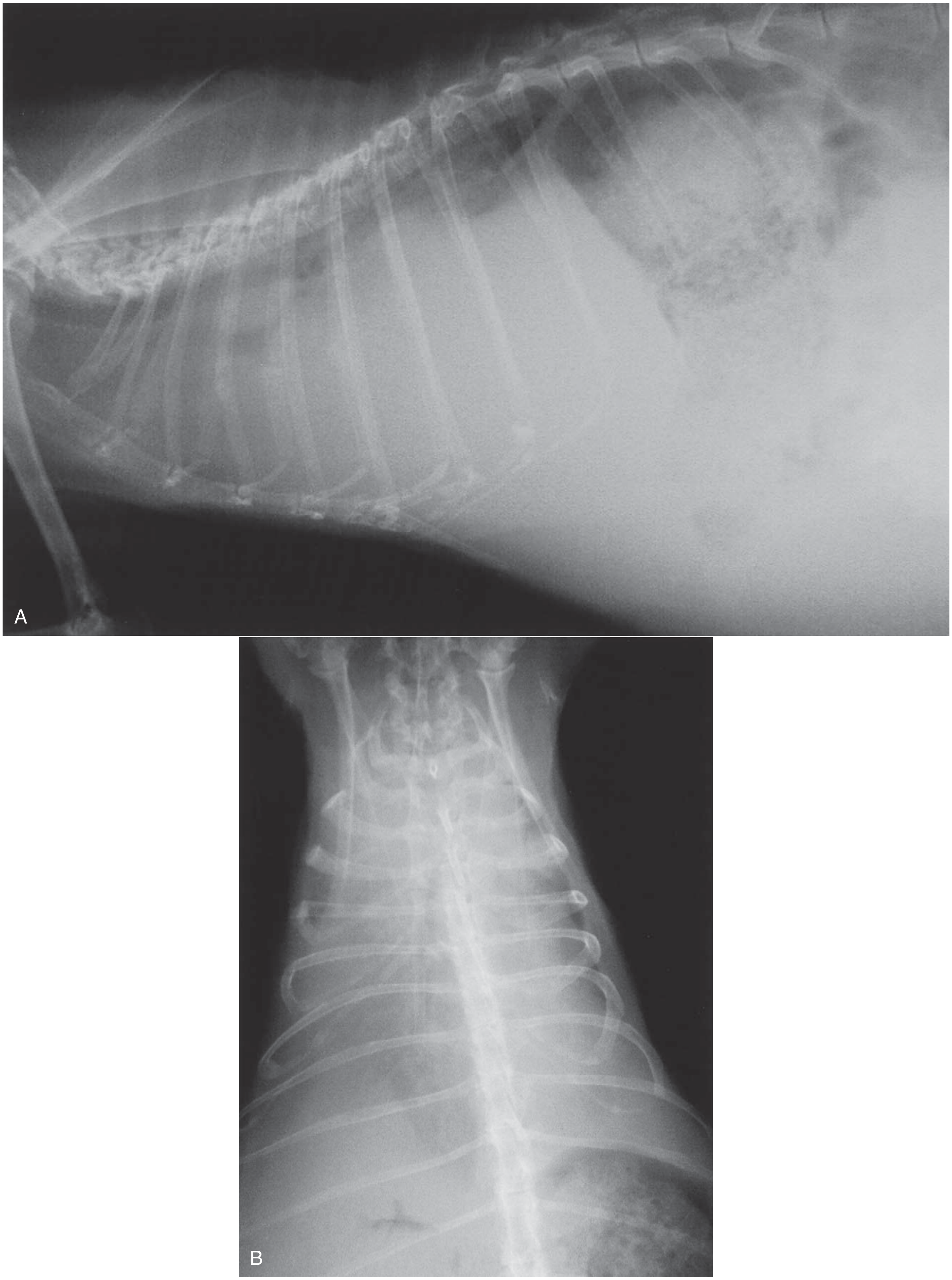

Figure 26-23 • A, Lateral and ventrodorsal **(B)** thoracic and partial abdominal images with widely disseminated uterine carcinoma. The lung metastases are so numerous and coalesced that it is difficult or impossible to see individual lesions. Even the heart is totally obscured. For its part, the abdomen is almost completely opaque, except for the air in the upper part of the stomach. The obvious distention is the result of a large volume of peritoneal fluid caused by the tumor and its satellites.

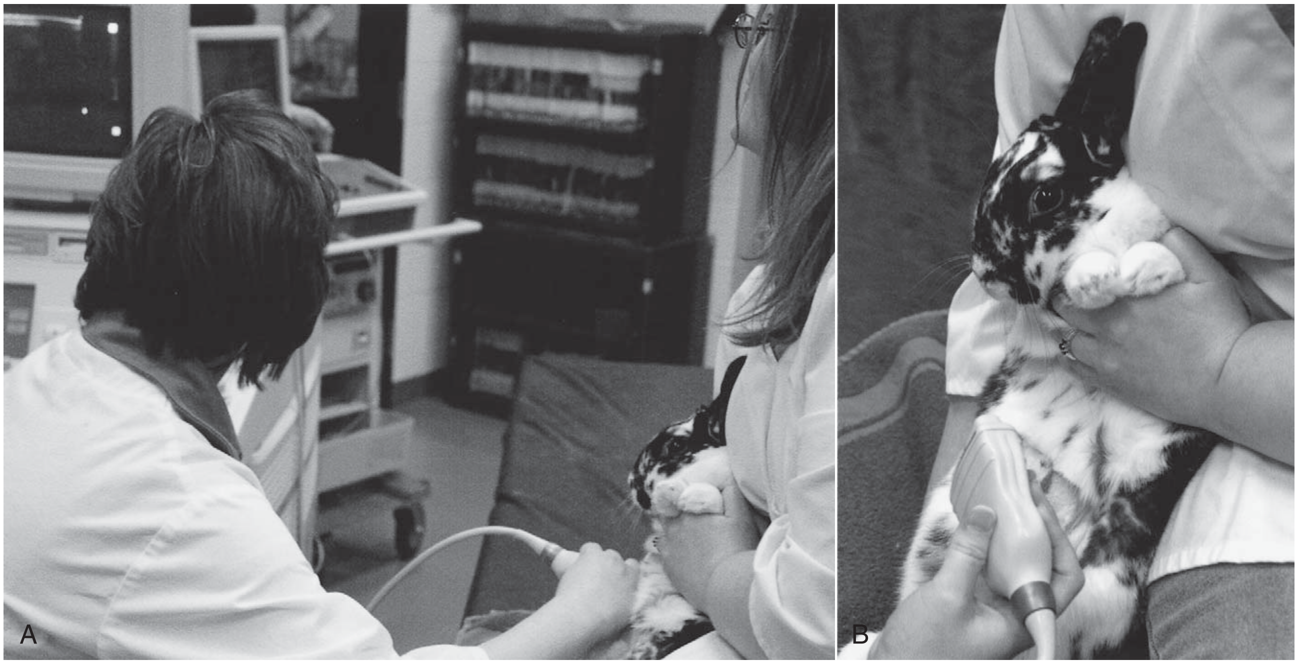

Figure 26-24 • A rabbit in the supported, upright position: side-rear **(A)** and side-front **(B)** for abdominal ultrasound.

Generally, it is impossible to discriminate between hair and food radiographically (Figure 26-26). To make matters worse, it is rare that the stomach contains hair or food alone. The more usual scenario is that the stomach is filled with an admixture of food, fluid, and air, with or without hairballs.

Gastric Dilation

Gastric dilation, usually with a combination of food, fluid, and air, is a regular radiographic finding in sick rabbits. Although such an appearance is likely to provoke thoughts of mechanical obstruction, this is normally not the explanation. Instead, it appears that in most instances, an overly distended stomach is the result of transient atony, not unlike that which often afflicts humans with various forms of stomach upset.

Another consequence of a massively fluid distended stomach in a rabbit is that it compresses the bowel mass into the central and caudal parts of the abdomen so much that it becomes nearly impossible to see whether there is any peritoneal fluid—a most important distinction when it comes to a suspected gastrointestinal perforation (Figure 26-27).

Bladder Stones

Radiographically identified bladder stones may assume a great variety of sizes, from small crystalline flocculations measuring only 1 or 2 mm to immense concretions that literally fill the bladder lumen. Most, however, are medium-sized stones (Figures 26-28 and 26-29). Occasionally, the volume and concentration of crystals become so great that the bladder resembles a positive-contrast cystogram (Figures 26-30 and 26-31).

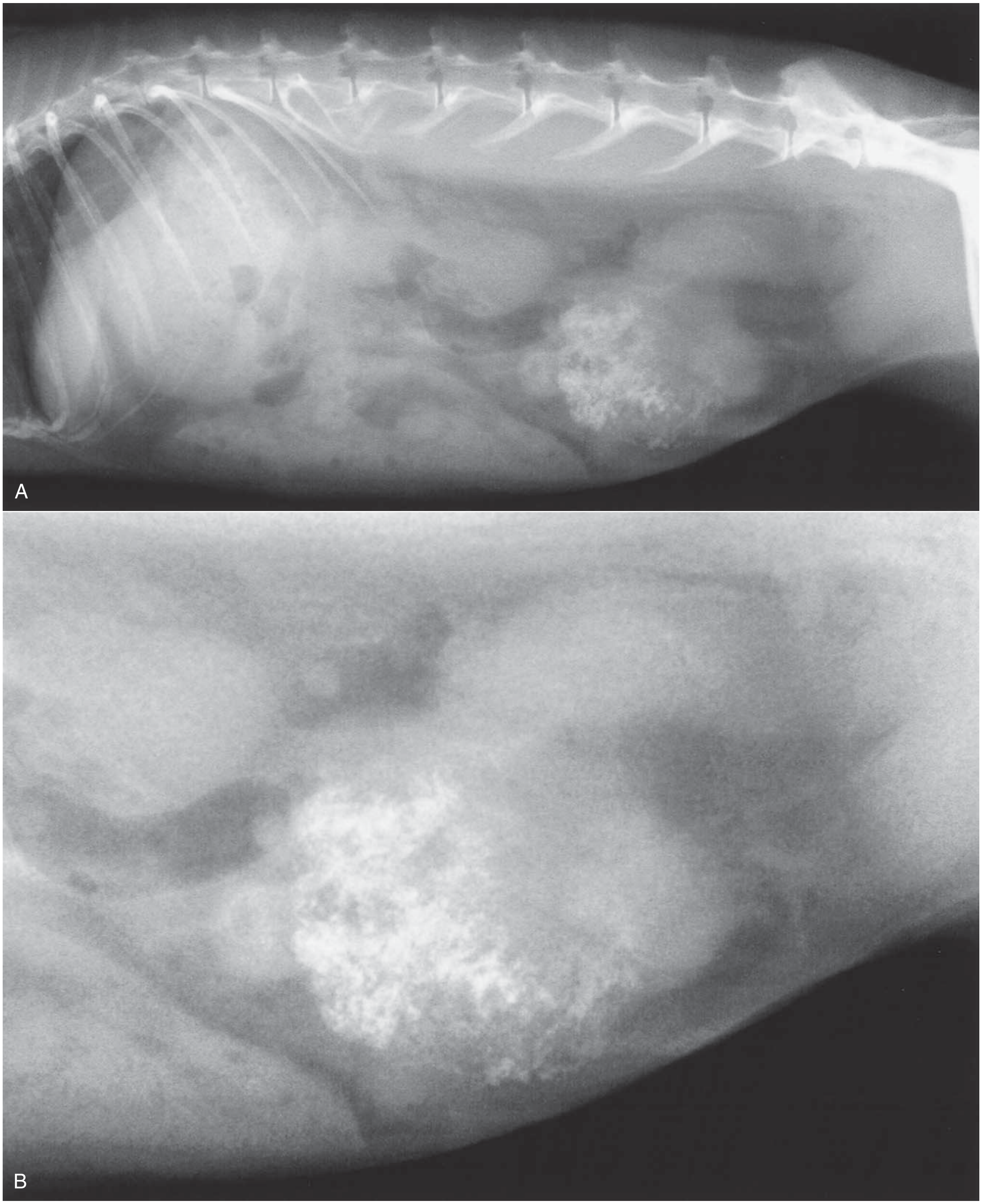

Figure 26-25 • **A,** Lateral, lateral close-up **(B),** ventrodorsal **(C),** and ventrodorsal close-up **(D)** views of a rabbit with a mineralized uterine carcinoma.

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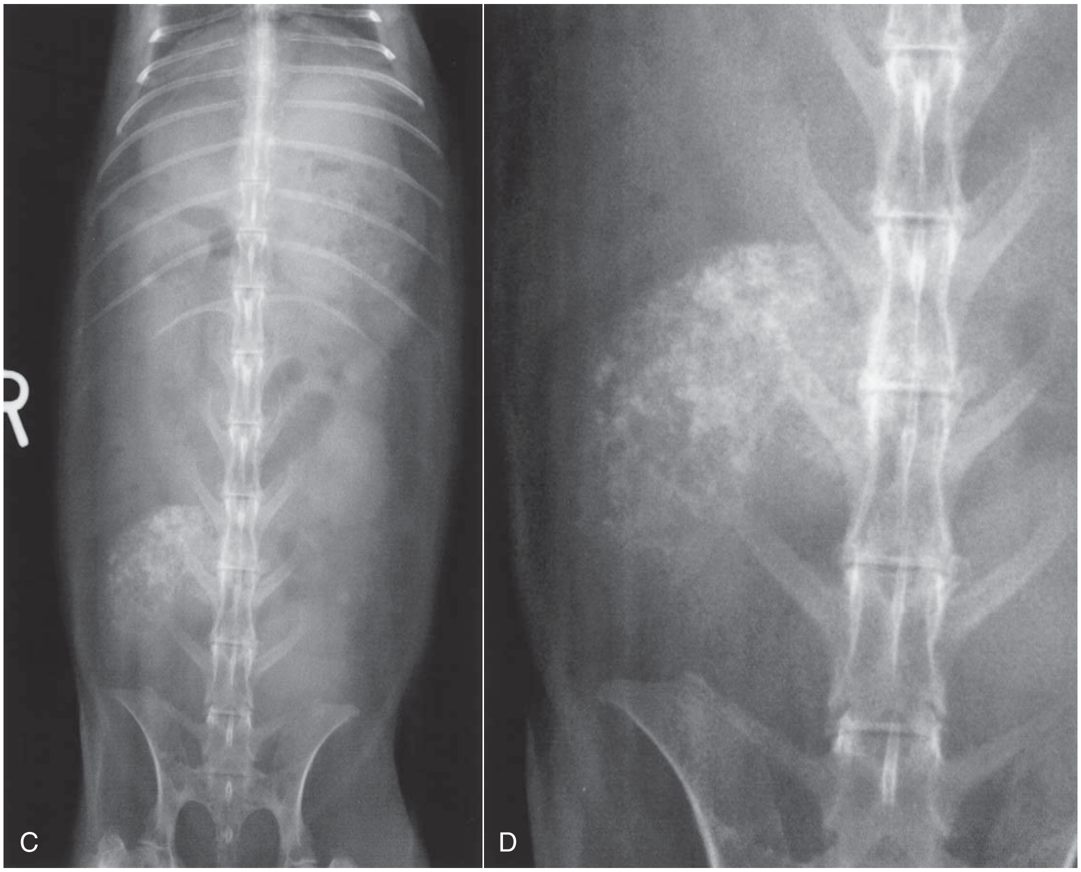

Figure 26-25, cont'd • For legend see p. 311.

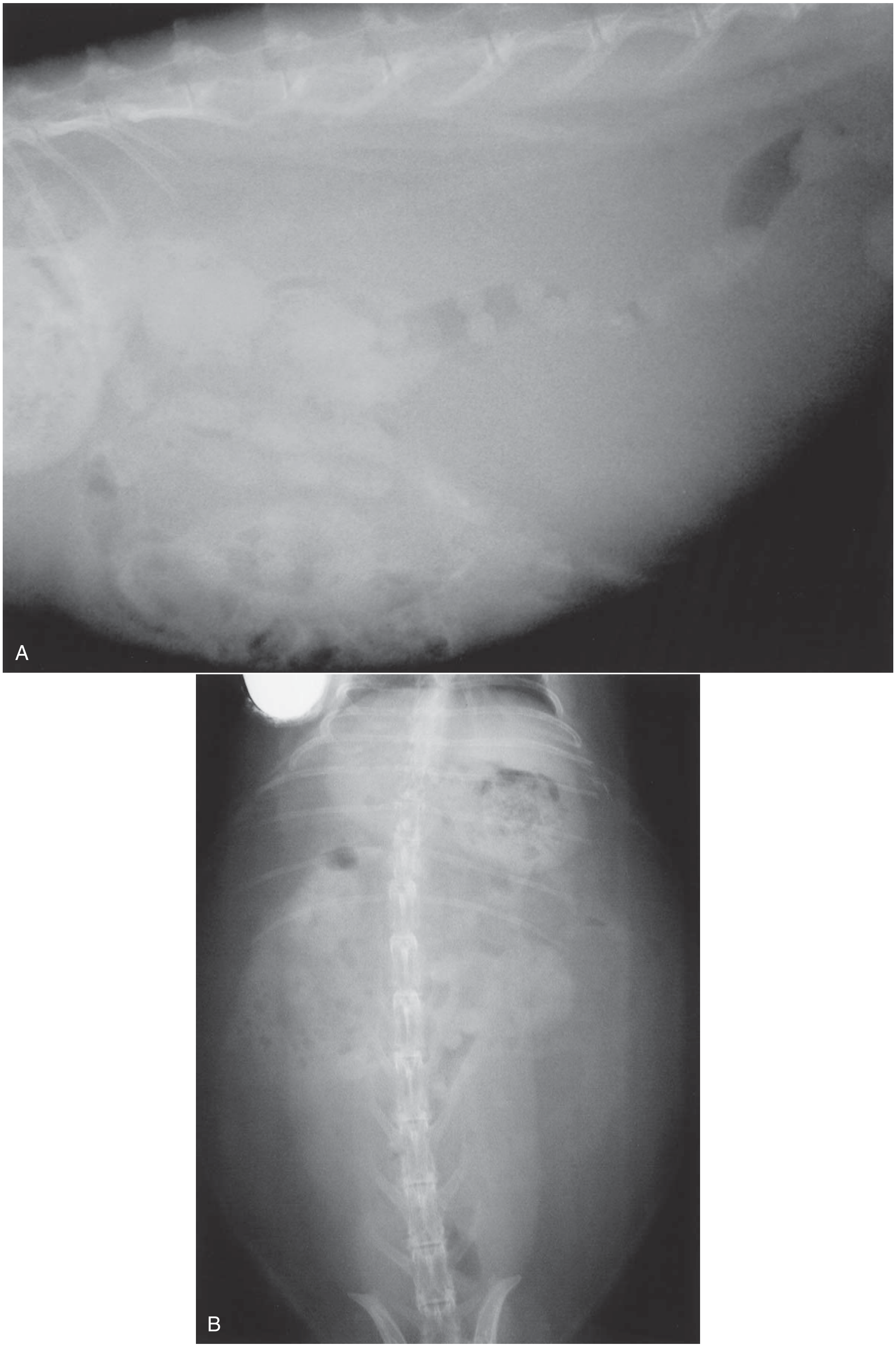

Figure 26-26 • A, Lateral and ventrodorsal **(B)** views of the abdomen of a rabbit with confirmed hairballs in its stomach. Even with ultraclose lateral **(C)** and ventrodorsal **(D)** views of the stomach, it is impossible to discriminate between hair and food.

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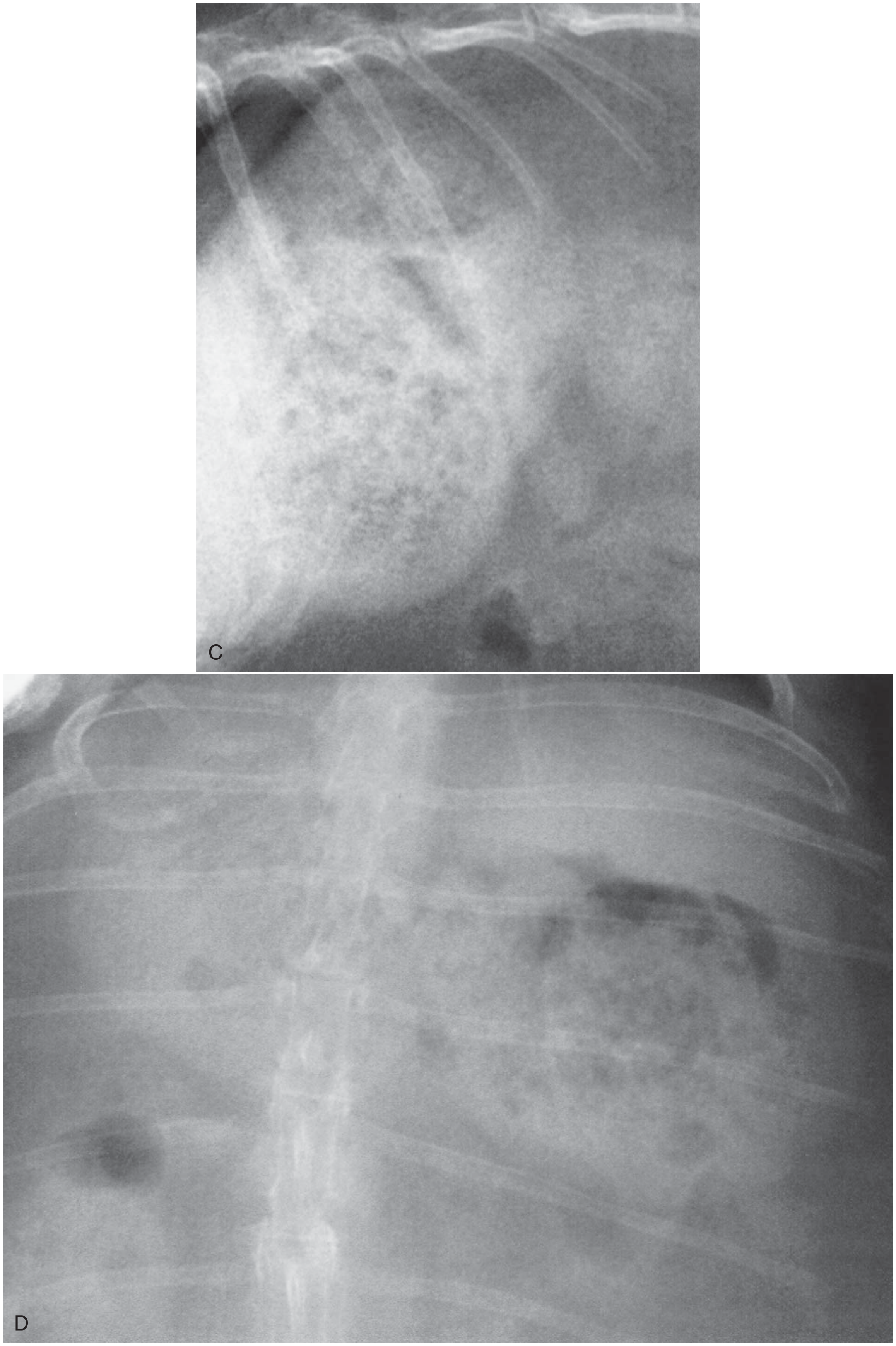

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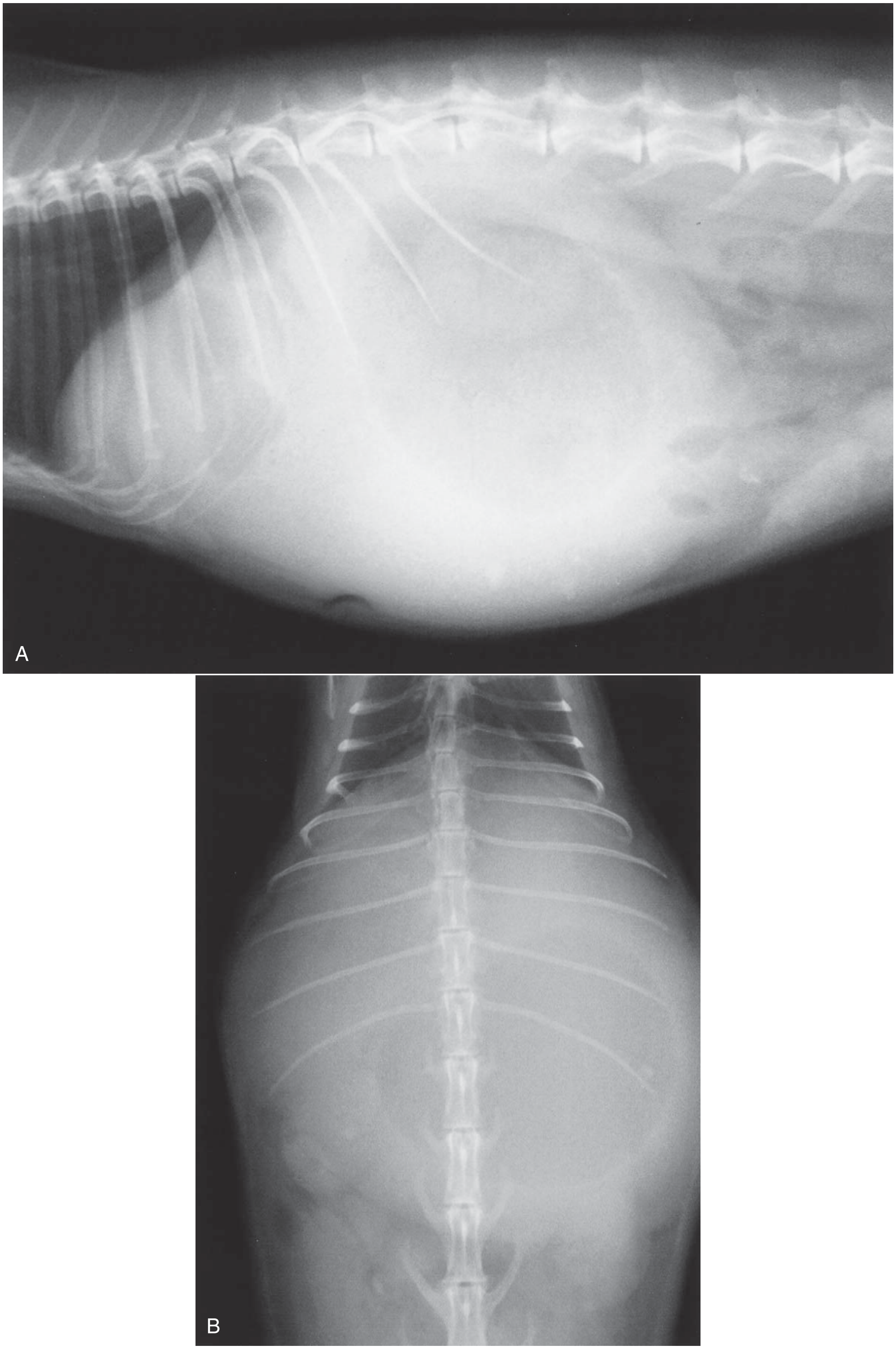

Figure 26-27 • A, Lateral and dorsoventral **(B)** views of a colicky rabbit with a distended abdomen show massive fluid distention of the stomach that makes it impossible to determine whether there is any peritoneal fluid.

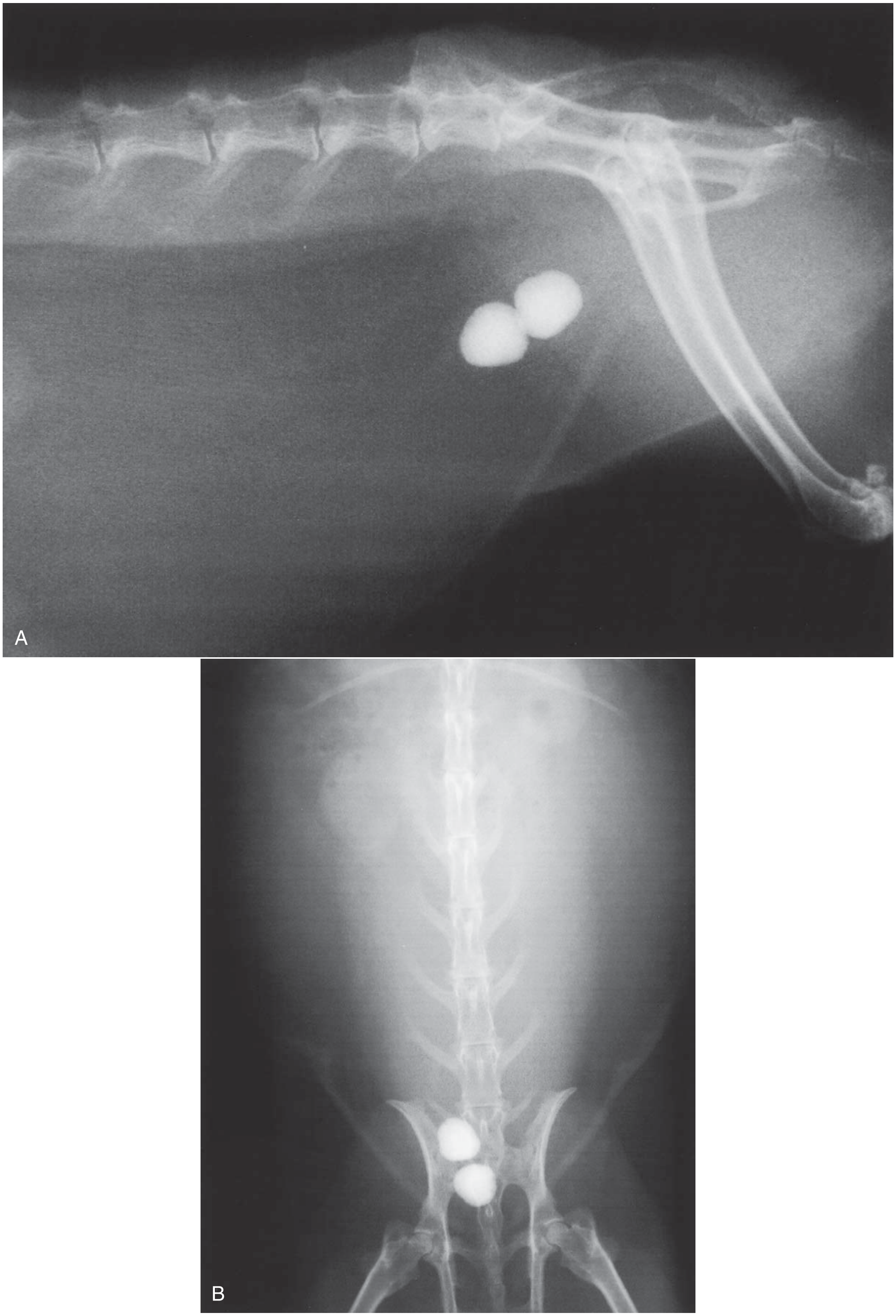

Figure 26-28 • A, Lateral and ventrodorsal **(B)** close-up views of the caudal abdomen of a rabbit show a pair of medium-sized bladder stones.

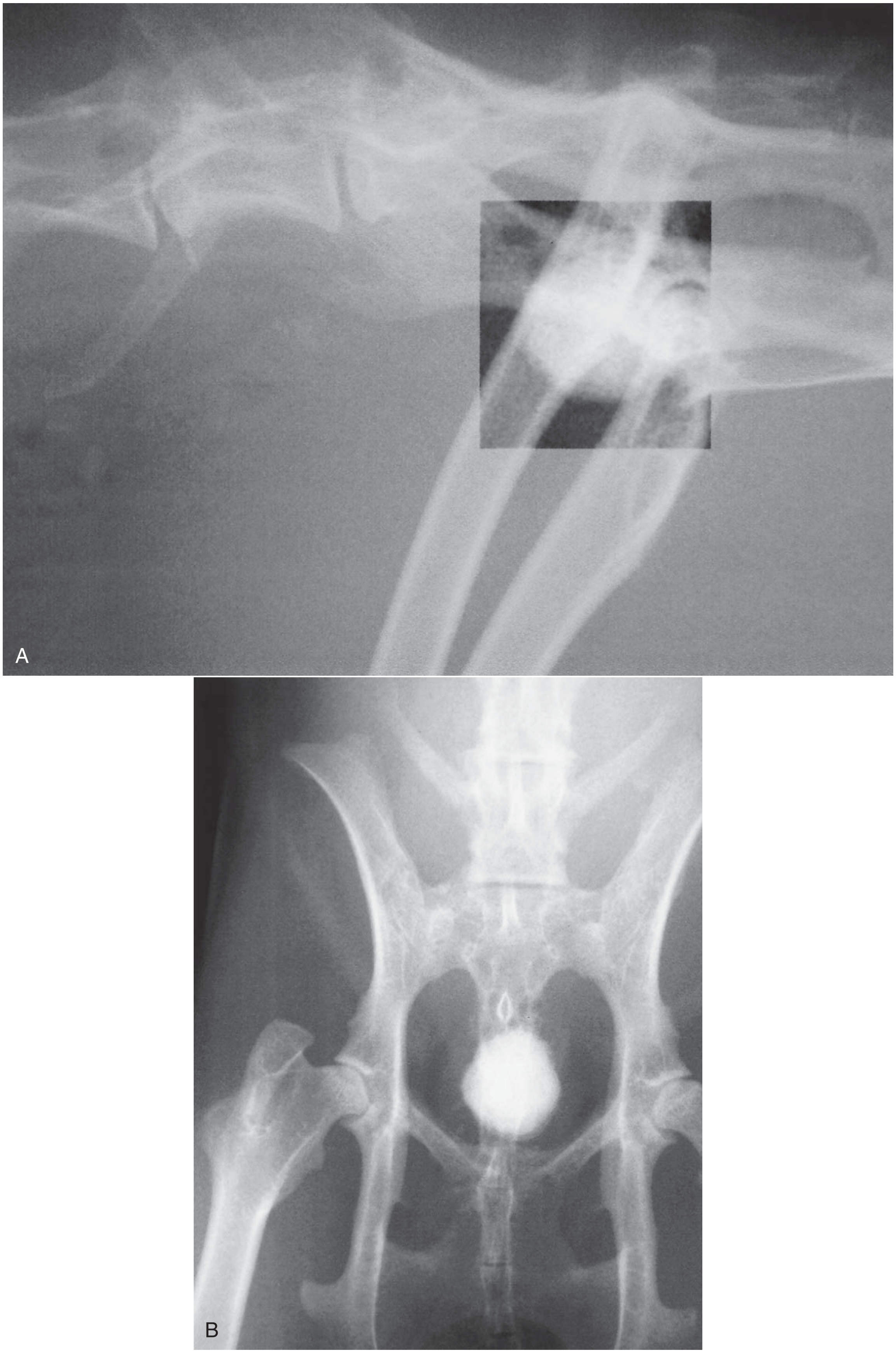

Figure 26-29 • A, Lateral and ventrodorsal **(B)** close-up views of the caudal abdomen of a rabbit show a single medium-sized bladder stone, which has been emphasized in the lateral projection to improve visibility.

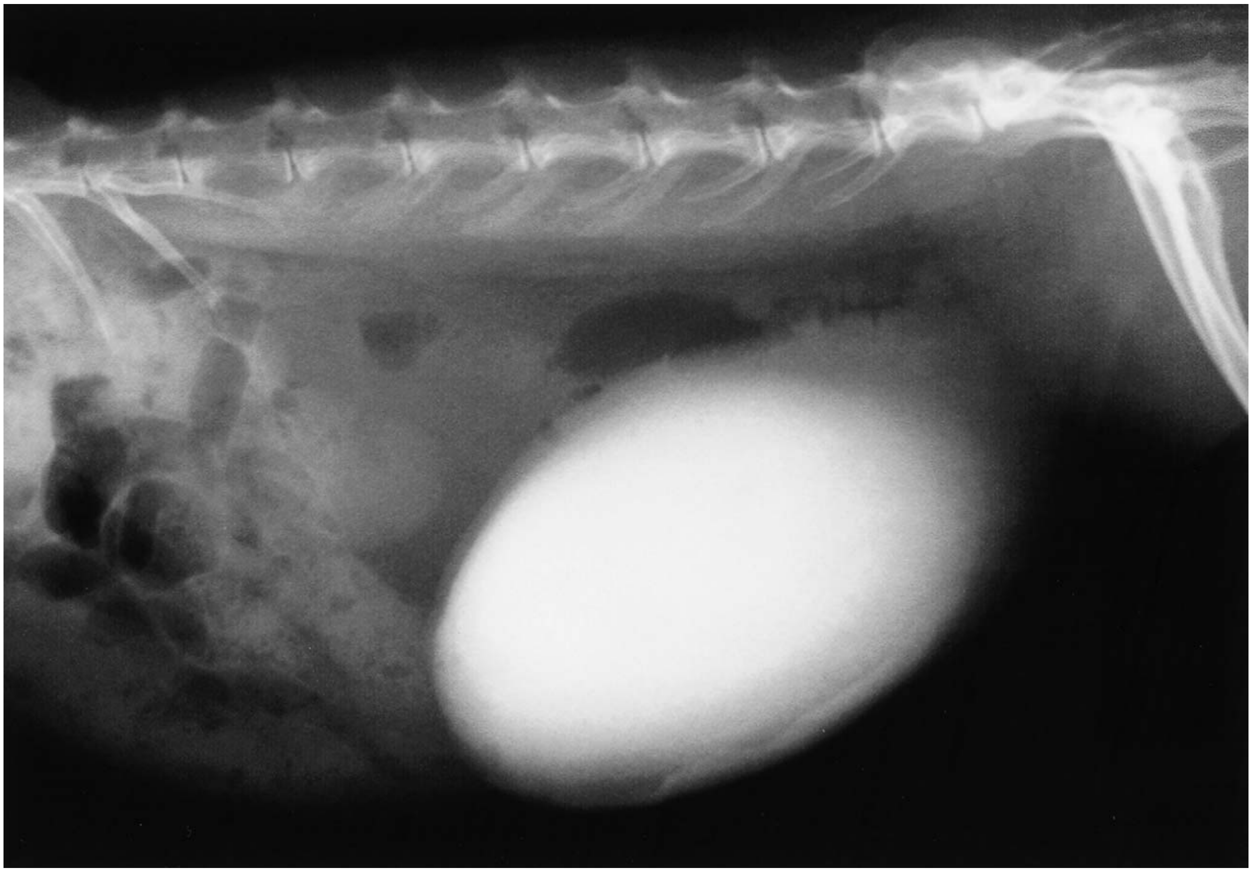

Figure 26-30 • Intense bladder opacification resulting from concentrated crystallization of the urine resembles positive contrast cystography.

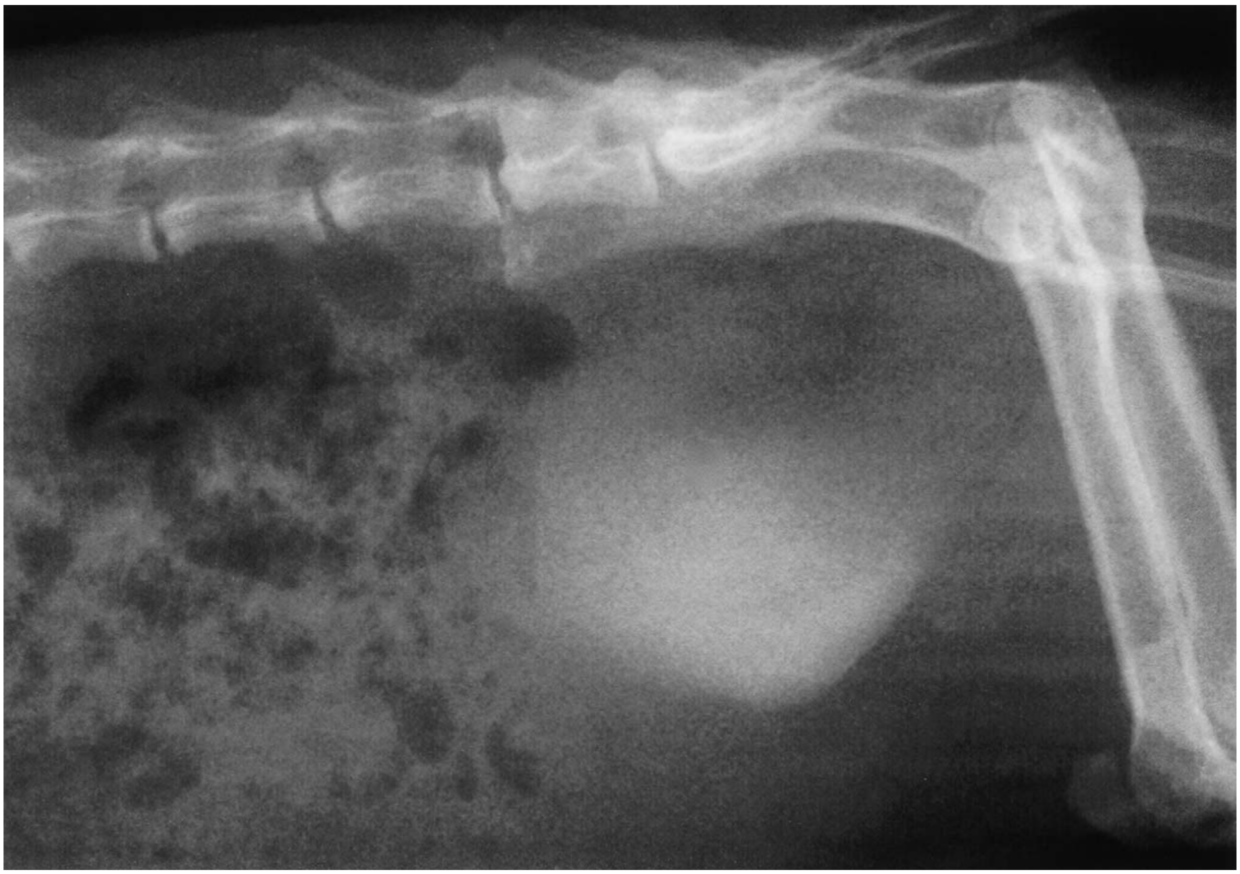

Figure 26-31 • Another example of crystalluria in a rabbit causing partial opacification of the urinary bladder.

Chapter 27

Ferrets

Ferrets are quite popular in our area, and as a consequence, we have the opportunity to image them regularly for a wide variety of ailments, including trauma, gastrointestinal obstruction, cancer, and heart disease (Figure 27-1).

RADIOGRAPHY

Radiographically, we treat ferrets much as we might treat cats, making the usual standard ventrodorsal and right lateral views, as well as a variety of supplementary and customized projections. Sometimes, we encounter ferrets that bite or refuse to remain still long enough to be imaged, in which case we use gas anesthesia (Figure 27-2). Occasionally, we perform barium studies in ferrets, usually in search of intestinal foreign bodies.

NORMAL RADIOGRAPHIC ANATOMY

In many ways, the radiographic anatomy of a ferret resembles that of a cat, particularly the torso, which is elongated and tapered at each end. However, the skull of a ferret, with its long, dorsally flattened cranium, is decidedly different from the more normally proportioned, gently rounded skull of a cat (Figure 27-3).

INJURIES

Like the other small pet mammals, ferrets often get under foot and sometimes sustain limb fractures or dislocations in the process (Figure 27-4). More serious, however, are thoracic crush injuries in which widespread lung bruising is capable of causing severe dyspnea.

If multiple lobes are ruptured, bleeding usually occurs, accumulating in the pleural space and resulting in varying degrees of secondary lung compression. Air may also escape from a ruptured lobe, joining the blood in the pleural space and further collapsing the lung (Figure 27-5). If allowed to go unchecked, the continued leakage of blood and air will eventually collapse the lung and suffocate the animal.

GASTROINTESTINAL FOREIGN BODIES

Ferrets, more than any other mammalian exotic, are inclined to eat small objects, and many of these objects obstruct their stomach or bowel. Again, like cats, obstructed ferrets vomit, cease to eat, and generally appear ill. Some exhibit palpable thickening of the intestine, and others do not. Radiography may real the culprit, provided it has sufficient density (Figure 27-6); otherwise, there is only indirect evidence of blockage such as distended small intestine.

Thread, string, ribbon, and the like will usually cause bunching of the bowel, provided the foreign material is fixed at some point, for example, beneath the tongue or in the stomach. Where intestinal gas is present, it is often broken up into small clusters, which is termed the *interrupted gas pattern,* suggestive of a fixed linear foreign body.

SELECTED DISEASES

Heart Disease

Ferrets suffer from a wide variety of congenital and acquired heart diseases: cardiomyopathy is the most common, similar again to cats. But unlike cats, ferrets can develop the dilated form of the disease, which has almost disappeared in cats since taurine deficiency was identified as the principal source of this form of the disease (Figures 27-7 through 27-10).

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Figure 27-1 • Veterinary student holds a pair of ferrets in the Radiology Department who appear more interested in one another than in the camera.

Figure 27-3 • Close-up view of the head of a healthy ferret shows its angular face and wide, dorsally flattened cranium.

Figure 27-2 • With its face partially obscured by the reflections coming off the anesthetic mask, a ferret watches the anesthetist before being radiographed.

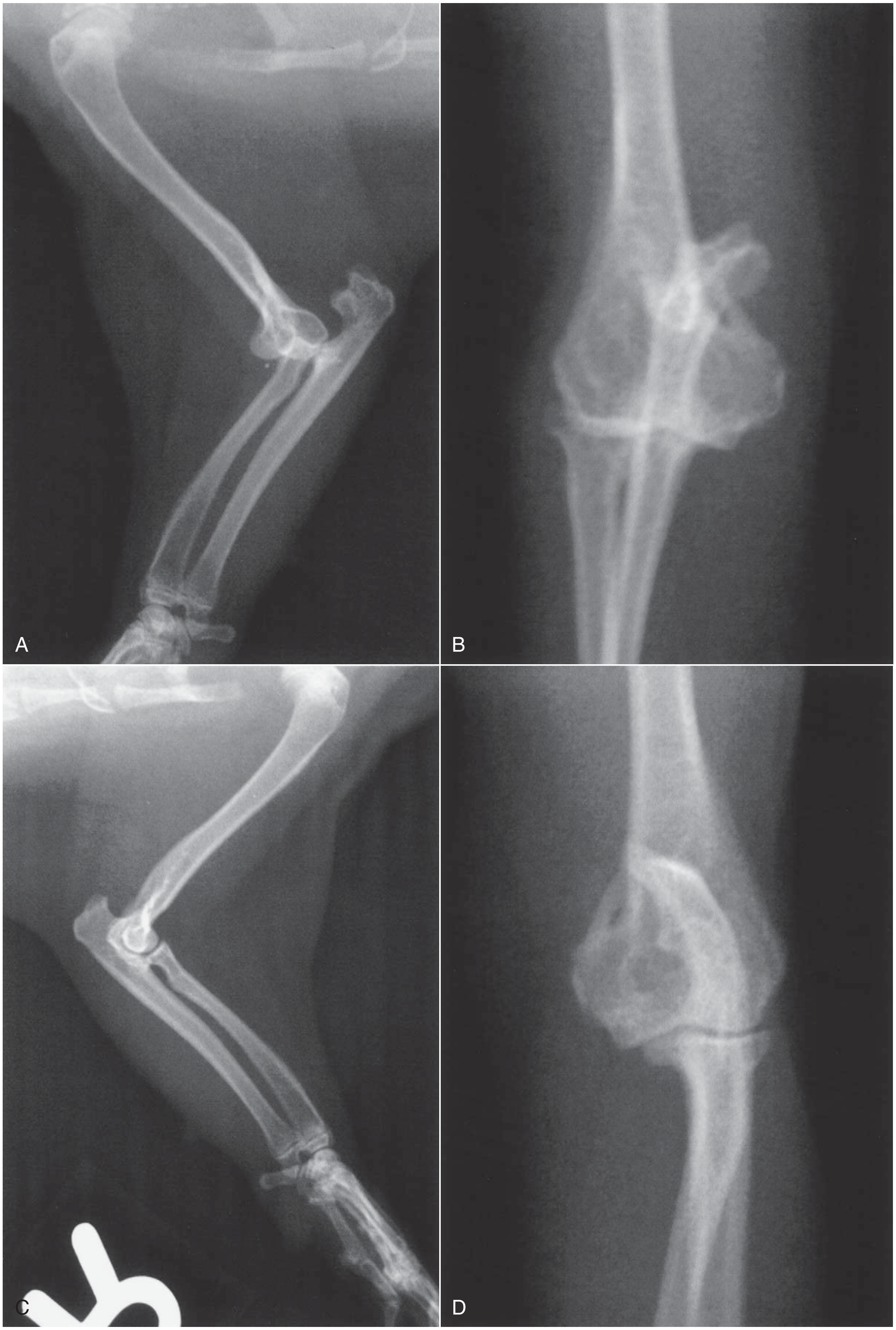

Figure 27-4 • A, Lateral and craniocaudal **(B)** views of a dislocated left elbow in a ferret. Comparable lateral **(C)** and craniocaudal **(D)** projections of the uninjured right cubital joint are provided for comparison.

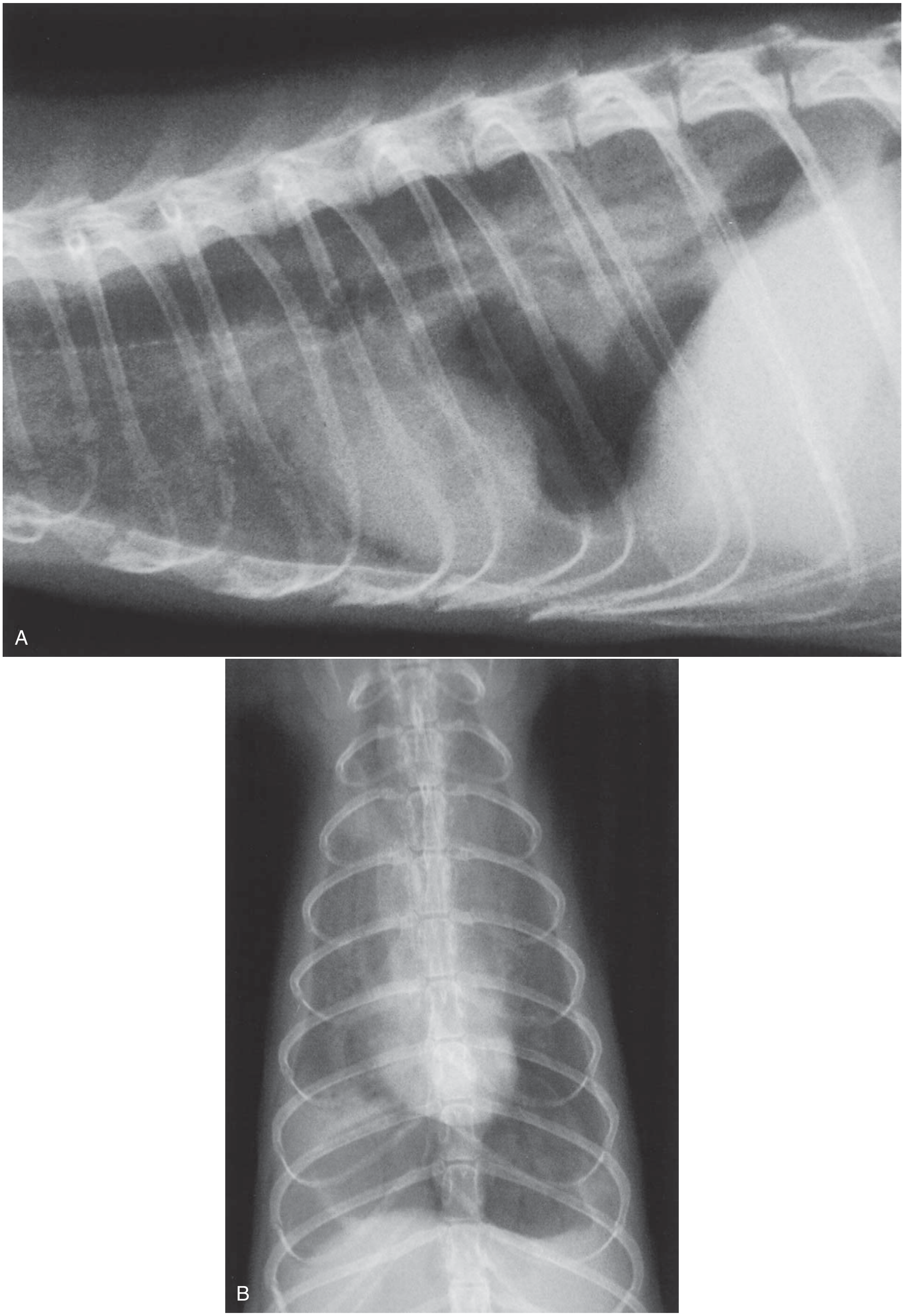

Figure 27-5 • A, Lateral and ventrodorsal **(B)** views of the thorax of a ferret that sustained serious chest injuries after a small child tripped and fell on it. The lateral projection is the most informative, revealing an abnormally dense, smaller than normal caudal lobe with an exceptionally clear border. This appearance is indicative of a ruptured lung lobe with a secondary pneumothorax.

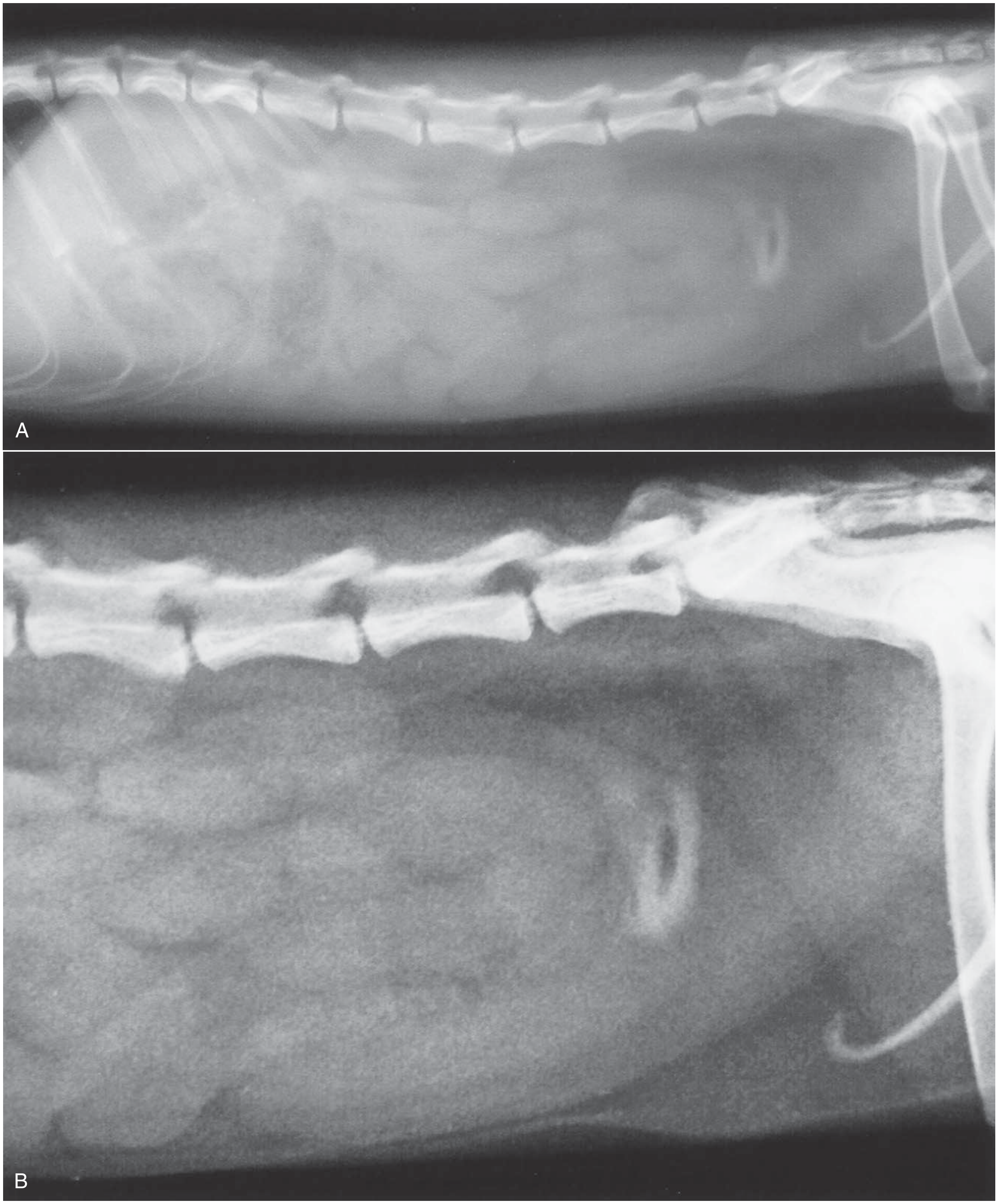

Figure 27-6 • A, Lateral and close-up **(B)** views of the abdomen of an obstructed ferret show an abnormal density caudally resembling a compressed oval (rubber tubing). A distended small intestine provides circumstantial evidence of a blockage.

Figure 27-7 • A ferret in congestive heart failure as a result of dilated cardiomyopathy is held on its back while being clipped for sonography. Note the distended abdomen, the result of secondary ascites.

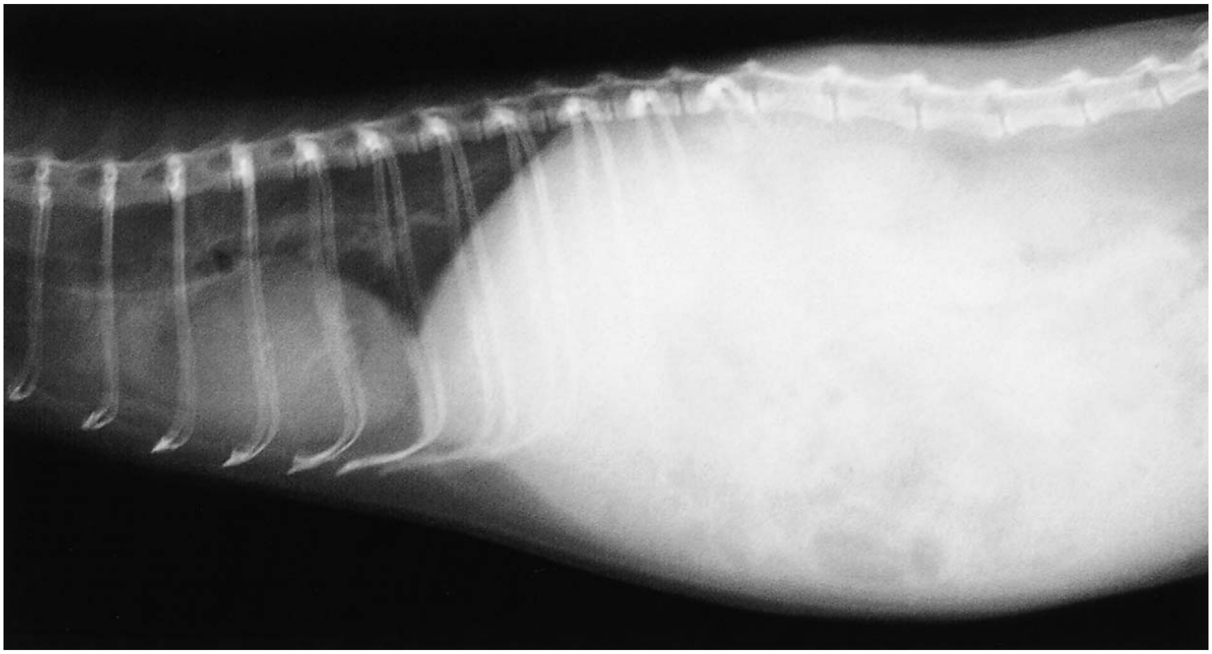

Figure 27-8 • Lateral orientation view of the ferret torso shown in Figure 27-3 shows cardiomegaly, pleural fluid, and ascites.

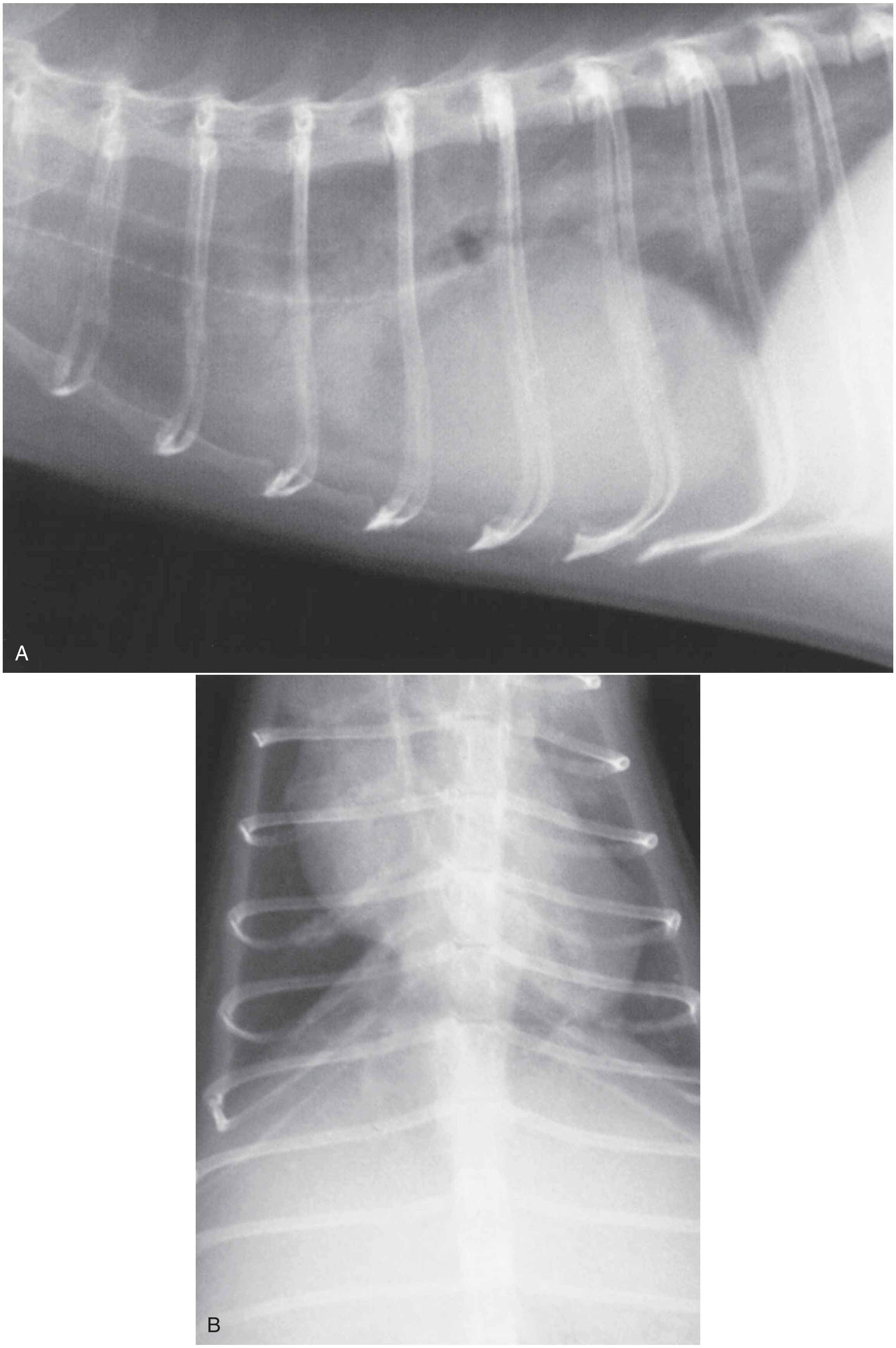

Figure 27-9 • A, Close-up lateral and ventrodorsal **(B)** views of the thorax of the ferret seen in the previous figure show marked cardiomegaly and pleural fluid.

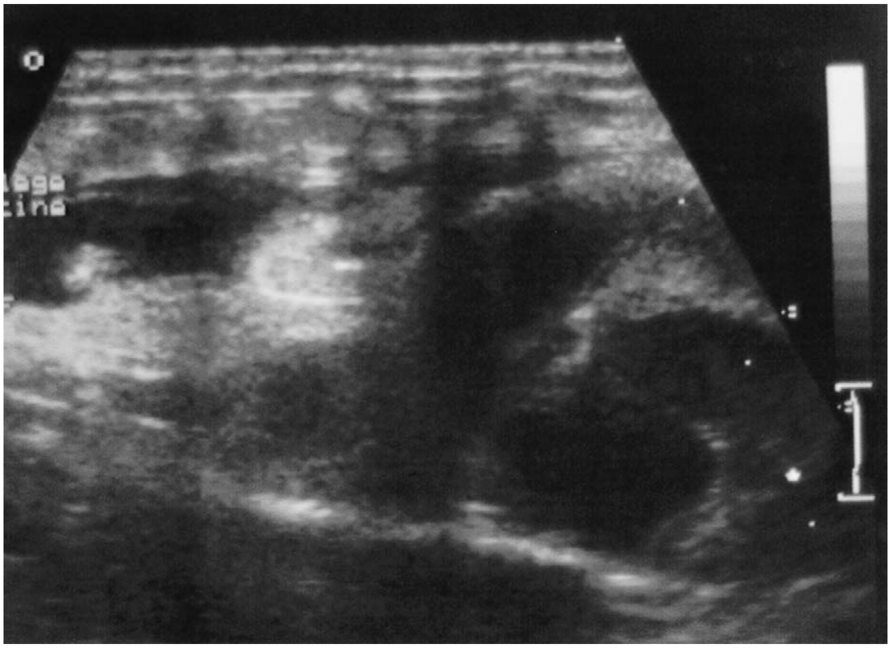

Figure 27-10 • Lateral cardiac sonogram reveals dilated heart chambers consistent with myopathy, pleural fluid, and related lung collapse.

Internal Abscesses

Abscesses may develop anywhere in the body, but those within the interior are the hardest to diagnose, thus the need for medical imaging. The precise cause of most of these localized infections is never determined. Associated clinical signs may relate to a specific organ system, for example, vomiting in the case of an abscess in the stomach wall (Figure 27-11). Other abscesses simply cause nonspecific signs of illness such as inappetence or lethargy.

Adrenal Disease

Adrenal disease is encountered regularly in ferrets, both as a secondary manifestation of pituitary disease and as a result of a primary pituitary tumor (Figure 27-12). In the case of pituitary-dependent disease, both adrenals become enlarged, whereas only the diseased gland increases in size in a primary adrenal tumor. Primary pituitary disorders are also much more likely to distort the appearance of the gland and alter its interior (as determined sonographically).

Dental and Paradental Disease

Dental examinations in small animals can be difficult, even with the aid of occlusal films (Figure 27-13). Performed with a conventional x-ray machine and receiver system, oblique projections become a necessity. Open-mouth obliques are even better. Anesthesia is mandatory (Figure 27-14). *Double film marking* will reduce the incidence of medical errors related to the radiographic misidentification of diseased teeth (Figure 27-15).

As with other mammals, advanced dental infections in ferrets are characterized by the loss of perialveolar bone with or without associated root destruction. Thus the presence of an apical "halo" is a reliable radiographic indicator of an active dental disease such as an abscess (Figure 27-16). Loss of mandibular or maxillary bone beyond the immediate vicinity of a tooth constitutes strong presumptive evidence of related osteomyelitis, especially when seen in conjunction with tooth destruction. The presence of purulent drainage usually indicates the formation of a sinus in the adjacent jawbone.

A standard dental series in a ferret should include (as with most animals) at least the four projections shown in Figure 27-17. The open-mouth position often reduces diagnostically confusing superimposition, especially in the rostral part of the mouth.

Occlusal film can also be used to eliminate dental superimposition but is difficult to position to avoid distorting the appearance of individual teeth *(geometric distortion)*. Placing a small lead marker on the surface of a draining sinus helps establish its potential origin when viewing subsequent radiographs. Likewise, sinography can be used to conclusively establish that a specific tooth is the source of drainage.

Spinal Fractures

Fortunately, spinal fractures rarely occur in ferrets; most fractures are crush injuries. Paraplegia is often the consequence, as is the case with dogs. With patience and a little ingenuity, it is possible to rehabilitate many of these animals (Figure 27-18).

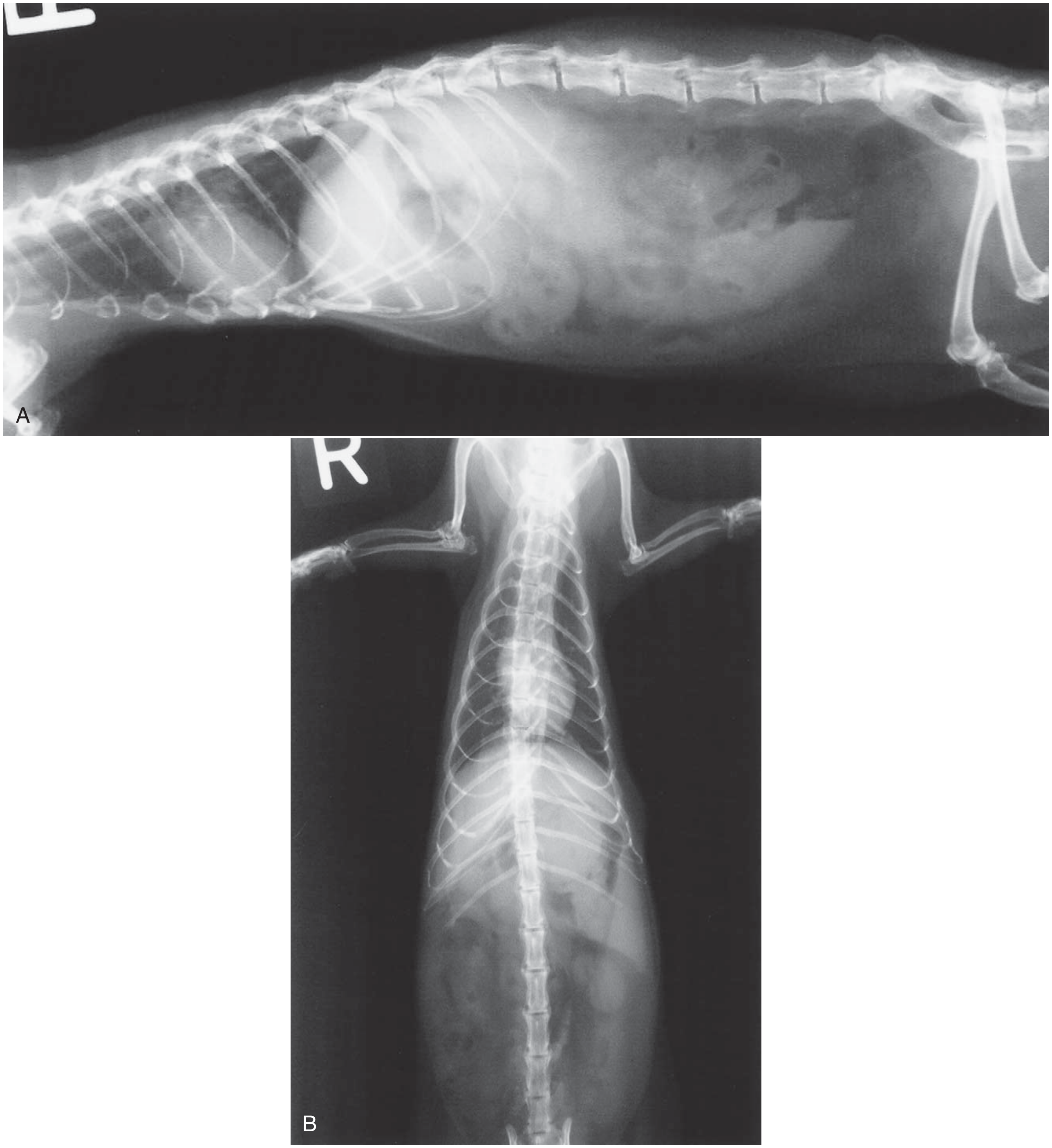

Figure 27-11 • A, Lateral and dorsoventral **(B)** views of the torso of a vomiting ferret suspected of having a gastrointestinal foreign body. Note the unusual shape, distribution, and location of the stomach gas. **C,** Close-up lateral and dorsoventral **(D)** views of the stomach region show a circular object displacing the stomach toward the left lateral abdominal wall and partially collapsing the lumen. **E,** A sonogram clarifies that there is a fluid-filled mass in or adjacent to the medial stomach wall, which later proved to be an intramural abscess.

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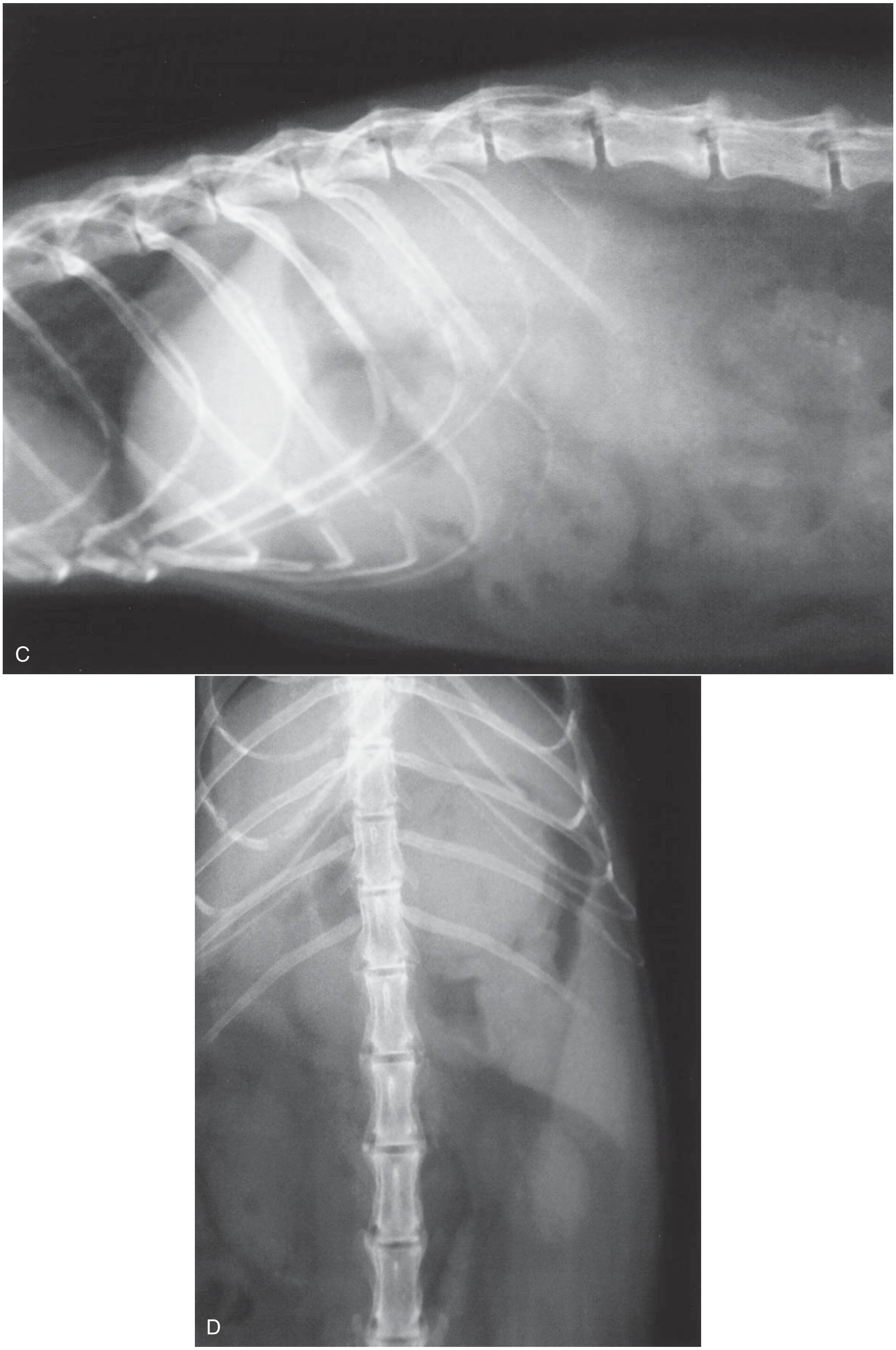

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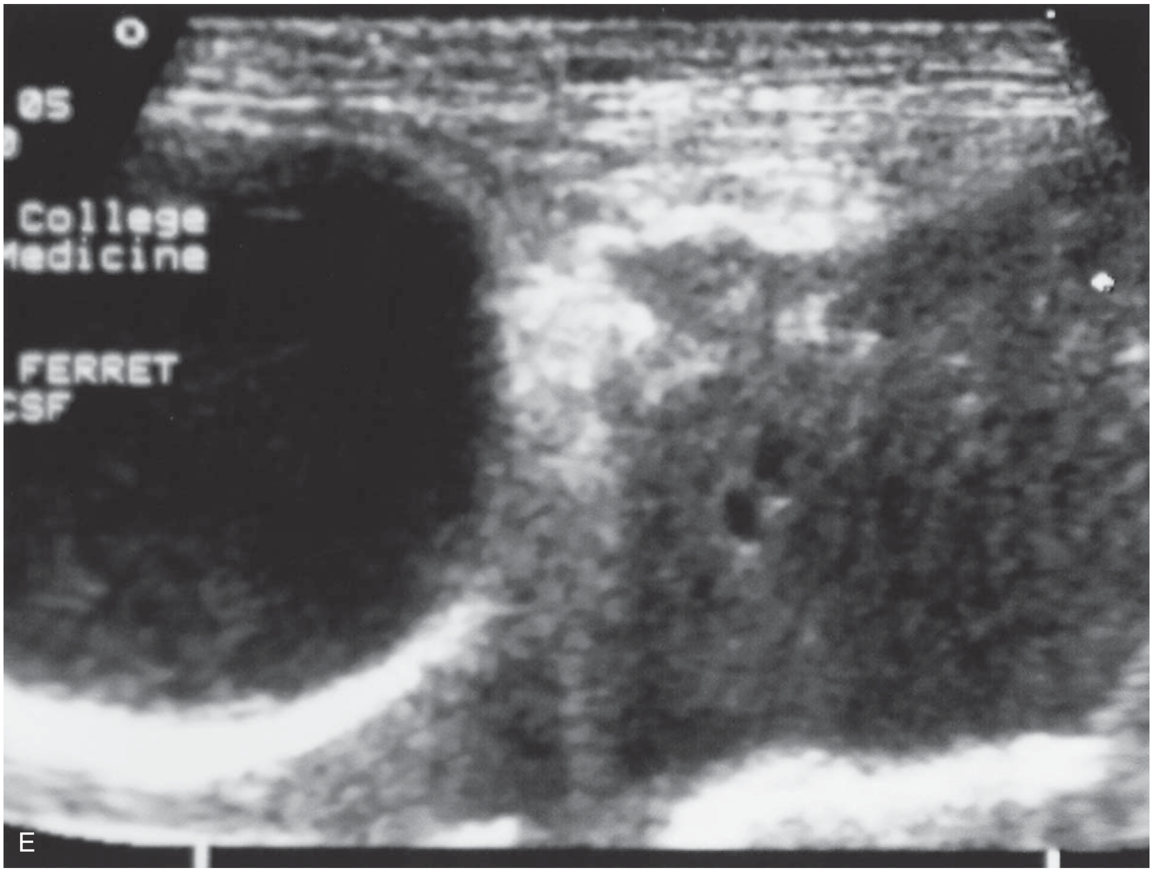

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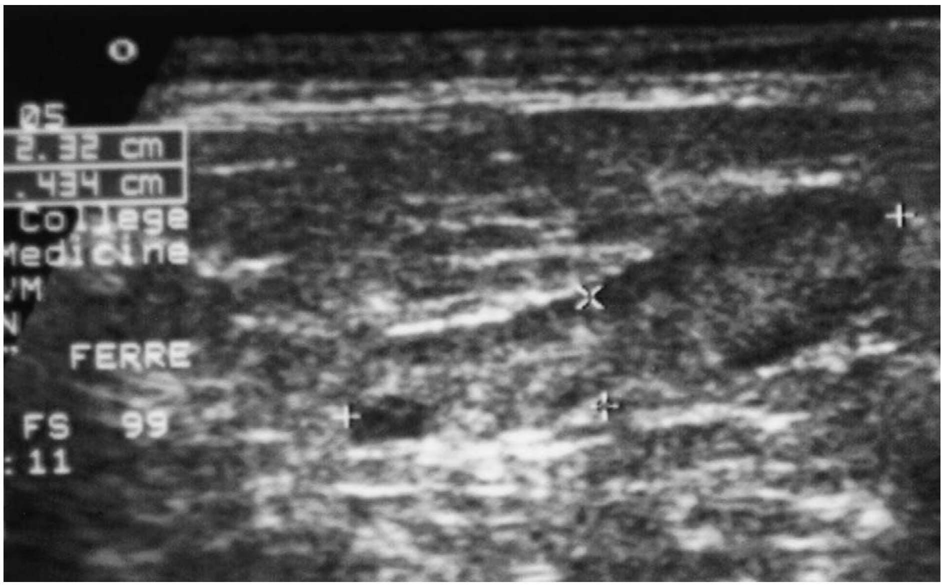

Figure 27-12 • Sonogram of an enlarged left adrenal gland in a ferret.

Figure 27-13 • Dental occlusal films drying in a crooked row, while others remain in the grip of forceps.

Figure 27-14 • An unconscious ferret is kept unconscious by gas anesthesia before radiography.

Figure 27-15 • Lateral open-mouth oblique projection of the left maxillary arcade illustrating double marking: the L marker signifies the profiled left maxillary teeth, while the R marker identifies the relatively obscure right maxillary dentition. This marking system will help prevent medical errors.

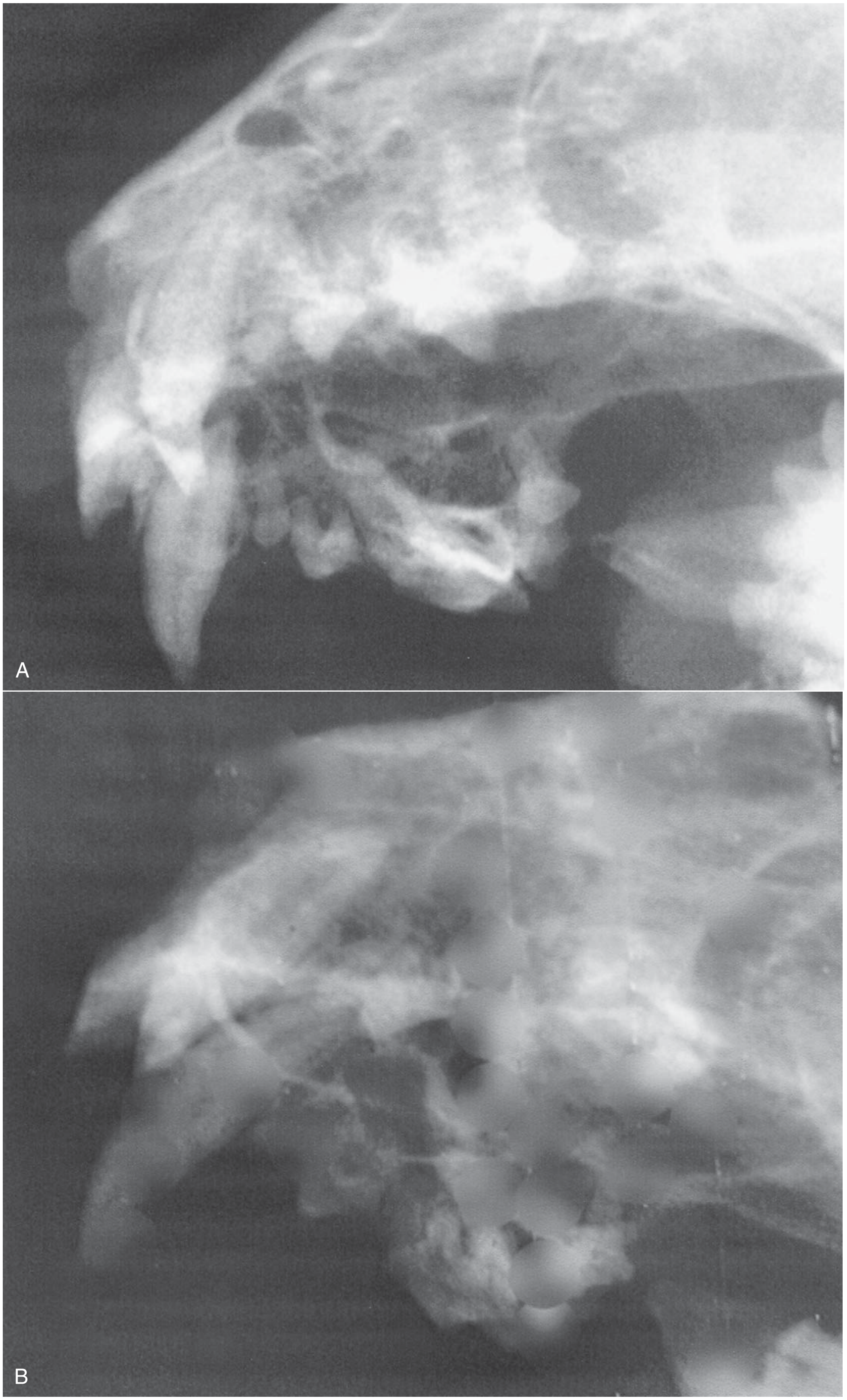

Figure 27-16 • A, Ultraclose, left lateral open-mouth oblique projection of an infected left upper canine tooth in a ferret shows a circular area of bone loss surrounding a partially destroyed root, consistent with a severe periapical abscess with secondary osteomyelitis. **B,** A similar view of the normal right upper canine tooth is provided for comparison.

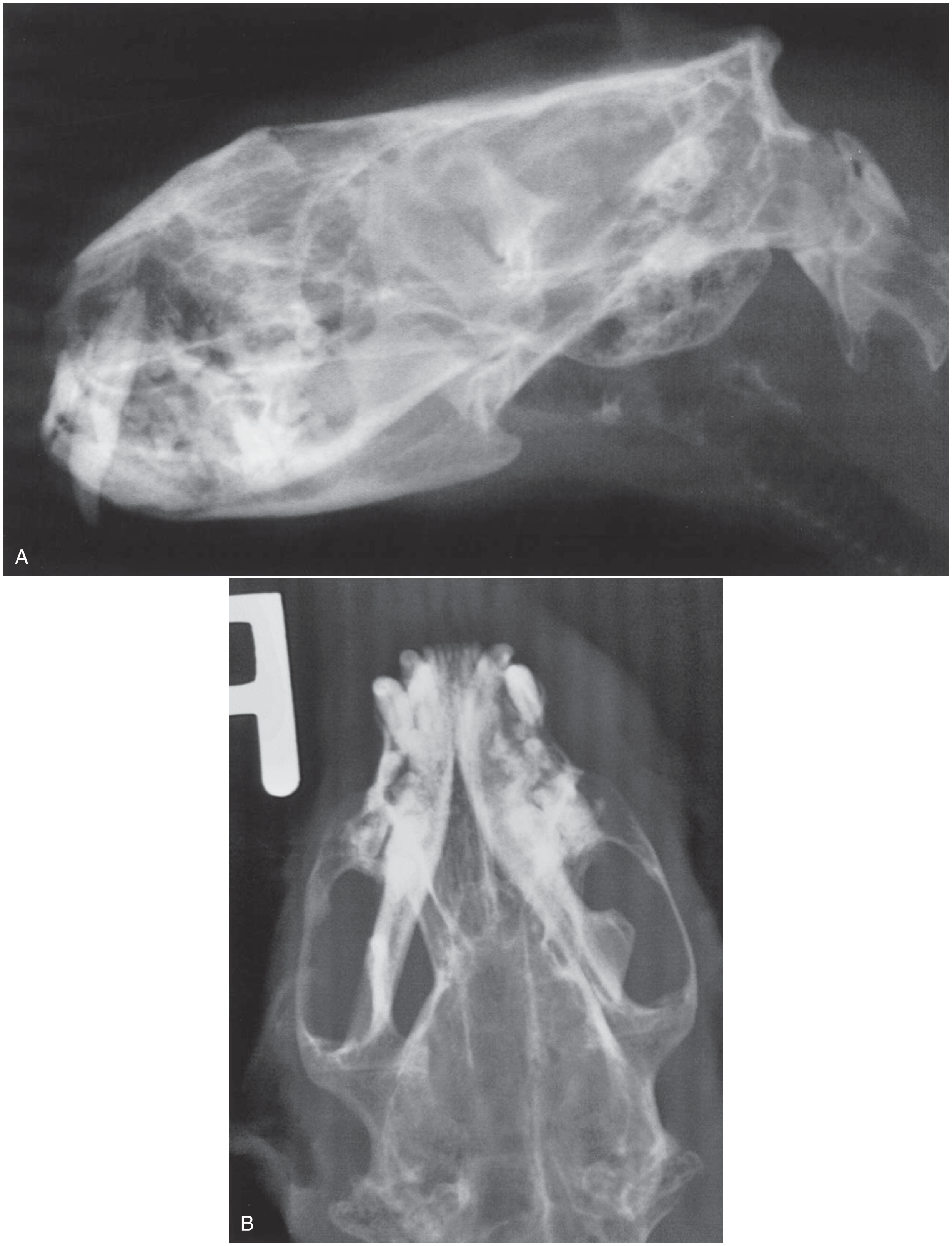

Figure 27-17 • Standard dental series in the ferret shown in previous figures consists of four views: lateral **(A),** ventrodorsal **(B),** left ventrodorsal oblique **(C),** and right ventrodorsal oblique **(D).** The ventrodorsal view was customized by moving the lower jaw slightly to the right, which afforded a clearer view of the left upper canine and surrounding maxilla, which have been partially destroyed by infection. Note the localized, left-sided facial swelling.

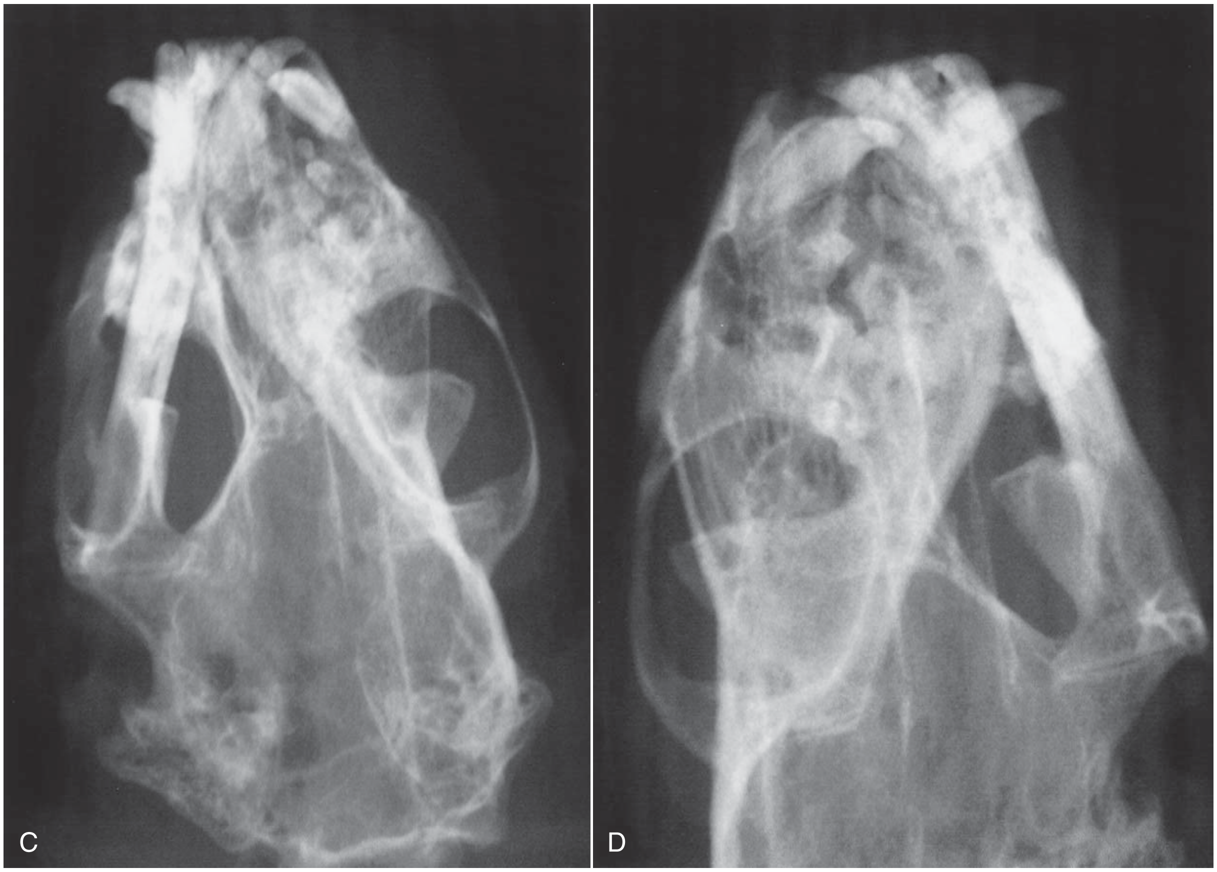

Figure 27-17, cont'd • For legend see opposite page.

Figure 27-18 • A surprisingly fit-appearing ferret does his two-a-day laps in a long hallway outside the small animal treatment room, a part of his rehabilitation program after a spinal fracture.

Chapter 28

Skunks, Squirrels, Raccoons, and Armadillos

The small collection of animals in this chapter does not constitute a taxonomic alliance but rather is a grouping of convenience. The first three, skunks, squirrels, and raccoons, are often found in rural areas, on the fringes of suburbia, and in larger urban parks. Our usual contact with such animals is through the Society for the Prevention of Cruelty to Animals (SPCA), when the SPCA brings an injured animal to us for first aid. Good Samaritans sometimes bring us orphaned young to be cared for until a permanent home can be found. Occasionally, we receive pet skunks or raccoons for a variety of ailments.

NORMAL RADIOGRAPHIC ANATOMY

Squirrel

The skull of the squirrel is its most distinctive feature when comparing it with other comparably sized mammals. In lateral profile, the skull resembles the egg of a small bird, symmetrically rounded caudally and tapered rostrally. Otherwise, squirrels resemble other small rodents, except for their long bushy tails (Figure 28-1).

Skunk

The chest of a skunk resembles that of a dog, with the exception of the heart, which appears much rounder. Both standard projections appear to show left-sided emphasis as one might expect with mitral insufficiency; however, this is normal in a skunk (Figure 28-2).

Because of an ample coat of perithoracic fat, the lung of skunks often appears increased in density and decreased in detail, mimicking pleural fluid or pneumonitis. Extrathoracic fat folds can be quite prominent in the dorsoventral or ventrodorsal projections.

Raccoon

Morphologically and radiographically, the chest and abdomen of raccoons resemble those of dogs (Figure 28-3).

Armadillo

Undoubtedly, the reader is wondering why armadillos have found their way into these pages, given the length and severity of our western Canadian winters, and the fact that their nearest natural habitat is nearly 2000 miles away. I spent a year in Texas while on sabbatical and all too regularly encountered this unusual animal lying on the roadside as I made my daily journey to and from the university. Since that time I have rarely had the opportunity to radiograph an armadillo, so clearly I am not an expert, but I could not resist the opportunity to show and comment briefly on their fascinating radiographic anatomy.

The overlapping protective plating of the armadillo, termed the *carapace*, gives the exterior surface of the animal a highly distinctive saw-toothed appearance. The carapace nearly reaches the cranium, which is disproportionately small compared to the trunk, and lies much further dorsal to the cervical spine than might be imagined. The thorax occupies considerably less of the total trunk length than it does in cats and dogs, an appearance accentuated by its abbreviated sternum.

The heart of an armadillo appears quite rounded in a lateral projection, its caudoventral border frequently concealed by the overlapping diaphragm. In the same view, a pronounced angle typically exists where the diaphragm meets the sternum, falsely suggesting a sternal fracture or diaphragmatic hernia. These appearances are accentuated by expiratory filming (Figure 28-4).

The abdomen of an armadillo is rendered radiographically unique by its armored plates, which

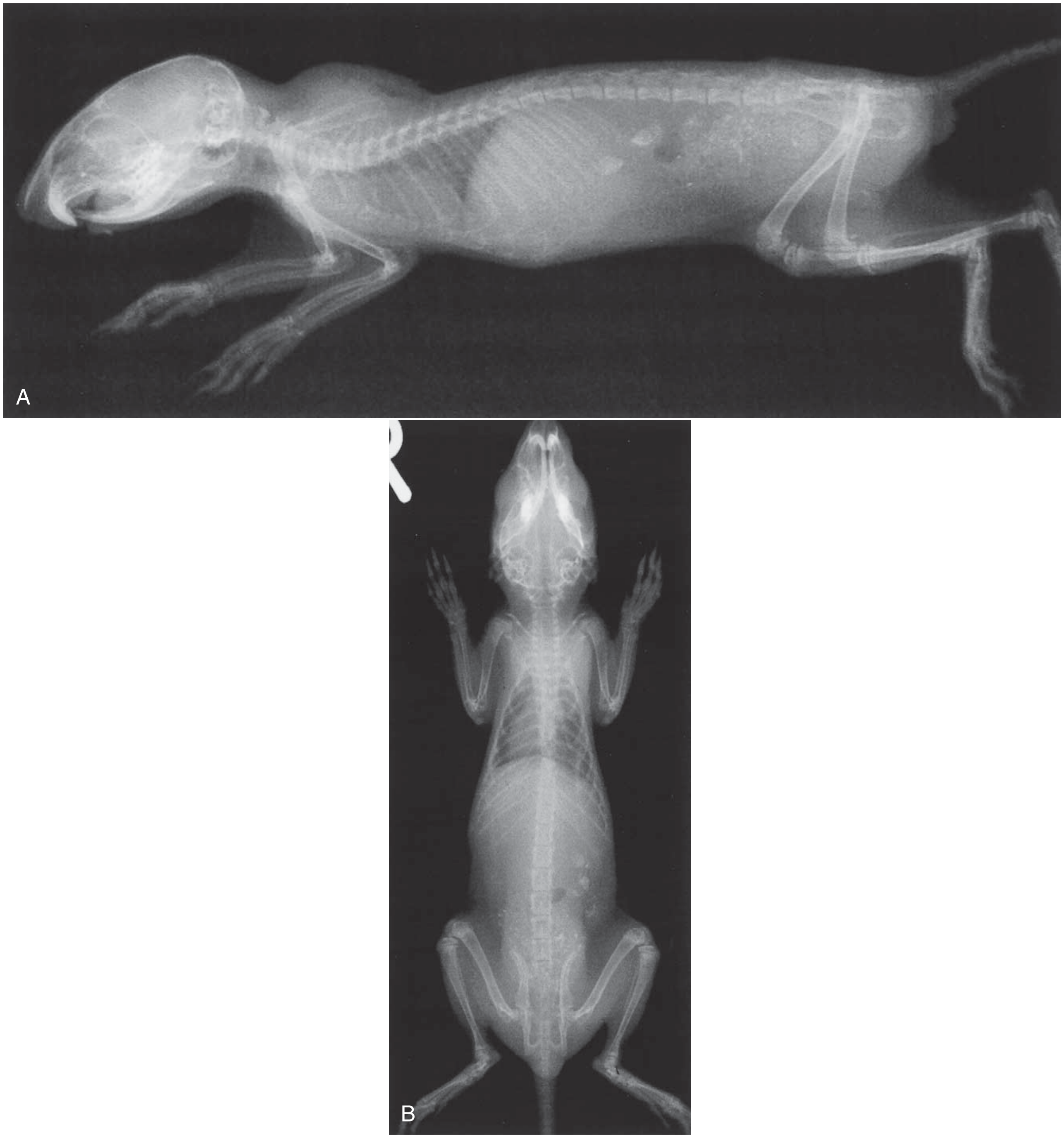

Figure 28-1 • A, Whole-body lateral and dorsoventral **(B)** views of a healthy gray squirrel. The cranial border of the heart is often difficult to discern, as in this instance, because of the animal's diminutive size, tapered thorax, and expiratory filming. If the forelimbs are not drawn fully forward, superimposition of the associated musculature further increases regional density.

produce a pattern of alternating light and dark transverse bands over the length of the torso, the former caused by the plates and the latter by the gaps between plates. The pelvis and hind limbs are also unique and should not be misread as fractures when seen as they are in Figure 28-5, tucked beneath the animal in a dorsoventral radiograph.

▮▮▮ DISEASES

Of the animals considered in this chapter, only the armadillo appears unique. Specifically, osteomyelitis in this species may resemble a malignant tumor, featuring widespread bone destruction, soft tissue swelling, and a *long zone of transition.* A case example is provided in Figure 28-6.

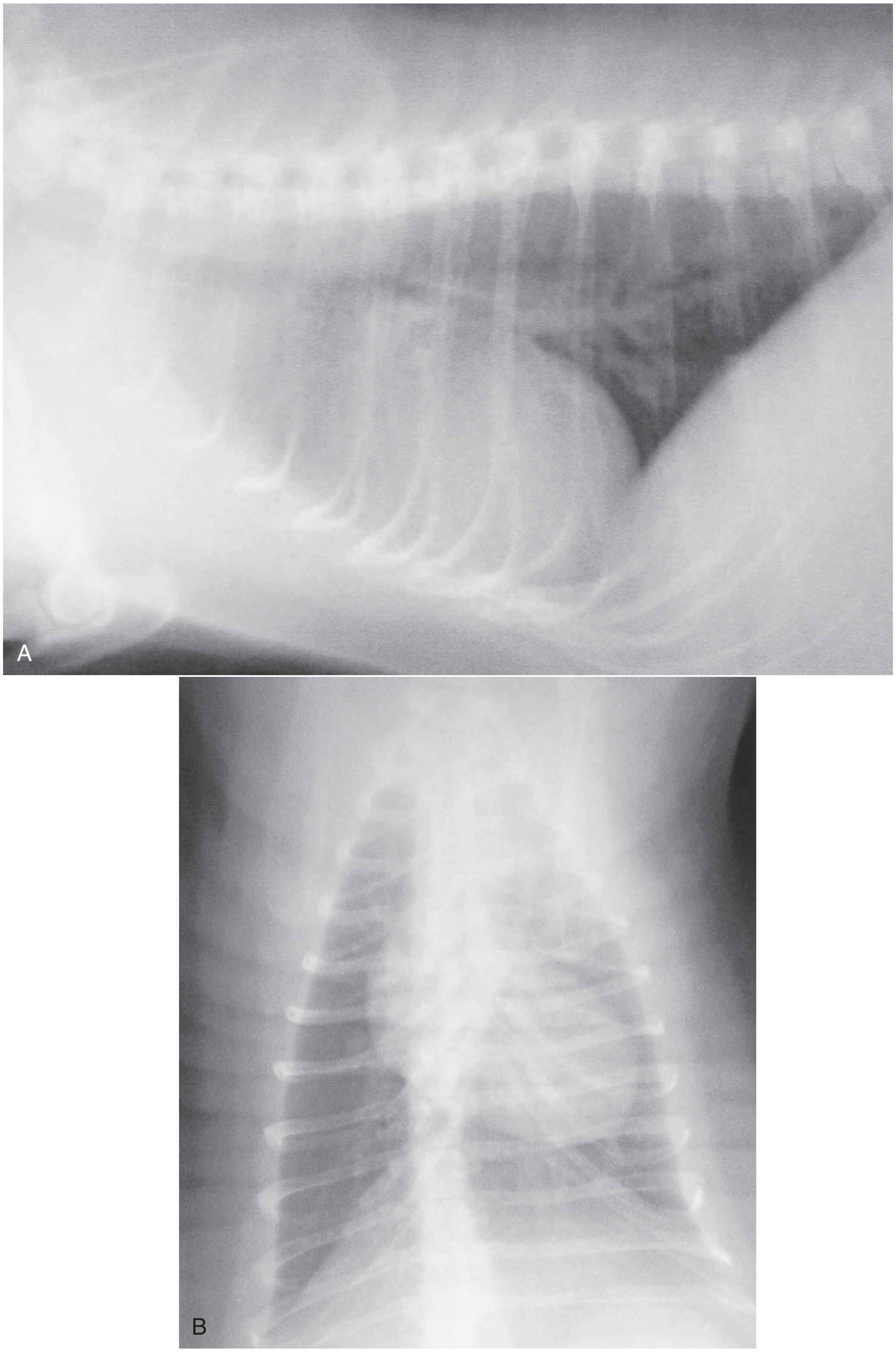

Figure 28-2 • A, Lateral and ventrodorsal **(B)** views of the thorax of a healthy skunk. Note the radiographic features, which are normal for a skunk, but suggest disease in a dog or cat: (1) an enlarged, rather bulbous appearing heart, which is being accentuated in the ventrodorsal projection because of obliquity; (2) fat-grayed lung fields; and (3) prominent extrathoracic fat folds. Blood vessels in the caudal lung lobes (lateral projection) appear overly dense because of *vascular crowding* brought on by expiratory filming. If uncertainty exists as to whether there actually is interstitial lung disease, one can simply check the ventrodorsal view that should appear normal in the case of vascular crowding, which is the case in this instance.

Figure 28-3 • An orphaned raccoon awaiting placement gets its accustomed daily exercise by climbing the links of its enclosure.

Figure 28-4 • Lateral view of the head (partial), neck, and thorax of a healthy armadillo shows the rounded heart, abbreviated lung, overlapping diaphragm, and angular midsternum typical of the species.

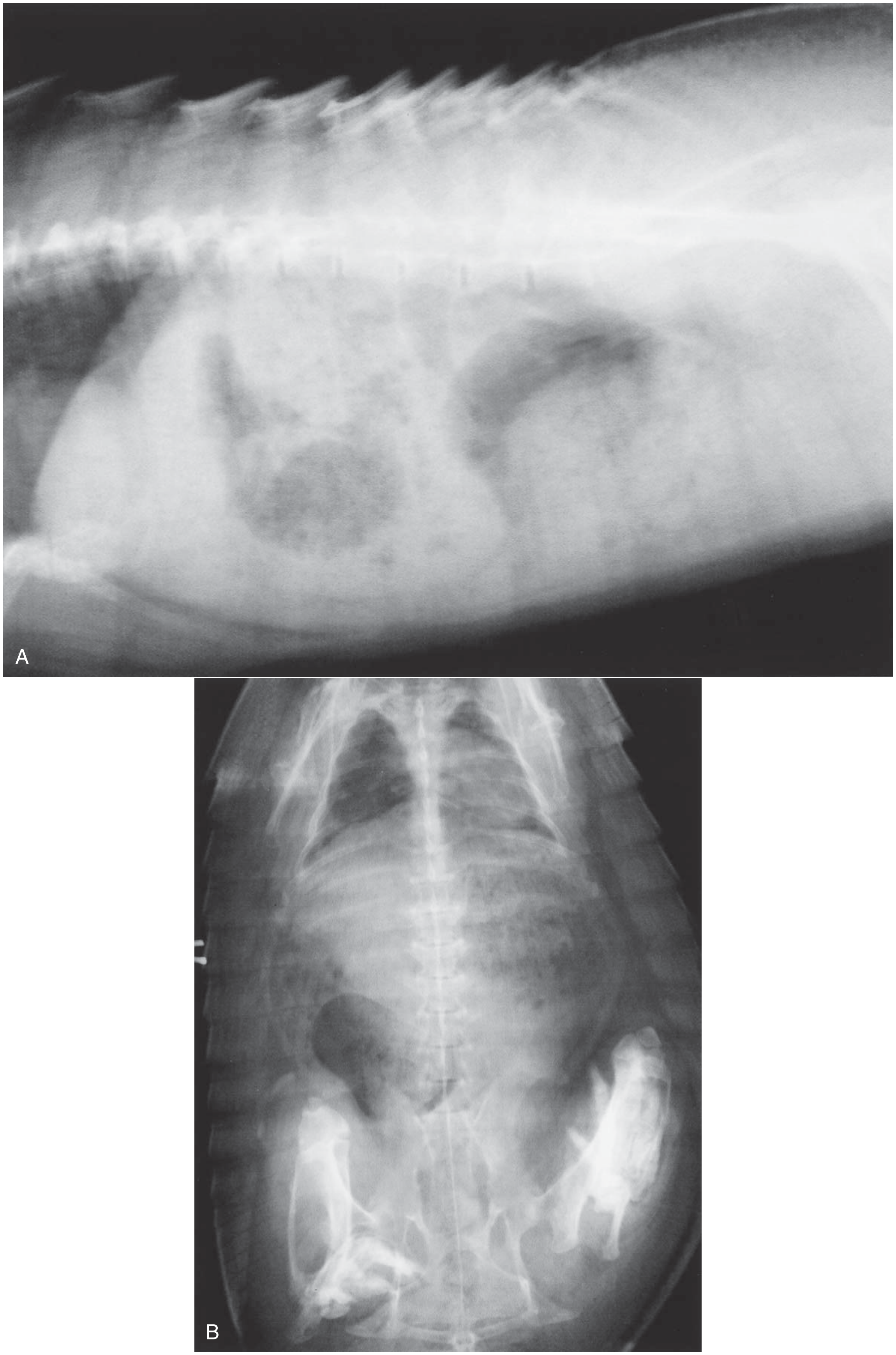

Figure 28-5 • A, Lateral and dorsoventral **(B)** views of a normal armadillo show the normal abdominal banding created by the overlapping plates of the carapace. The unfamiliar appearance of the pelvis and femurs, especially when tucked up under the animal, can lead to an erroneous diagnosis of fracture.

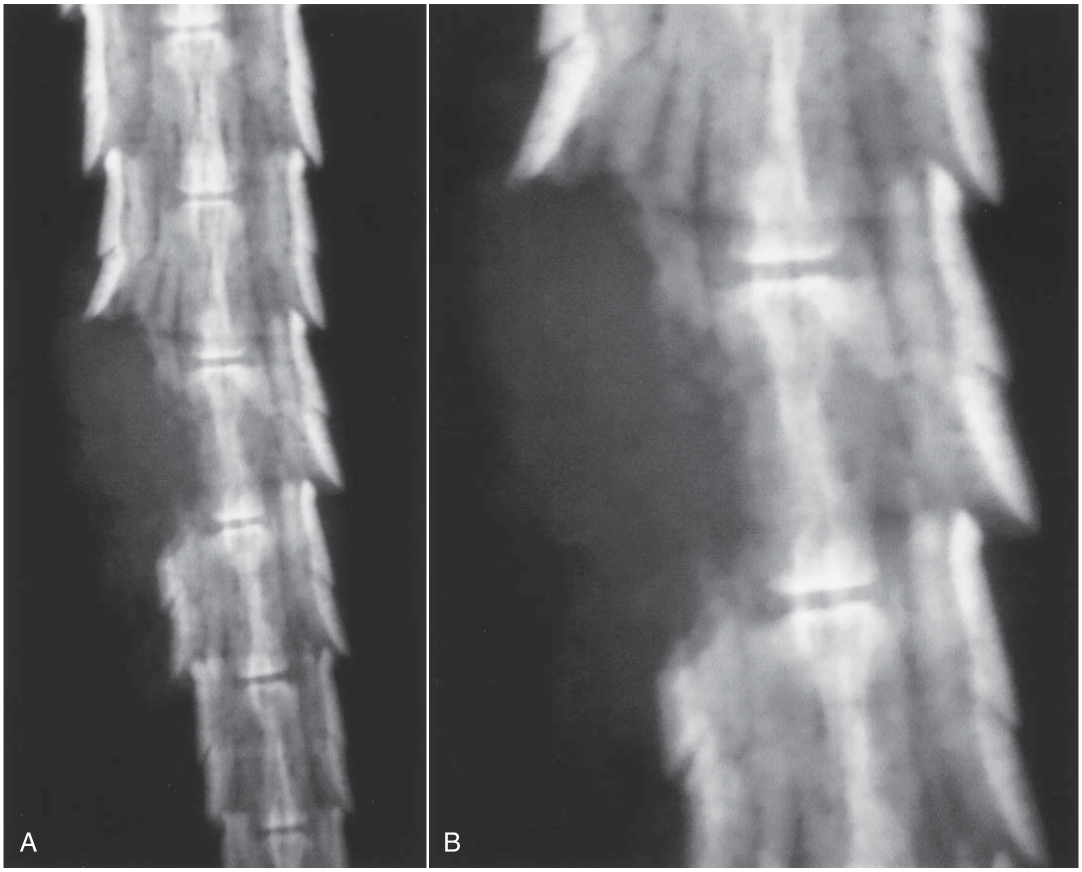

Figure 28-6 • A, Orientation and close-up **(B)** dorsoventral views of the tail of an armadillo show severe destruction of the right lateral aspect of one vertebra and portions of those in front and behind. The adjacent muscle is swollen and deformed. These lesions were presumptively diagnosed as a bacterial infection but obviously share some features of cancer.

Chapter 29

Monkeys and Other Nonhuman Primates

As a veterinary student and later as a veterinarian, I worked with a variety of monkeys and other nonhuman primates. As a radiologist, I occasionally see monkeys from our local zoo, but I rarely see pet monkeys. Once or twice, I have radiographed circus monkeys. I have no dealings with research facilities, and animals from the zoo are invariably accompanied by their keepers and are anesthetized by experienced zoo veterinarians before being radiographed.

Having worked in a large metropolitan zoo and spent time as an observer in a regional primate center, I have gained enormous respect for these animals but perhaps the most lasting impression has been of their strength and agility. Accordingly, I must advise great care and caution when radiographing nonhuman primates.

For example, an inexperienced veterinarian would be well-advised to obtain expert advice before attempting to handle, restrain, anesthetize, and radiograph even a small primate. Better yet, the handler or experienced owner should assist with the primate. Zoos and veterinary colleges can be most helpful in this regard. The help is out there, and veterinarians should take advantage of this help and will be glad they did.

NORMAL RADIOGRAPHIC ANATOMY

Morphologically, monkeys and other nonhuman primates resemble people, more or less. They have hands, fingers, feet, and toes. Many have prehensile tails that are capable not only of grasping, but of bearing the entire weight of the animal. Some parts, for example, hands, function almost exactly as do their human counterparts, while other parts of the anatomy, like the lung, more closely resemble those of dogs and cats (Figure 29-1).

The skull of a nonhuman primate, for example, a Capuchin monkey, lies somewhere between that of a human and a dog. The predominant anatomical feature is the large hemispherical cranium, set above and behind a foreshortened, doglike face. The neck is short like that of a human.

The trunk is quite elongated, not unlike that of a cat. Seen in lateral profile, the thorax appears relatively small compared to the abdomen, which is tapered caudally (Figure 29-2). From the ventrodorsal perspective, the primate heart bears a strong resemblance to the human heart.

The limbs are disproportionately long in comparison with the torso. Likewise, the hands and feet appear large compared to the rest of the forelimbs and hind limbs. The fingers often appear distinctly curled when radiographed, even in an anesthetized animal (Figures 29-3 and 29-4).

INJURIES

Monkeys are subject to most of the same injuries as people, as well as a few that are unique to their aerial activities. For example, a baby monkey loses its grip on its mother, falls to the floor of its enclosure, and strikes its head. The baby appears stunned but otherwise alright. A few weeks later a bump appears on the top of its head, which gradually enlarges. Skull radiography reveals an expansive lesion on the upper half of the cranium, the result of intradiploic hemorrhage or intraosseous hematocele. Most such lesions, although alarming, are harmless and largely disappear with advancing age.

DISEASES

Nutritional Secondary Hypoparathyroidism

Over the years, the most common disease I have diagnosed in pet primates has been nutritional secondary

Figure 29-1 • Full-length lateral view of an unconscious Capuchin monkey. Note the protruding brow ridge, elongated face, short neck, tapered, catlike torso, and long arms, hands, legs, and feet.

hyperparathyroidism, which is typically evidenced by decreased bone density. Many of these animals present with acute limb pain or lameness, which is the result of an insufficiency fracture. Depending on the duration of their disease and other circumstances, some animals may have had previous fractures. Often, these are of the folding variety, with or without obvious deformity, or alternatively may appear as overt malunions.

Hypovitaminosis D

Vitamin D deficiency causes similar skeletal lesions—some quite severe—including pronounced spinal curvature and collapse of the pelvic canal (Figures 29-5 through 29-7). Deformity of the pelvic canal and, particularly, overt collapse may lead to chronic constipation and in the case of females, mechanical dystocia. After dietary correction, some or all of the previously mentioned long bone changes may disappear or at least partially regress. Unfortunately, the spinal and pelvic deformities are in large part irreversible.

Heart Disease

Apparently, primates are subject to most of the congenital and acquired diseases seen in humans. As with humans, primates, including the Great Apes, may develop both the primary and secondary forms of dilated cardiomyopathy (Figure 29-8).

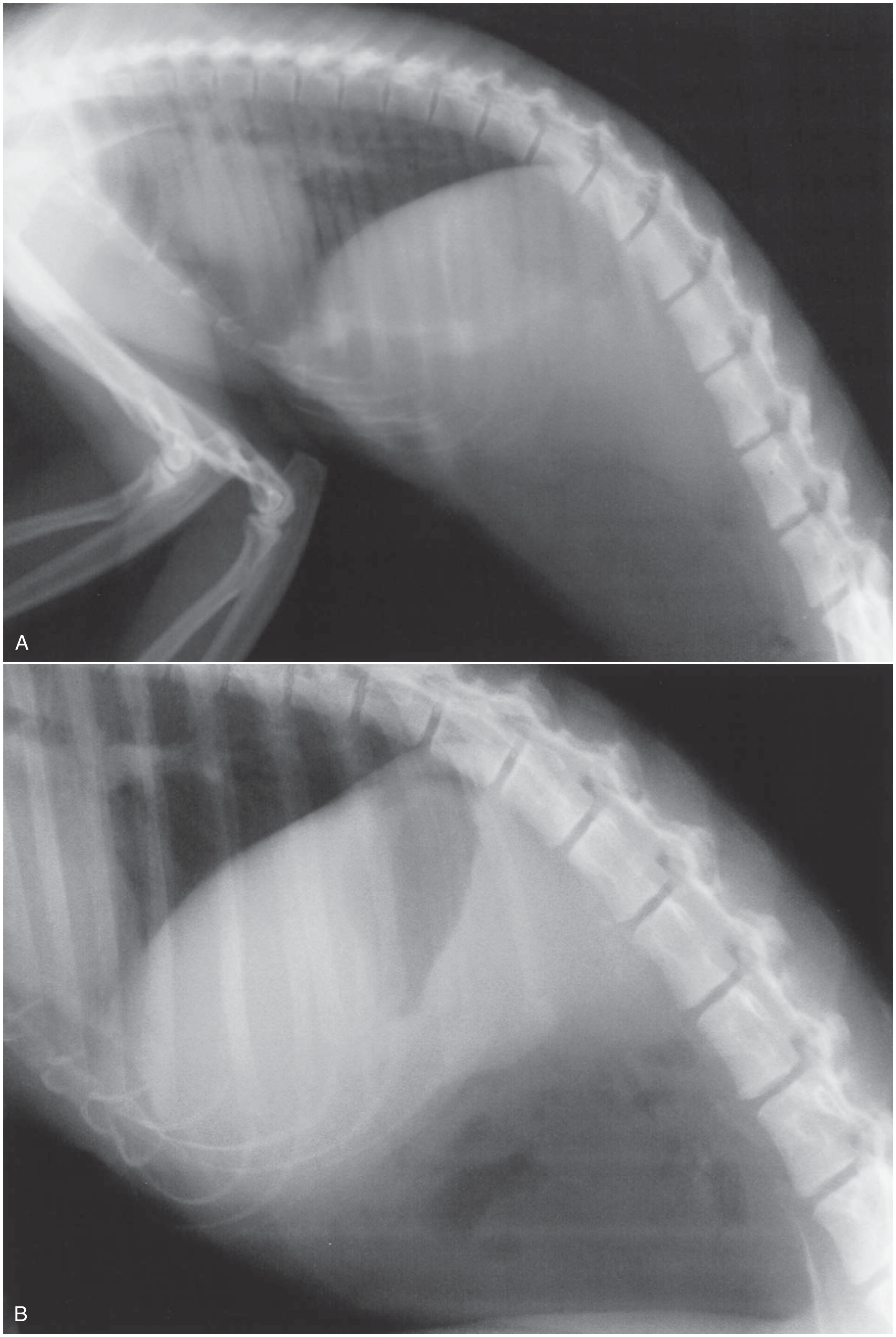

Figure 29-2 • A, Lateral and lateral close-up **(B)** views of the trunk of the monkey shown in Figure 29-1.

Figure 29-3 • Lateral view of the forelimbs, wrists, and hands of the monkey shown in Figures 29-1 and 29-2. Note the long slender curled fingers.

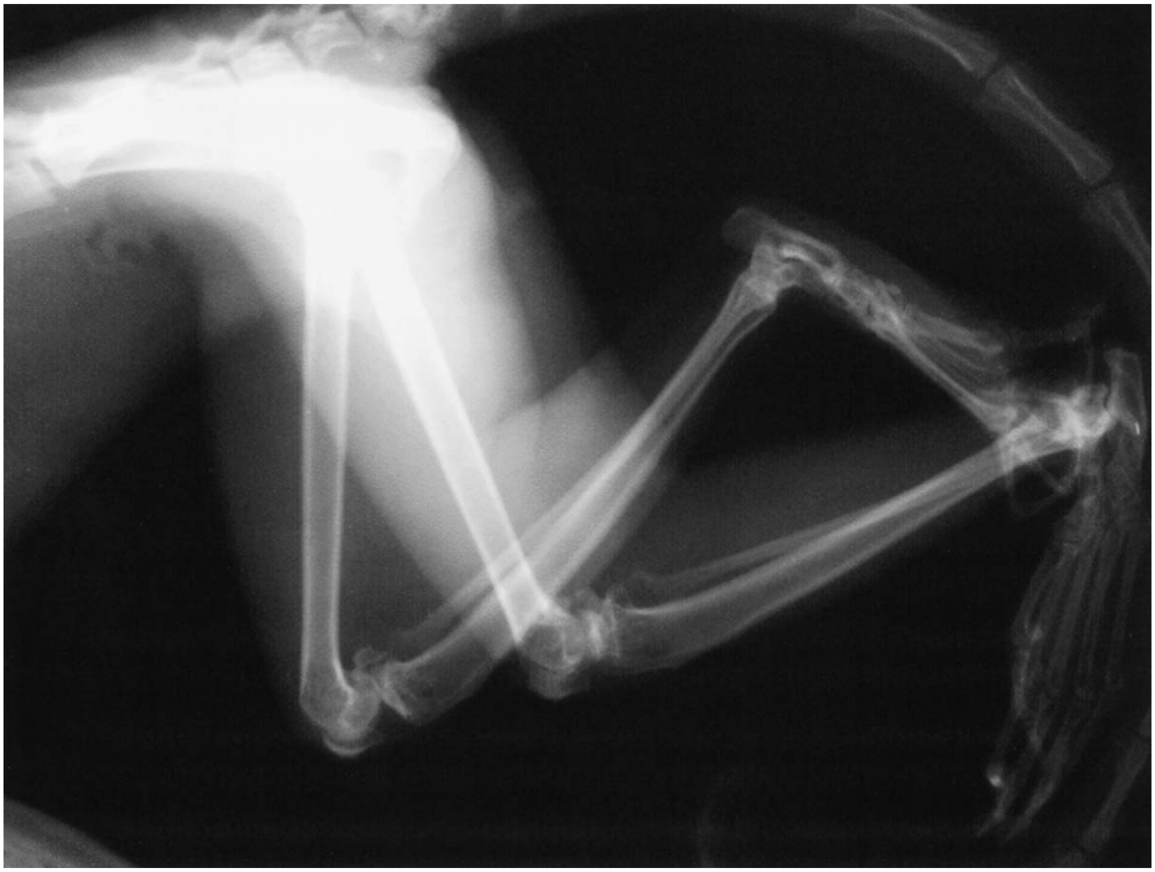

Figure 29-4 • Lateral view of the hind limbs of the monkey shown in Figures 29-1, 29-2, and 29-3. Note the disproportionately large feet.

Figure 29-5 • Close-up view of the lumbar spinal region of an immature Wooly monkey with advanced hypovitaminosis D. Note the pronounced swayback, pelvic collapse, and bilateral femoral curvature.

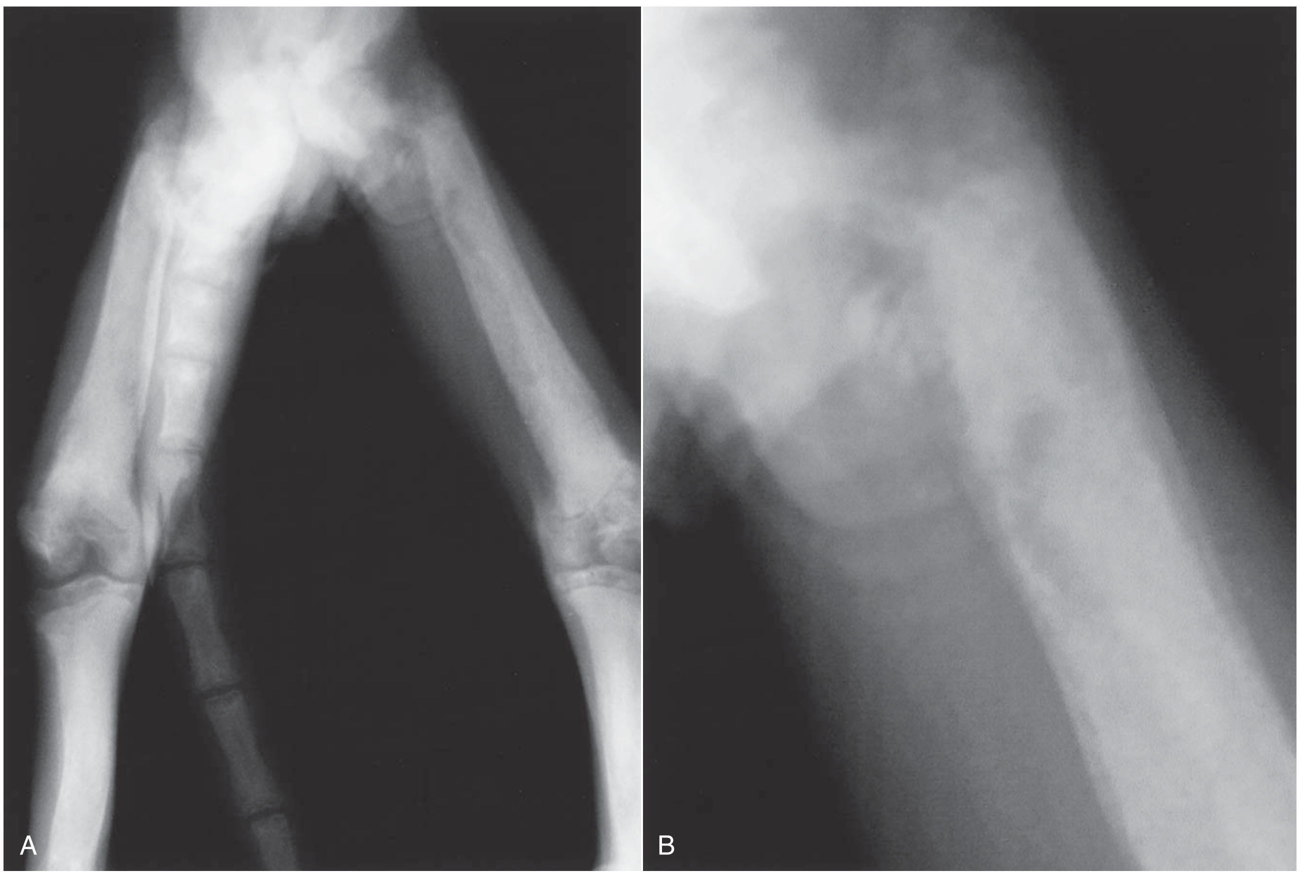

Figure 29-6 • **A,** Ventrodorsal view of the pelvis, hips, and femurs of the Wooly monkey shown in Figure 29-5 shows multiple abnormalities, including (1) collapsed pelvis, (2) multiple femoral insufficiency fractures, (3) disorganized new bone on both the interior and exterior surfaces of the left femur *(right)*, and (4) poor corticomedullary distinction. **B,** Close-up view of the left hip and proximal femur shows the distinctive "apple core" appearance of a subacute femoral neck fracture and the typical washed-out appearance of nutritionally deprived bone that eventually succumbs to insufficiency fracture.

Figure 29-7 • Six-month progress, ventrodorsal view of the pelvis, hips, and proximal femurs of the Wooly monkey shown in Figure 29-5 reveals little or no improvement in the appearance of the pelvis; however, all of the fractures appear to have healed, and the femurs have assumed a more normal appearance.

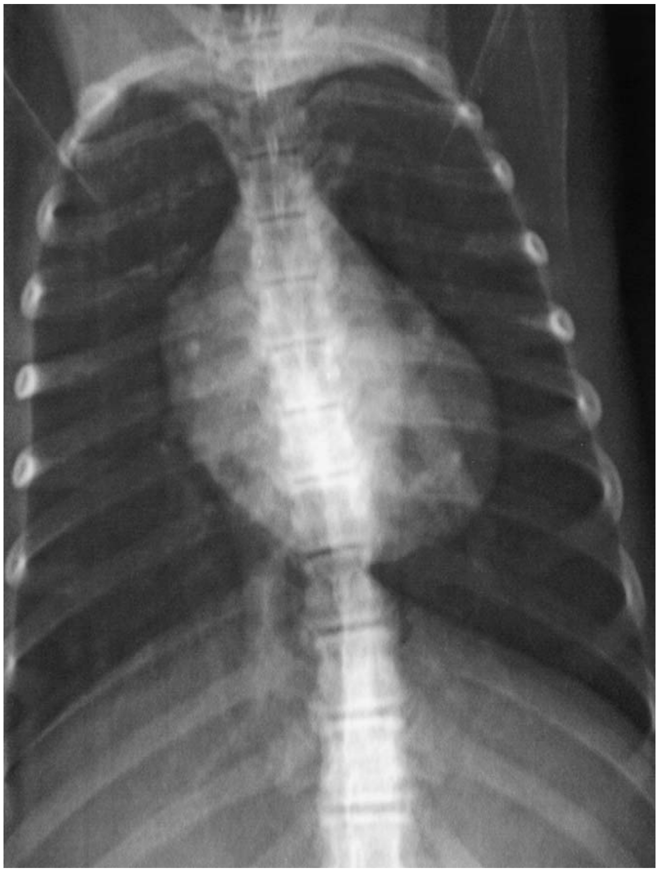

Figure 29-8 • Erect ventrodorsal image of a Capuchin monkey with presumed primary dilated cardiomyopathy but no current signs of failure.

Chapter 30

Acreage Pets: Alpacas, Llamas, Miniature Horses, Miniature Goats, and Pot-Bellied Pigs

Beginning in the late 1980s and early 1990s, an increasing number of families moved from our city out into the "country." In fact, these urban pioneers moved into *transition lands* midway between the city and surrounding farmlands, which provided the relative solitude of country living, albeit on a much smaller scale, with the amenities of the nearby city.

At about the same time, the profitability of nontraditional livestock, such as pot-bellied pigs, miniature horses, ostriches, llamas, alpacas, and elk, was coming under increasing economic scrutiny. As ranchers began to divest themselves of these exotic species, often at bargain-basement prices, acreage dwellers were quick to react. As a result, many of these animals found themselves living the good life, although not always in the care of people who understood their unique needs.

Inevitably, these animals required veterinary care, including medical imaging. Initially, our imaging efforts were almost entirely devoted to sonographic conformation or denial of pregnancy, especially in pot-bellied pigs and miniature horses, but soon expanded into a full-fledged medical imaging service. A selective sampling of the various disorders afflicting these animals follows, with examples of how we go about getting the desired images.

ALPACAS AND LLAMAS

Alpacas and llamas are a kind of camel, or *Camelids*. They are distinguished from one another by two things: their size and hair coat. The llama is two to three times as large as an alpaca and has a coarse hair coat, as opposed to the alpaca's fine fleece. These animals also differ in purpose: the alpaca is prized for its fine coat, and the llama is valued for its strength and endurance. In other words, the llama might be termed the *ship* of the Andes, and the alpaca could be considered the *sheep* of the Andes. Llamas are the more aggressive of the two animals. Both species are quite inquisitive (Figure 30-1) and seem to enjoy the company of humans (Figure 30-2).

Not unexpectedly, both animals seem to suffer from the same diseases: crooked legs (angular limb deformities), dietary deficiencies (metabolic bone disease), gastrointestinal impactions and foreign bodies, and a varied assortment of injuries, including fractures and infections.

Radiography

Alpacas are rather timid animals that often become apprehensive when brought to the Radiology Department (Figure 30-3). A *cria* (baby alpaca) is best brought to medical imaging accompanied by the mother alpaca (Figure 30-4). A sizable juvenile or adult is best imaged in a large animal x-ray facility (Figure 30-5), whereas a cria may be x-rayed in either a large or small animal suite (Figure 30-6).

Diseases

Limb Curvature and Deformity. The legs of most newborn alpacas and llamas are to some degree crooked when born. However, these natural angulations soon disappear as the cria grows and gains strength. It is only when such deformities persist that veterinary advice is usually sought. True angular deformities may involve one or both legs and nearly always the forelimbs. Their precise cause is often unknown. In some instances, curvature in the distal radius is evident, incriminating asymmetrical development of the distal radial physis (Figure 30-7).

Less frequently, one or more carpal bones exhibit abnormal morphology: increased porosity, diminished size, and abnormally round shape, touching off a diagnostic debate as to whether the animal's carpi are

Figure 30-1 • A pair of young llamas stare inquisitively at the camera.

Figure 30-2 • An alpaca lays quietly as its student attendants look on.

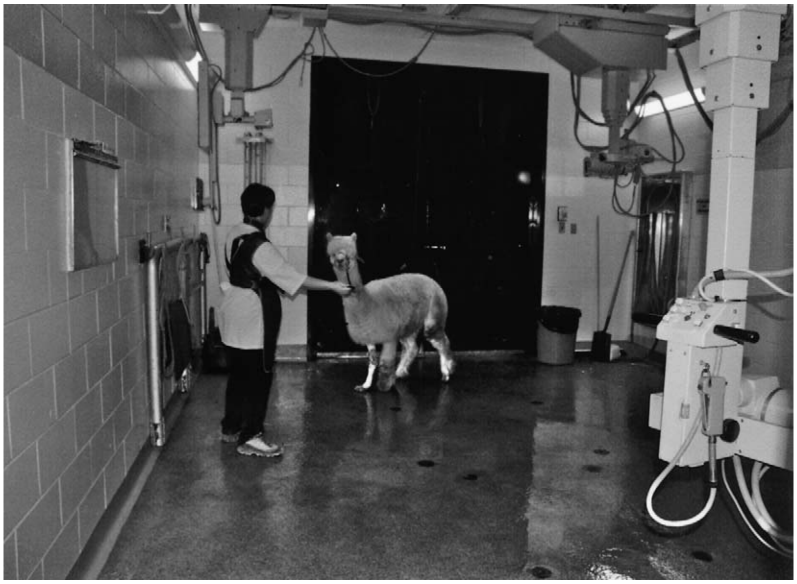

Figure 30-3 • An alpaca balks as it enters radiology and sees the imposing, ceiling-mounted x-ray machine.

Figure 30-4 • A pair of young animals in the Radiology Department for the first time are comforted by the presence of their mother.

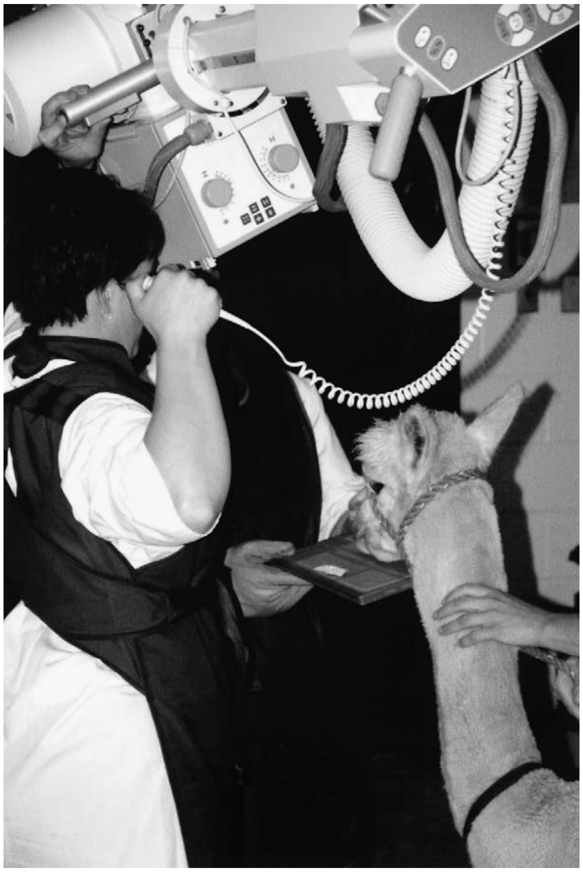

Figure 30-5 • An alpaca has its head positioned over an x-ray cassette just before having an oblique projection of its mandible made.

Figure 30-6 • A young alpaca and its student handlers pause before entering the small animal x-ray suite.

Figure 30-7 • Frontal view of the midforelimbs of an immature alpaca centered on an imaginary perpendicular line drawn through the center of the pectoral muscles. In this view, standardized to the midsagittal line of the animal's trunk, it is not only possible to determine what degree of angular deformity exists (varus/valgus) but as important, to determine whether there is also axial or *torsional* deformity. This is termed the *Nancy view* in recognition of the radiology technician who assisted in its development and subsequent validation.

premature, immature, or "dysmature." In the latter instance, I never cease to be amazed at how often *normal* carpal bones are mistakenly diagnosed as hypoplastic simply because the viewer is unfamiliar with the projectional variations that typically accompany limb curvatures.

Occasionally, limb curvature is seen, in which the affected bones exhibit the characteristic changes of *rickets*: flared metaphyses and abnormally widened and irregular growth plates, which typically are found throughout the appendicular skeleton (Figure 30-8). Unlike the simple *valgus* and *varus* curvatures seen with asymmetrical physeal growth, the rickets-like cases show more complex deformities that often include axial angulation. Unlike simple carpal (or combined carpal-fetlock) curvatures, other important joints, such as the hips, are also involved (Figure 30-9).

Congenital and Traumatic Dislocation of the Elbow. As crias grow, one or more of their joints may appear to be developing abnormally, usually indicated by some sort of nonpainful mechanical lameness that often involves one or both elbows. Radiographically, it is usually apparent the joint is abnormal, especially if the opposite limb is normal and can be used for comparison, but the precise cause of the deformity may be unclear.

Congenital dislocations of the elbow usually exhibit the following radiographic features: (1) complete dislocation of the humeroradial joint, (2) hypoplasia of the radial head, and (3) a pronounced cranial curvature of the olecranon.

Traumatic dislocation is also characterized by luxation of the radial head but can usually be distinguished from congenital dislocation by the presence of a *false joint* formed with the distal humeral shaft (as seen in the flexed lateral projection) and marked hypoplasia of the distal humeral epiphysis (Figure 30-10). Additionally, a cria with a traumatic dislocation of its elbow usually cannot fully extend its injured leg, unlike an animal with a congenital luxation.

Both congenital and traumatic dislocations of the elbow eventually lead to dramatic changes in the appearance of the involved bones, particularly their cortices, which may become asymmetrically thick on the load-bearing side. In the proximal ulna, participation in the remodeling process is most evident in the semilunar notch, which becomes intensely sclerotic.

Osteomyelitis. The radiographic manifestations of osteomyelitis are no different in Camelids than in other mammals: bone destruction, cavitations, sequestration, and a typically unsuccessful attempt by the host to wall off the infection with new bone. Sequestra usually occur in bones surrounded by minimal musculature, such as the large metacarpal and metatarsal bones, as occurs in horses (Figure 30-11).

Infections also occur commonly in the lower jaw, usually secondary to dental infection (Figure 30-12)

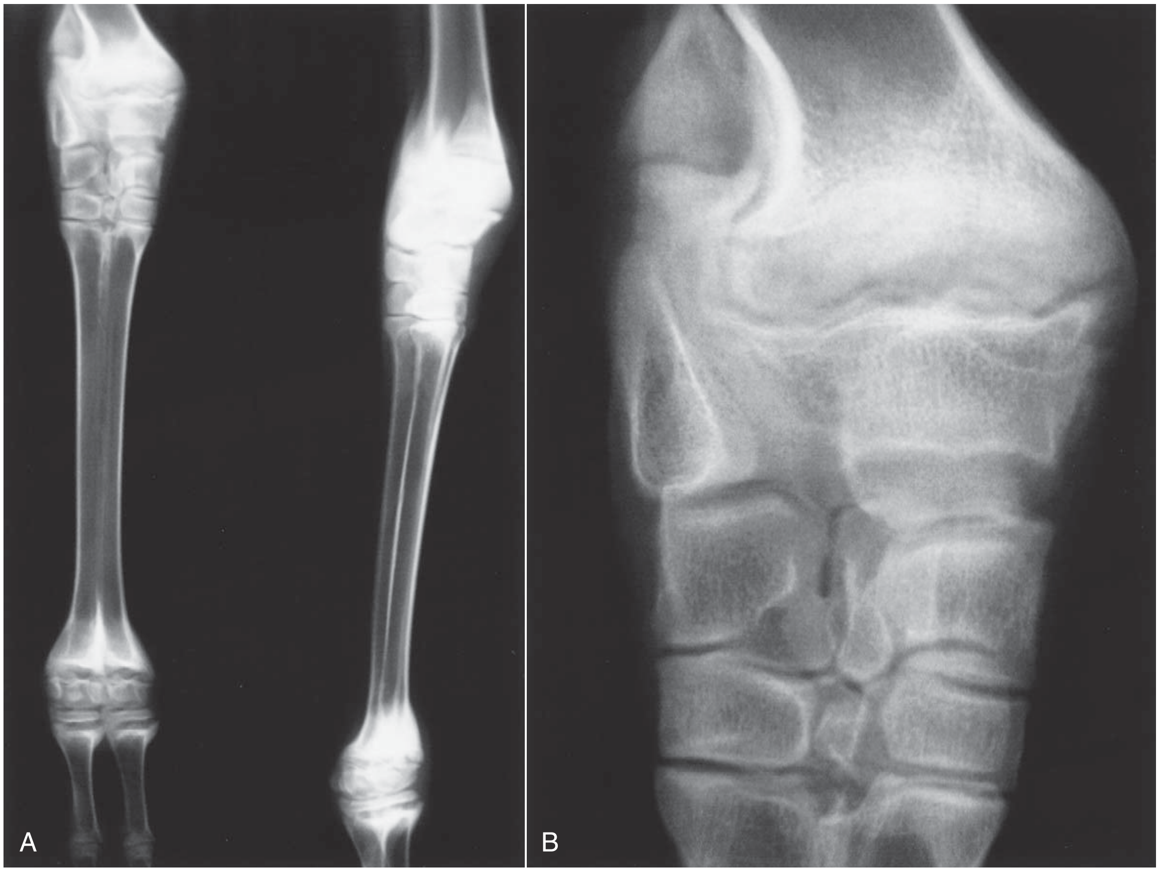

Figure 30-8 • **A,** *Nancy view* of a young alpaca with suspected rickets, which is affecting all of its appendicular growth plates to the extent that the animal's forelimbs (shown here) and hind limbs are quite crooked. **B,** A close-up view of the right carpus shows flaring of the distal radial and ulnar metaphyses, in addition to widening ectasia of the associated growth plates.

Figure 30-9 • Coxal joints of a young alpaca with suspected rickets show marked flaring of the proximal femoral metaphyses in conjunction with widened, irregular growth plates.

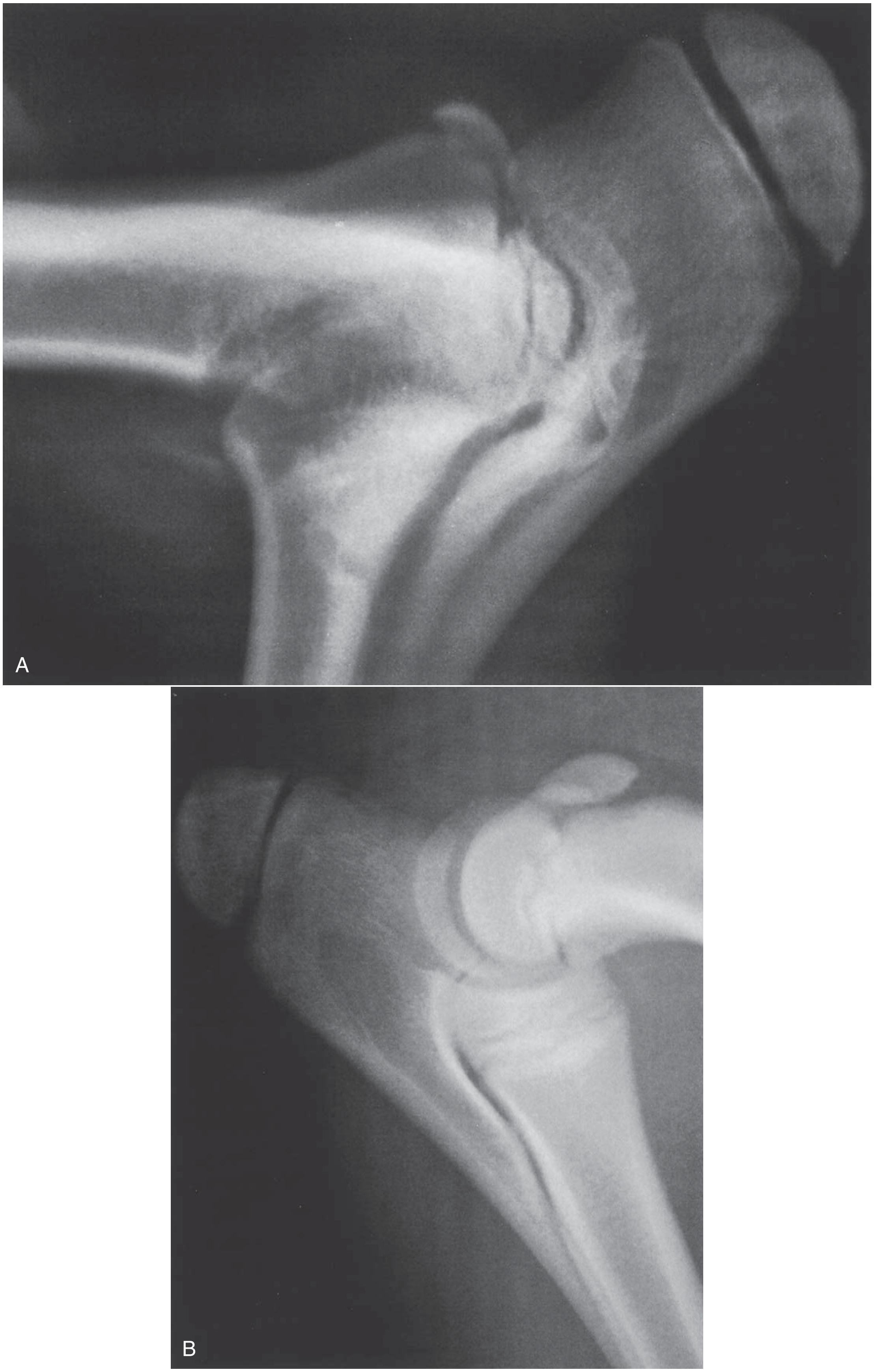

Figure 30-10 • A, Radiograph of a young llama with a suspected old injury to its left elbow shows (1) a dislocated humeroradial joint with formation of a *pseudoarthrosis*, (2) hypoplasia of the distal humeral epiphysis and medial epicondyle, (3) sclerosis of the semilunar notch of the ulna, and (4) abnormally thickened interior radial and ulnar cortices. **B,** A comparable view of the animal's normal right elbow is provided for comparison.

Figure 30-11 • Lateral view of the midtibial body of a juvenile alpaca shows a sequestrum, which is the result of an earlier devascularizing injury to the overlying soft tissue. The lesion features all of the classic elements: a sequestrum, involucrum, and cloaca.

Figure 30-12 • Close-up view of a badly abscessed mandibular cheek tooth showing extensive cortical destruction and accounting for associated drainage.

and less frequently from wounds or systemic infection (Figure 30-13).

Nasolacrimal Duct Obstruction. Llamas and alpacas have more than their share of nasolacrimal disease. When present or suspected, the nasolacrimal system is best evaluated by opacifying it with contrast solution, a procedure termed *dacryorhinocystography*. A case example is shown in Figure 30-14.

A plain film should be done first (as in sialography) to ensure adequate radiographic technique and positioning. The duct should be manipulated and injected with great care. A nonionic, diagnostic iodine solution should be used, and care should be taken to not overfill the duct. If injection pressure seems abnormally high, it should not be forced; rather a radiograph should be made and then an attempt made to identify the cause. The opposite side should be used as a control (as required), and the contrast should be flushed out of the system once the necessary images have been obtained.

Gastrointestinal Impaction and Foreign Body. Gastrointestinal blockage, either temporary or permanent, often leads to colic. Most foreign bodies have a similar effect, with those in the stomach often leading to vagal indigestion. Radiography can prove helpful, especially in identifying a foreign body, such as a wire, or a localized or regional impaction (Figure 30-15).

▮▮▮ MINIATURE HORSES

To date, our work with miniature horses has been confined to the sonographic confirmation of pregnancy (Figure 30-16) and to a lesser extent the assessment of colicky abdomens.

▮▮▮ MINIATURE GOATS

We occasionally image pet goats, as well as miniature dairy goats. These are small, sturdy animals that are a great deal easier to handle than their full-sized counterparts (Figure 30-17). Miniature goats are subject to the same diseases as standard-sized goats, including pneumonia, which in some instances can be quite severe, leading to abscess, perforation, and pneumothorax (Figure 30-18).

▮▮▮ POT-BELLIED PIGS

The breeding and rearing of pot-bellied pigs have not proved economically profitable in western Canada, and consequently, the popularity of these animals has plummeted. During their halcyon days, we regularly performed ultrasound on these unique pigs for pregnancy confirmation but no longer do this. Now, the waning population of pot-bellied pigs resides almost exclusively on acreages as pets (Figure 30-19).

Anatomically, pigs, including miniatures such as the pot-bellied variety, differ from other farm animals in their lungs, limbs, and skulls.

The lungs of these pigs contain both an exterior and interior pleura, the later dividing the lung into something resembling *macrolobules*. This generous complement of intrapulmonary pleura gives the porcine lung its normal linear density pattern that may cause the inexperienced to diagnose nonexistent lung disease.

The limbs of pigs are short and stout, almost dwarflike. The skull is massive, featuring immense jaws with formidable teeth and in the case of boars, long tusks.

Injuries and Diseases

Pot-bellied pigs, like other acreage pets, are subject to the occasional attack by roving dogs, sustaining bite wounds that can require veterinary attention. But the ailment encountered most often is septic arthritis, which in its severest expression involves the associated bones, and thus is more accurately termed *septic arthritis-osteomyelitis*.

Infection may be introduced either through the systemic circulation, in the event of a bacteremia, or by direct inoculation in the case of a penetrating wound. Either way, the bacteria enter the joint and typically colonize the synovium, inflaming it and causing the formation of an excessive volume of synovial fluid, which visibly swells the joint.

If the swelling becomes severe enough, a sinus may develop in the overlying skin, providing both drainage and often some measure of pain relief. But the respite is short-lived, however, because the sinus soon seals closed, precluding further drainage and allowing the pus to re-form. Concurrently, the bone begins to undergo dissolution, often on the epiphyseal side of the growth plate in the case of very young animals and on the metaphyseal side of the physis in older individuals.

Sesamoids and secondary growth centers, along with large condyles, seem particularly susceptible to destruction. With sufficient bone loss usually comes pathological fracture, whereas devascularization encourages the formation of one or more sequestra. Many of the foregoing manifestations of septic arthritis-osteomyelitis are exemplified in the case examples in Figures 30-20 through 30-22.

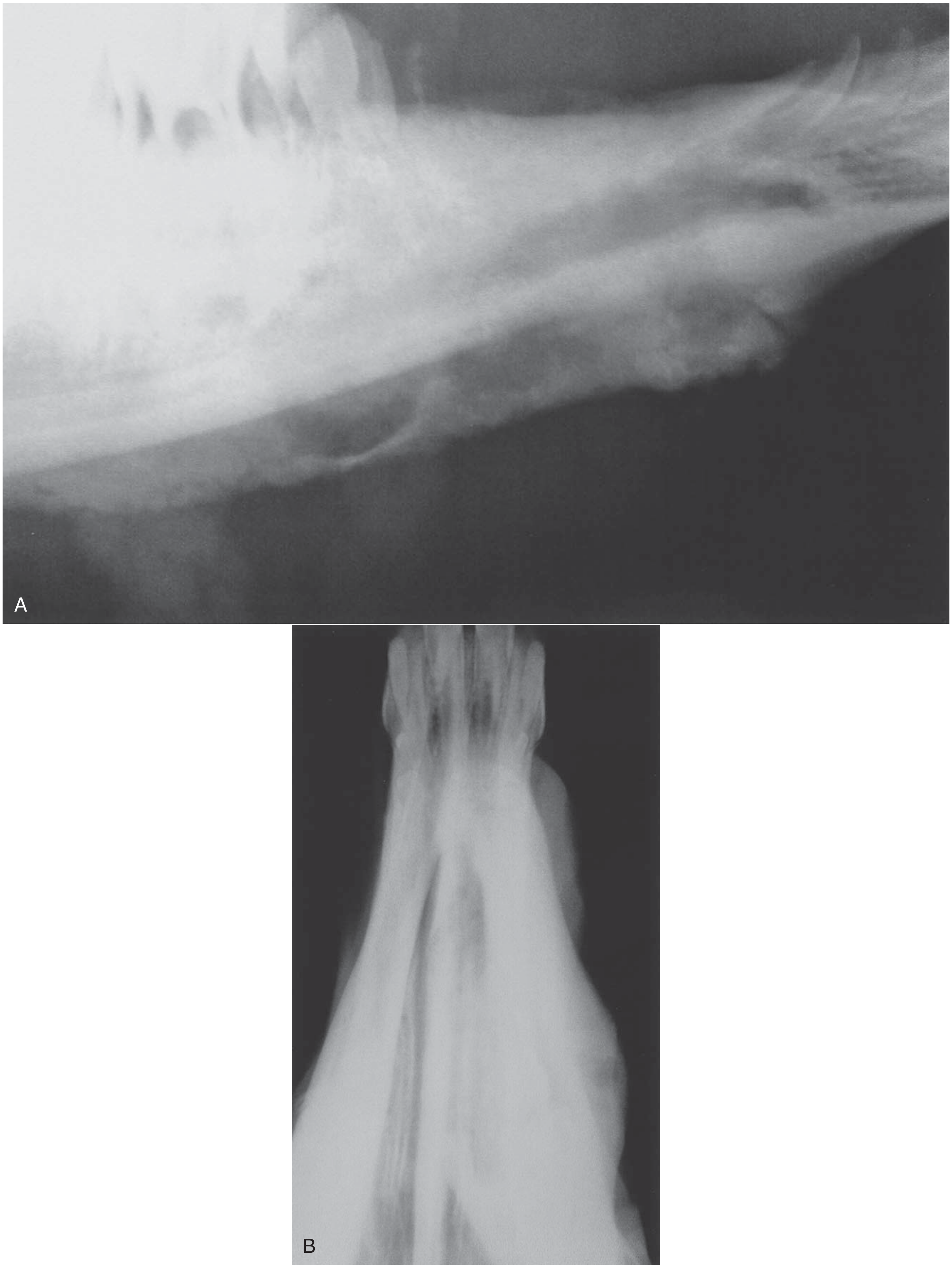

Figure 30-13 • A, Close-up lateral and right dorsoventral oblique **(B)** views of the right central mandible show a large, elaborately cavitated region of new bone spanning much of the length of the right ramus indicative of chronic infection such as actinomycosis.

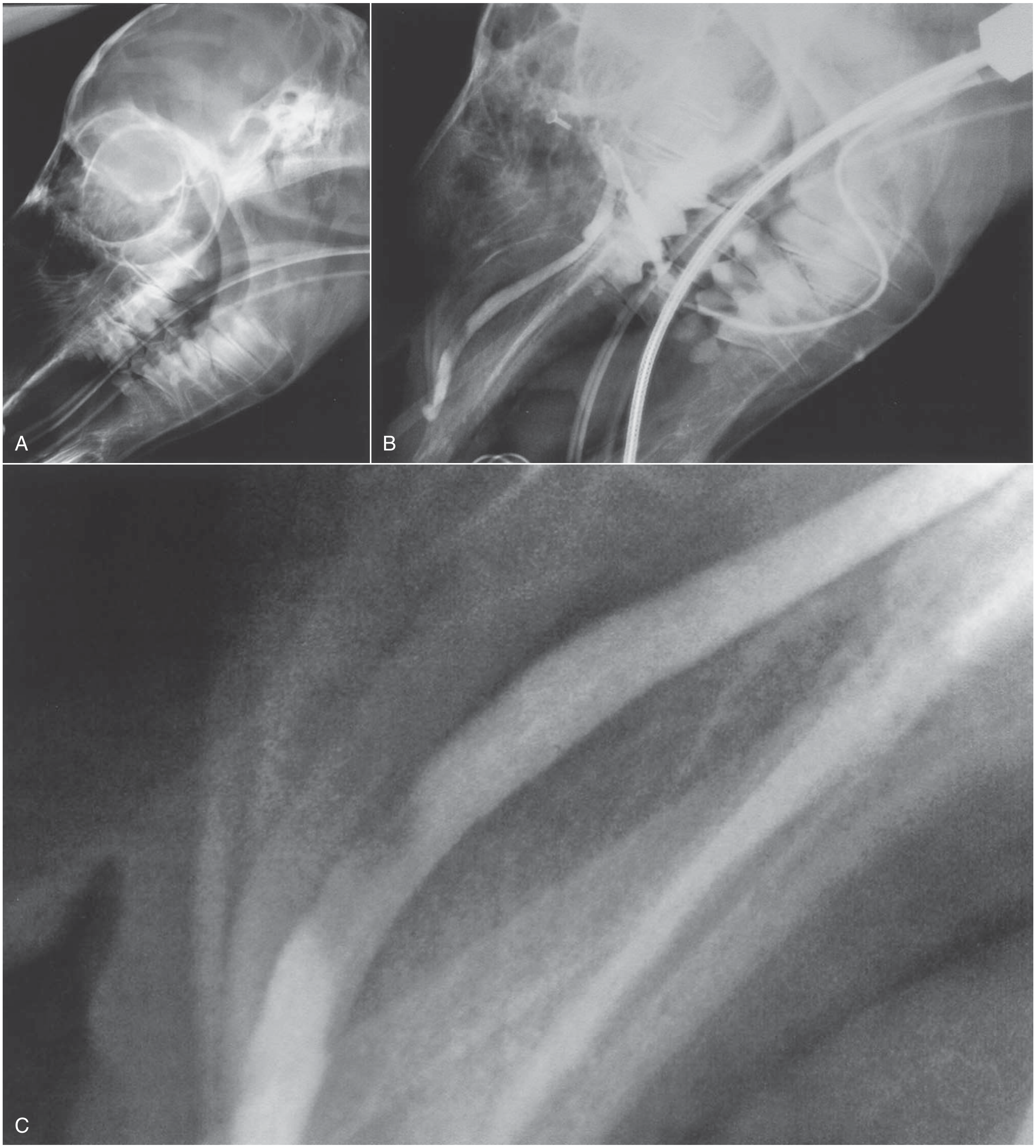

Figure 30-14 • A, Survey film of the central facial region of an alpaca with a suspected nasolacrimal duct obstruction appears normal. **B,** Lateral and ultraclose lateral **(C)** views show a medium-sized filling defect distally with marginal irregularity dorsally, consistent with a luminal mass or mass effect.

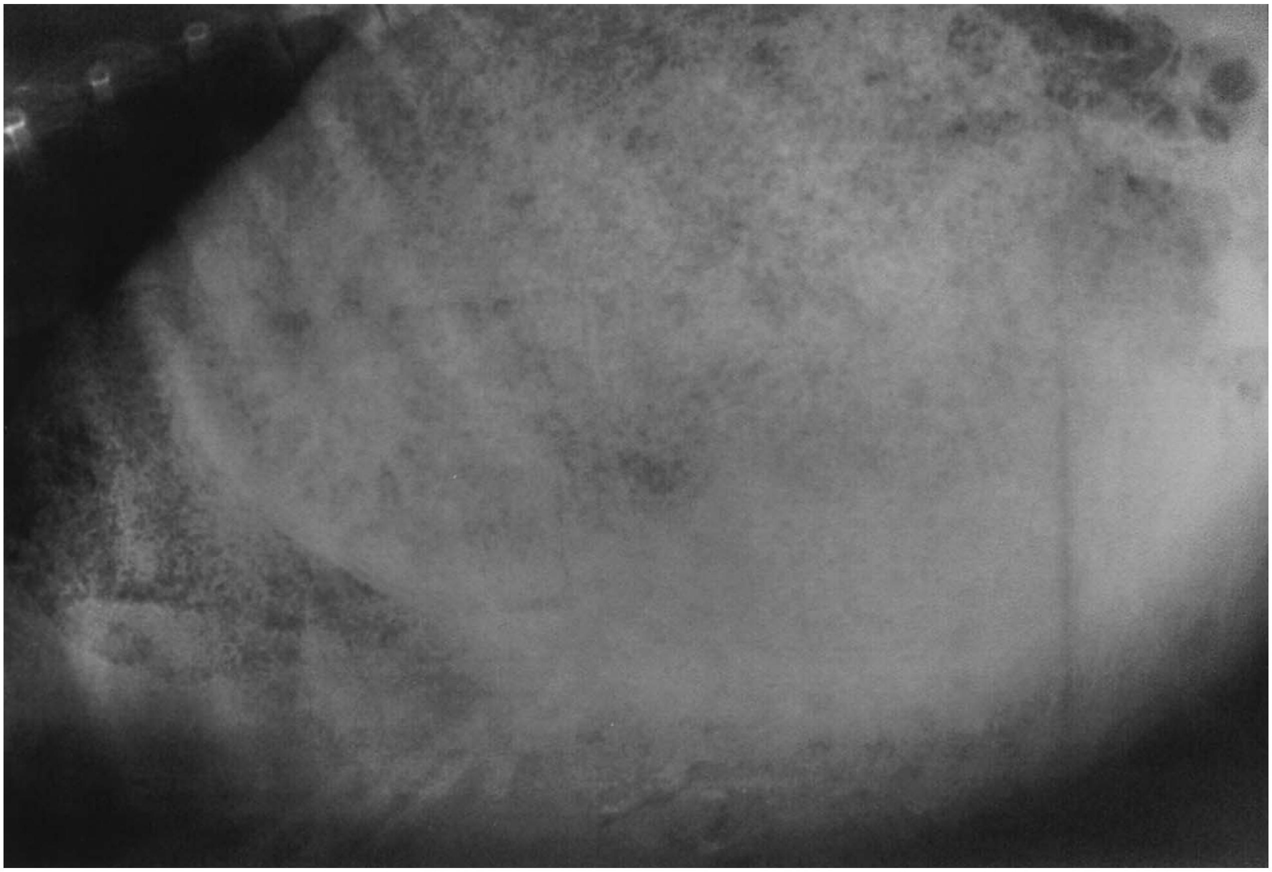

Figure 30-15 • Lateral view of a young alpaca with a gastric impaction. A small vertically oriented wire is located in the midst of the food mass.

Figure 30-16 • Sonographer studies the monitor as student assistant scans between the animal's hind legs in search of a fetus. The owner steadies the horse's head, keeping the mare at ease.

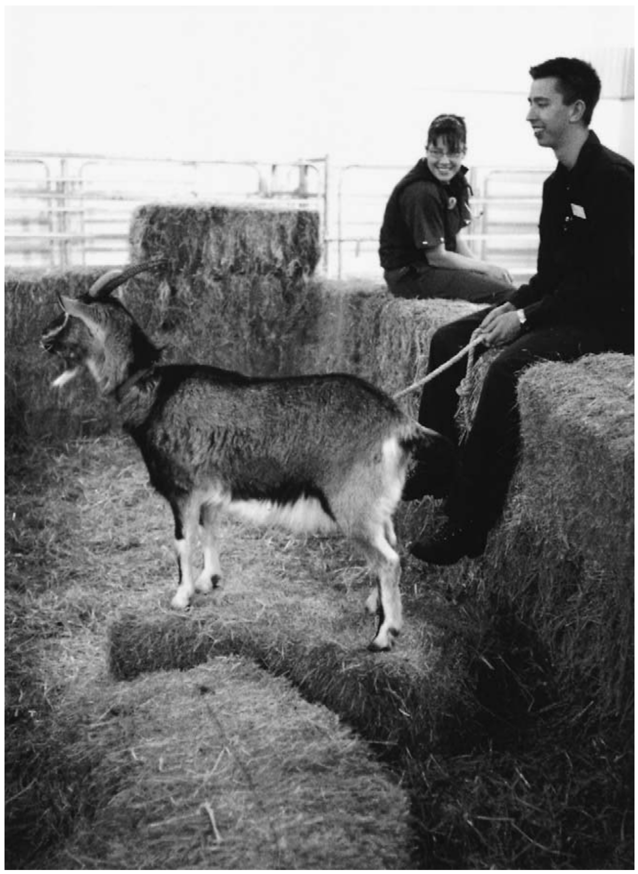

Figure 30-17 • A miniature goat surveys its domain as student handlers look on.

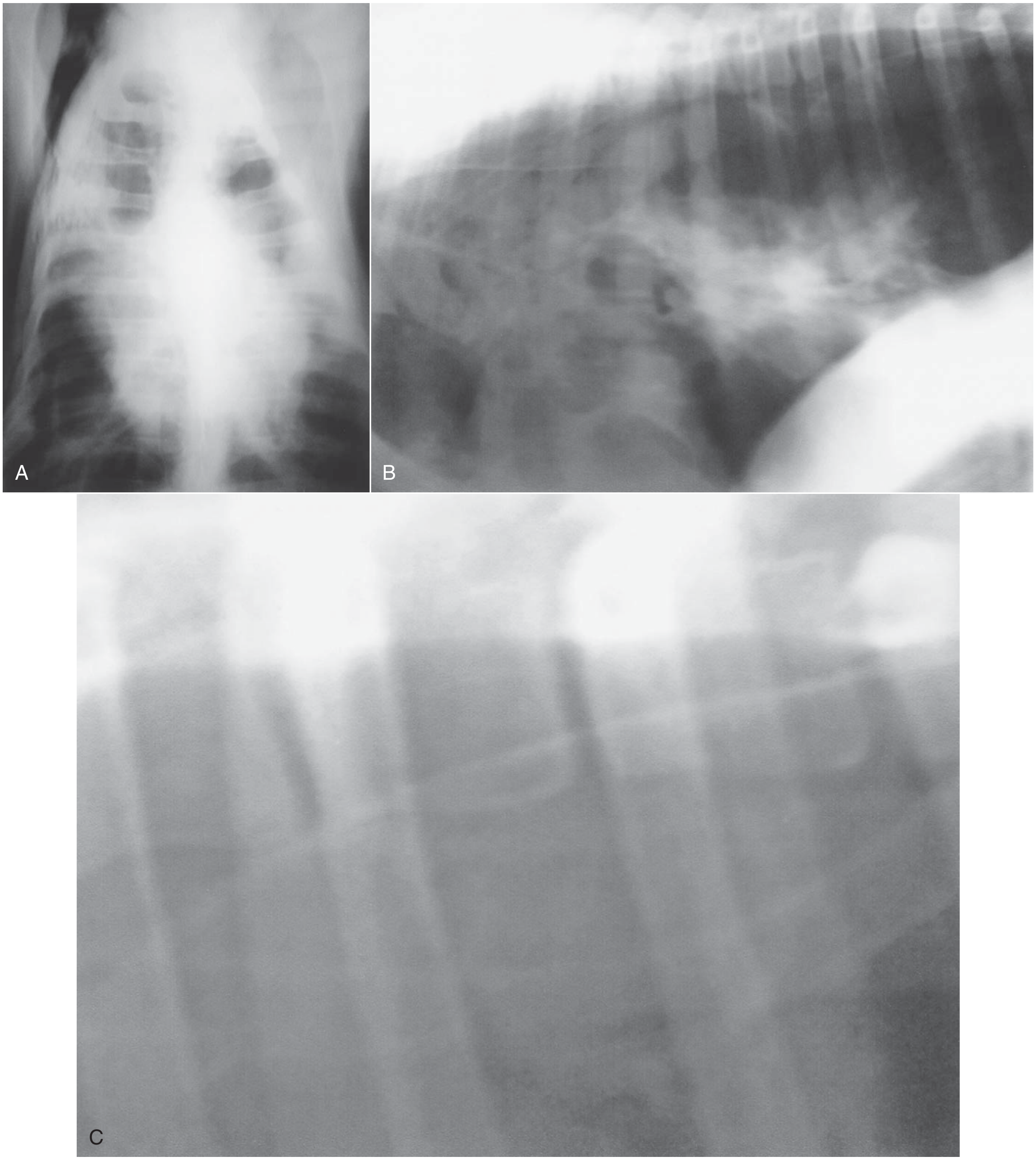

Figure 30-18 • A, Ventrodorsal and lateral **(B)** views of the chest of a pneumonic miniature goat. Both views are marred by motion unsharpness because of dyspnea and show bilateral consolidation ("double pneumonia") and a medium-volume pneumothorax. **C,** An ultraclose lateral view of the caudal dorsal thorax reveals the dorsal surface of the partially collapsed right caudal lung lobe, appearing as a gracefully arched, light gray line crossing the upper half of the image, accentuated by free pleural air.

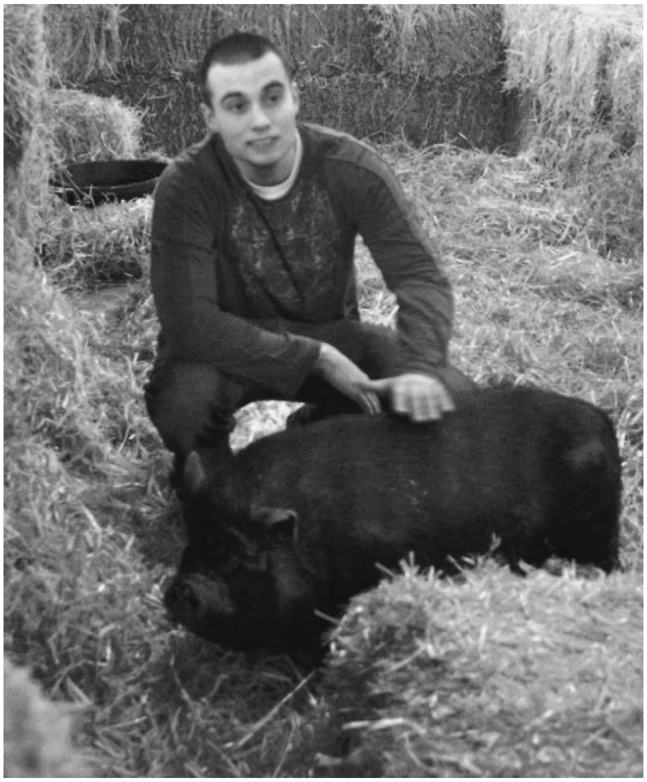

Figure 30-19 • Veterinary student comforts a pot-bellied pig during Veta Vision 2007.

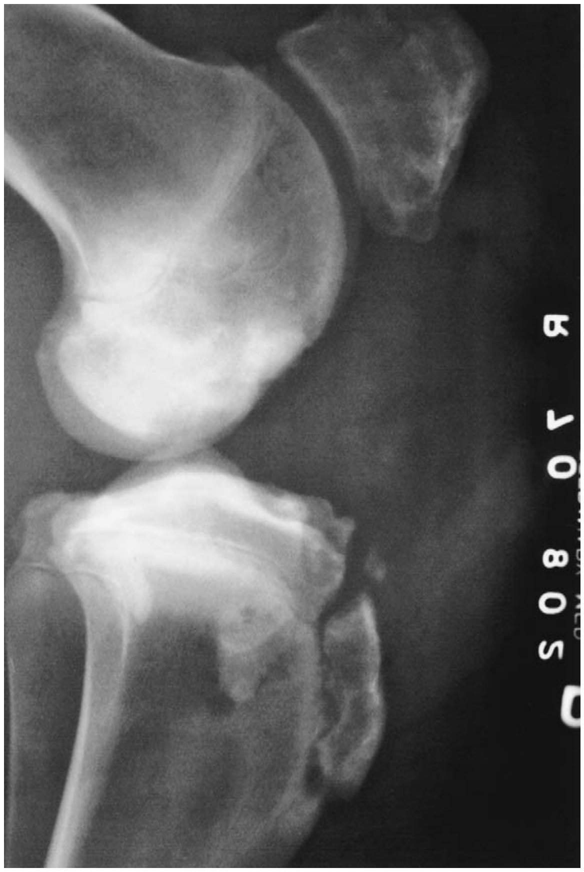

Figure 30-20 • Close-up lateral view of the stifle of an immature pig with septic arthritis-osteomyelitis causing massive joint swelling, atmospheric contamination via an actively draining sinus, and partial destruction of the patella and underlying apophysis.

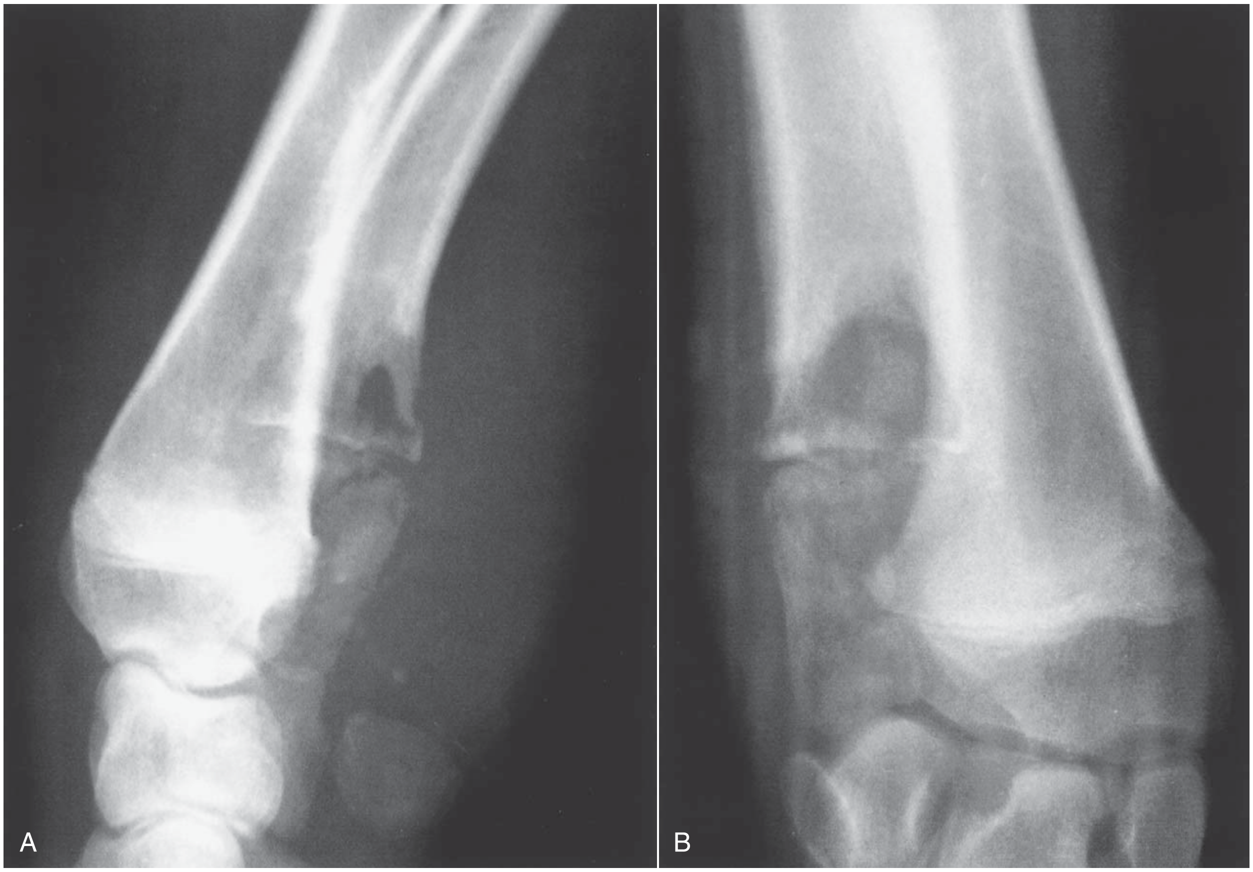

Figure 30-21 • A, Lateral and craniocaudal **(B)** views of the distal radius and ulna of an immature pig with septic arthritis-osteomyelitis show intense bone loss and sequestration on both sides of the distal ulnar physis in addition to marked overlying swelling.

Figure 30-22 • Ultraclose view of the stifle of a young pig with advanced septic arthritis-osteomyelitis that has destroyed the inner articular surface of its lateral femoral condyle, the medial aspect of its tibial plateau, much of its medial meniscus, and in the process, resulted in multiple, tightly clustered pathological fractures on both the epiphyseal and metaphyseal sides of the medial aspect of the proximal tibial physis *(left).*

Chapter 31

Performance and Demonstration Pets: Bear and Bison

Some exotic pets are accomplished film and television performers. In the last few months, we have radiographed a bear and a bison, both of which had extensive and impressive resumes. Other exotic pets serve as demonstration animals, usually in academic settings such as zoology or biology laboratories. One such animal we have attended to is a pet caiman.

BEAR

Over the years, we have cared for a number of bears—circus, zoo, and wild—and each of these bears has presented its own unique group of logistical challenges, particularly in regards to imaging. The most recent of these was a large black bear with a diseased upper canine tooth requiring a root canal. To examine, image, and perform surgery on the animal, it first had to be adequately restrained, which meant general anesthesia. This proved far easier than anticipated because the bear was not only a highly trained pet, but a seasoned motion picture performer, comfortable with the people, lights, and noise that typically accompany movie making. No darting was required!

After uneventful sedation, the bear was anesthetized, vital sign monitors were placed and activated, and the animal was imaged while on an adjustable padded table with a portable x-ray machine (Figure 31-1). After the procedure, the bear was imaged again as shown in Figure 31-2. The resultant radiograph is seen in Figure 31-3, and the surgery was deemed successful.

Bears are a handful, or perhaps a "paw-full" (Figure 31-4). The owner and trainer should be available as the animal is unloaded, sedated, anesthetized, examined, imaged, operated, imaged again, recovered, reloaded, and sent on its way to make more entertaining films.

BISON

Taming and training a bison bull calf is an arduous, time-consuming task requiring enormous patience, and taking a full-grown bull through its paces on a movie set is mind-boggling. Keith Houston is one of the few men to have accomplished such a feat with his partner "Pete."

We were introduced to Pete, a bison bull, in the summer of 2006. He was ill according to Mr. Houston, his owner and trainer; vagal indigestion and *hardware disease* were suspected. Having Pete's trainer present facilitated everything we did and perhaps more importantly, made it much less stressful on the animal.

Mr. Houston supervised the unloading and movement of Pete, including his placement of the bull in a squeeze-chute so that radiographs could be safely done (Figure 31-5). Once secured, the radiographer took over, but the trainer remained so that Pete would stay calm (Figure 31-6). Once the imaging was completed, the trainer escorted Pete back to his stall.

Unfortunately for Pete, radiographs disclosed a pair of wires (Figure 31-7), one of which appeared to have penetrated the reticulum and migrated through the diaphragm and into the nearby lung, or worse, into the pericardium, causing *infectious pericarditis*. Obviously, *reticuloperitonitis* was also a possibility.

A magnet was given (Figure 31-8) and appeared to fix the smaller of the two wires, indicating a high probability that it was free in the reticular lumen (versus fixed in a reticular fold or embedded in the reticular wall). The remaining wire continued to appear outside the reticulum, probably in the thorax.

Figure 31-1 • A large black bear is swarmed by radiographers making final positional adjustments before radiographs are made with a portable x-ray machine *(top center)*. An anesthetic machine and a plethora of monitors appear in the right foreground, while the animal's dentist, Dr. James Anthony *(far left)*, looks on.

Figure 31-2 • A black bear is positioned on an x-ray receiver in preparation for a lateral oblique radiograph of the affected upper canine tooth.

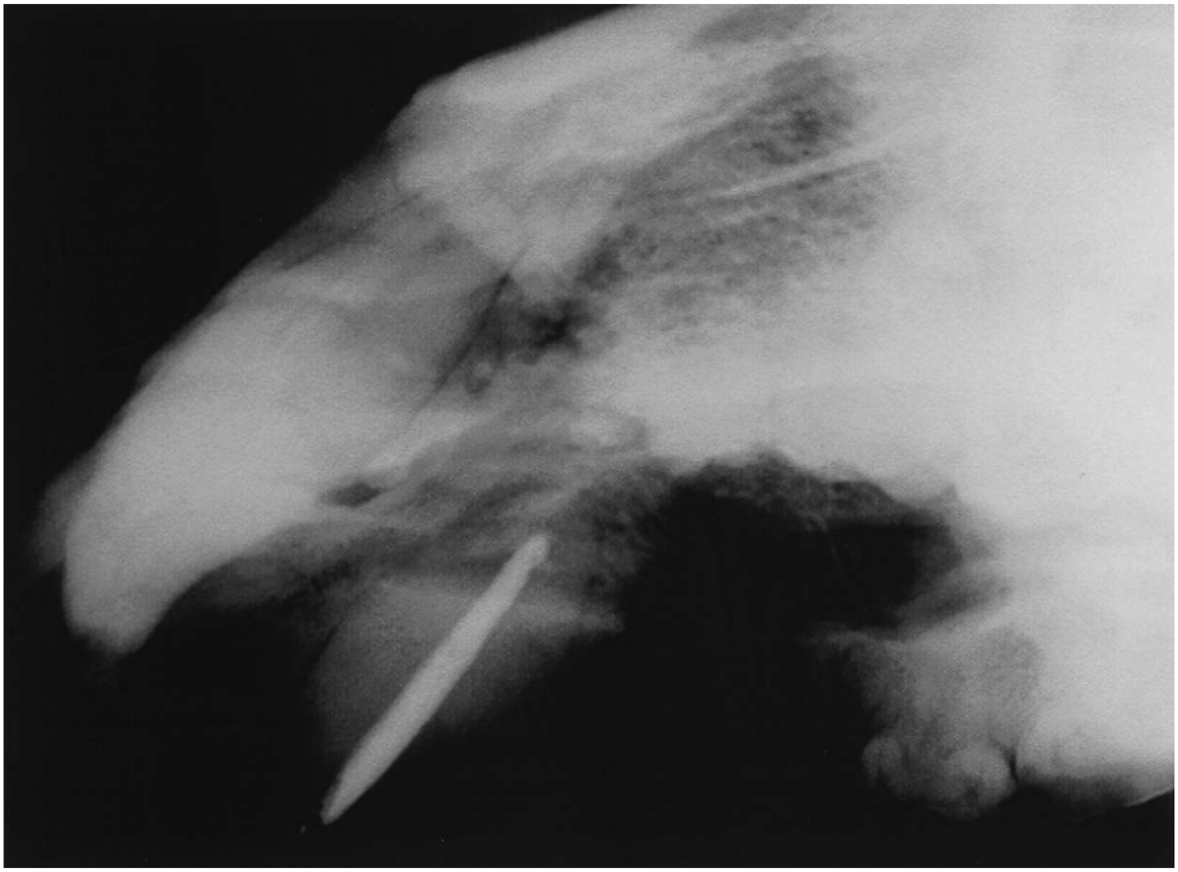

Figure 31-3 • Close-up lateral oblique view of the upper canine tooth of the bear shown in Figures 31-1 and 31-2 with a pin in the root canal of the affected cuspid.

Figure 31-4 • Skeleton of a Canadian Polar bear graphically illustrating the animal's formidable "jaws and claws."

Figure 31-5 • A trained adult bison is loaded and secured in a portable squeeze-chute prior to being radiographed as his owner-trainer oversees.

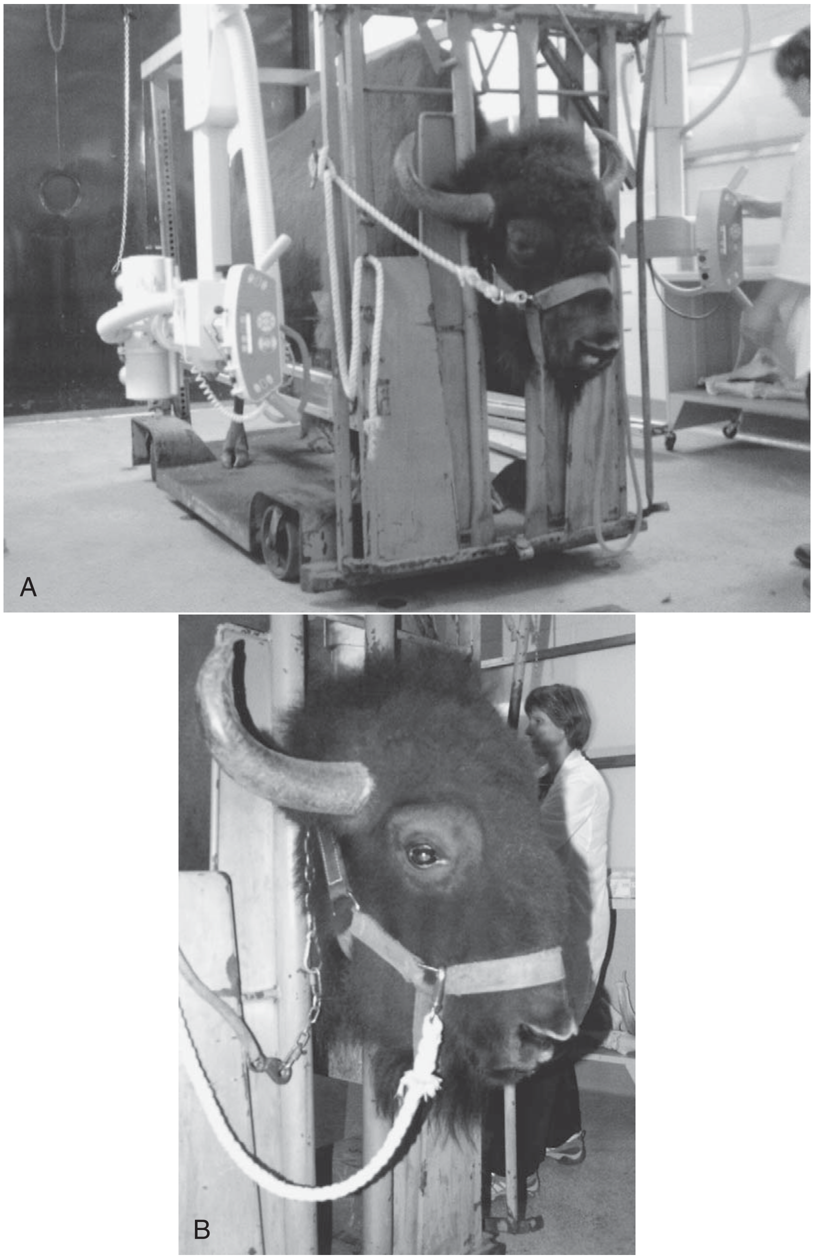

Figure 31-6 • "Pete" about to have his reticulum and caudal thorax imaged for a suspected penetrating reticular foreign body **(A).** Great care must be taken in handling these enormously strong and surprisingly quick animals, especially when working around the head with its large hooked horns **(B).**

Figure 31-7 • Close-up lateral view (portrait orientation) of the reticular field shows a pair of wires, one of which appears to be in the reticulum *(lower center)*, the other in the diaphragm, lung, or heart *(upper left)*.

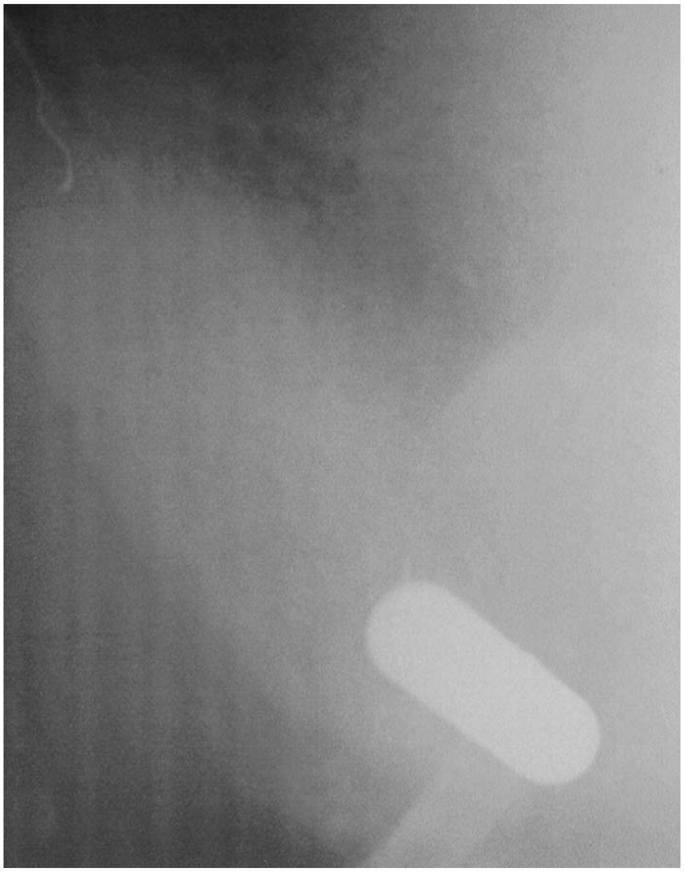

Figure 31-8 • Ultraclose lateral view of the reticular field after administration of a magnet shows the smaller of the two wires attached to the magnet, but the other remains outside the reticulum.

SECTION III

The Reptiles

Chapter 32

Snakes

Snakes are amazing creatures that evoke a variety of emotions in humans, ranging from fear to fascination (Figure 32-1). Children are often intrigued by snakes (Figure 32-2) and generally are quite willing to handle them (Figure 32-3), unlike many adults, who are quick to express the oft-heard sentiment, "I don't like snakes!"

I have frequently heard others say that cats have an instinctual fear of snakes or worse that cats and snakes are mortal enemies. Having owned cats for much of my life, I can attest to the fact they seem to greatly dislike vacuum cleaners, but whether it is the snake-like hose or the loud noise the machine makes, I cannot say. To test this theory of cats disliking of snakes, I have often taken my cat to a nearby wooded area where young boys and girls regularly search for snakes. My cat, who is accustomed to being walked on a leash, shows great curiosity when around snakes and frequently sniffs them (provided they remain still long enough) but to date has never harmed one (Figure 32-4).

RADIOGRAPHY AND NORMAL RADIOGRAPHIC ANATOMY

Generally, we try to radiograph snakes while they are fully awake, provided they remain still long enough to obtain an exposure. Most snakes prefer warm surfaces over cool surfaces and thus are reluctant to remain on x-ray cassettes any longer than necessary (Figure 32-5). This difficulty can be easily overcome by first warming the cassette, thus encouraging the snake to remain still, at least long enough to obtain an exposure.

In such circumstances, we often begin with a dorsoventral view of the snake's entire body, coiled on an appropriately sized cassette (Figure 32-6). Multiple cassettes are used in the event the snake's entire body will not fit on a single receiver, for example, with a large boa or python.

Among reptiles, snakes are unique in their ability to deform their face and jaws to accommodate the consumption of otherwise inedible prey. This feat is achieved through the coordinated but physically separate movement of the jaws, which, aided by their

Figure 32-1 • A garter snake briefly exposes itself as it wends it way across a narrow woodland trail.

Figure 32-2 • Secure in her father's arm, a young girl claps her hands to draw the snake's attention, seemingly with some misgiving.

Figure 32-3 • A young boy reluctantly shows off the garter snake he has just captured before releasing it and searching for a larger one.

Figure 32-4 • My cat is transfixed by a wild garter snake but makes no effort to harm it.

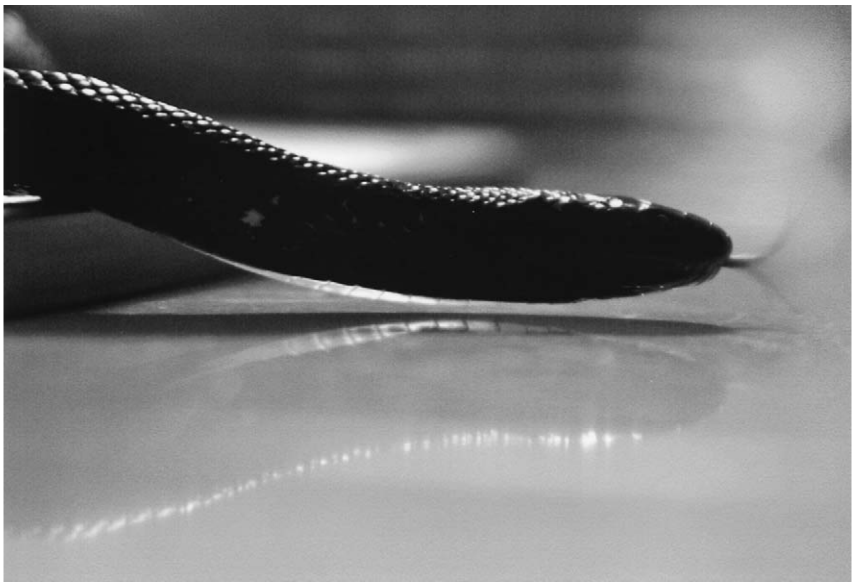

Figure 32-5 • Mexican black king snake is reluctant to remain on an uncomfortably cool x-ray cassette, a problem easily solved by prewarming.

Figure 32-6 • Table-level view of a Mexican black king being adjusted atop an x-ray cassette moments before being imaged.

multiple rows of rearward facing teeth, enable the snake to "climb over its victim," much as a mountaineer might scale an ice wall with an ice ax and crampons, step-by-step and inch-by-inch. The *kinetic capacity* of the snake's skull is immediately evident on inspection of a dorsoventral radiograph, which shows a mandible consisting of physically separate right and left halves (Figure 32-7).

The visceral layout of snakes is predictable because of the animal's morphology and specifically its long cylindrical coelomic cavity (there is no diaphragm). Thus it is quite reasonable to expect a series of elongated organs arranged in a columnar manner and for the most part, this is the case.

The major radiographic observations apparent in a whole body dorsoventral view of a snake are (1) the surprisingly small, triangle-shaped skull; (2) the countless number of vertebrae, typically seen in a combination of partial and complete loops; (3) rib pairs that extend the length of the body; and (4) the gas-filled lung, plus or minus an associated terminal air sac (Figure 32-8). The intestine may contain a variety of variably sized and shaped gas pockets, whereas the solid organs are for the most part individually indiscernible.

Congenital Anomaly

It seems that no roadside "museum" in the southwest United States is complete without a two-headed snake, which if alive is certain to be the star attraction. Imagine the questions asked by the children once the family gets back on the road. The radiographic example shows a rattler from the southern part of Saskatchewan; the arrangement of paired skulls and Y-shaped cranial spine is typical (Figure 32-9).

INJURIES

As might be anticipated, crush injuries, some severe enough to fracture the spine, are among the most common affecting snakes. Amazingly, some spinal fractures cause substantial deformity but little obvious incapacitation (Figures 32-10 through 32-13).

Cardiac Blood Sampling

Sonographic location of the heart *before* attempting cardiocentesis greatly reduces the risk of an iatrogenic injury (Figure 32-14). Once the heart has been located sonographically, its position is marked on the overlying skin and a blood sample is obtained (Figure 32-15).

Figure 32-7 • Close-up dorsoventral view of the skull of a boa showing separate right and left halves of the mandible, which are key to the snake's ability to enlarge its oral cavity, enabling it to swallow out-sized prey.

Figure 32-8 • A, Full and partial **(B)** whole-body dorsoventral views of a healthy boa are dominated by skeletal elements to include the skull, spine, and ribs. The air-filled lung and air sacs are also evident, as are three small- and medium-sized intestinal gas pockets. The solid organs are indefinable as such, instead appearing as a diffuse gray background density.

Figure 32-9 • A, Whole-body orientation and close-up **(B)** views of a two-headed rattle snake with a typical division of the associated portion of the spine.

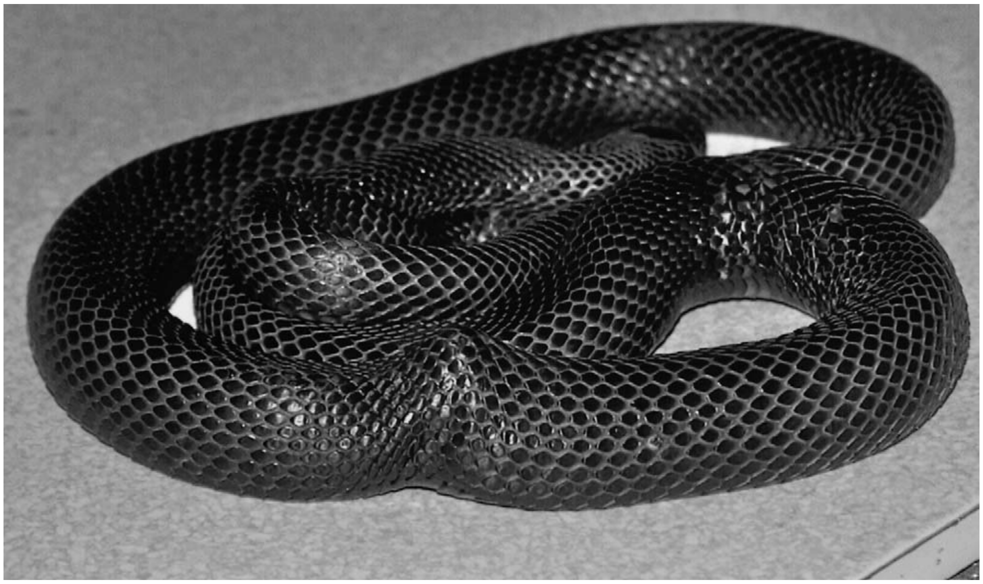

Figure 32-10 • A Mexican black king snake lies coiled on an x-ray cassette awaiting radiography. Note the deformity in the center of the lowermost coil, the result of a previous spinal fracture.

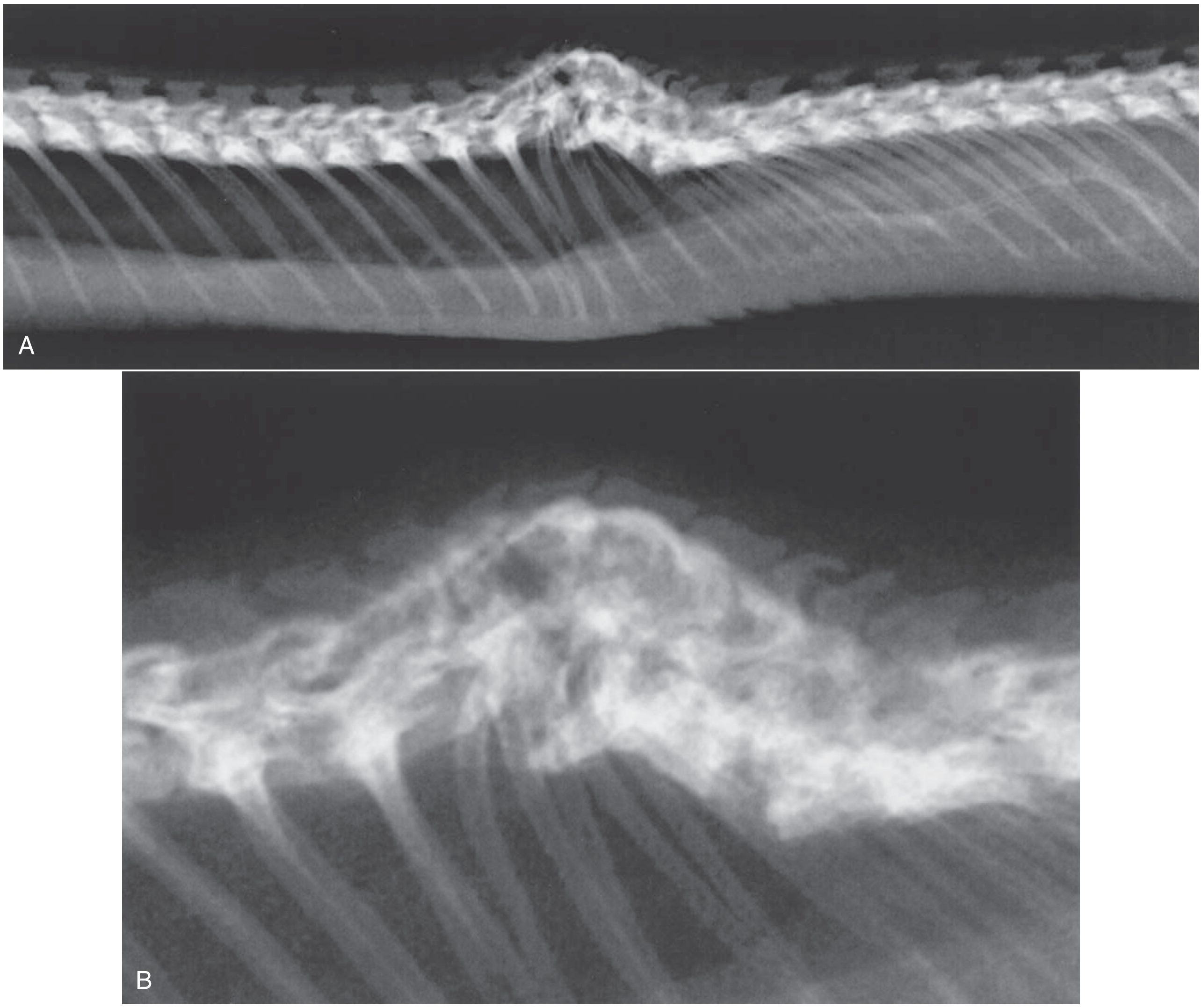

Figure 32-11 • **A,** Orientation and close-up **(B)** lateral views of the king snake shown in Figure 32-10 reveal a chronic-appearing spinal malunion, presumably sustained some time ago. Fortunately for the snake, the outward displacement of the fracture fragments *(expression-type fracture)* preserved some semblance of a spinal canal, and consequently, the cord escaped serious injury.

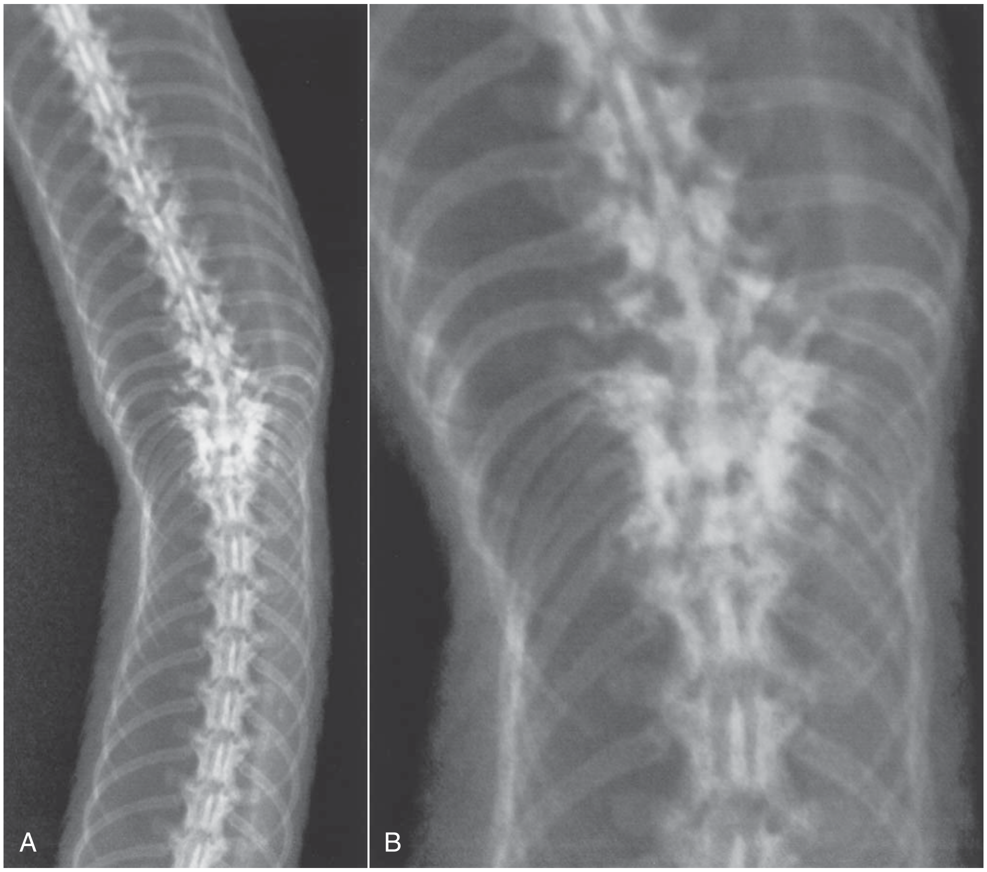

Figure 32-12 • **A,** Orientation and close-up **(B)** ventrodorsal views of the king snake in Figures 32-10 and 32-11 show its midspinal malunion from another perspective.

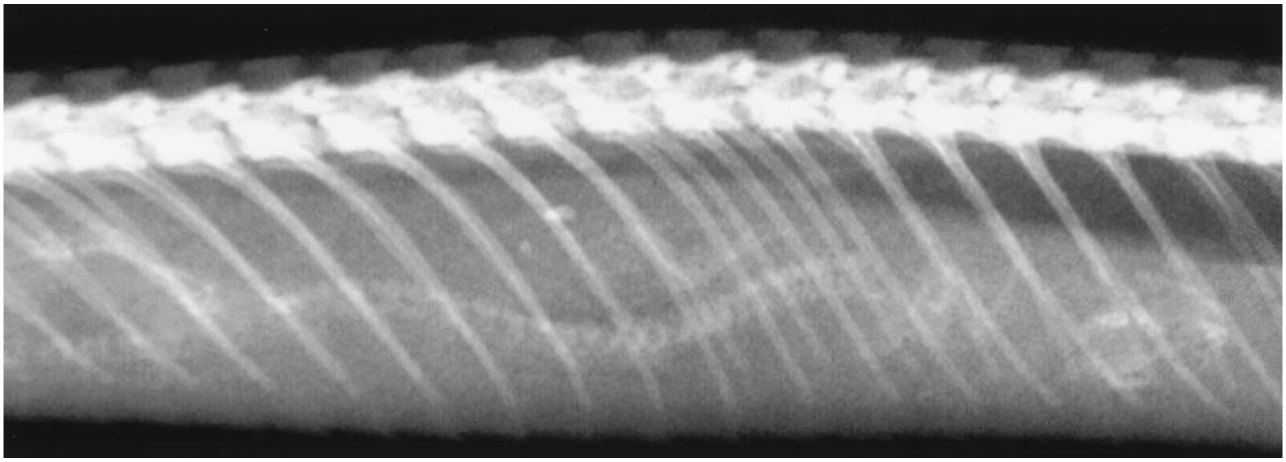

Figure 32-13 • Close-up lateral view of the king snake in Figures 32-10 through 32-12 shows the skeletal remnants of an earlier meal.

Figure 32-14 • Veterinarian identifies the precise location of the corn snake's heart before obtaining a blood sample.

Figure 32-15 • Veterinarian obtains blood from the heart of a corn snake after first locating it sonographically.

Chapter 33

Lizards

The lizards we see in our practice are mainly iguanas (Figure 33-1), followed by the smaller lizards such as the hooded dragon (Figure 33-2) and chameleon (Figure 33-3) and occasionally, the large muscular skink (Figure 33-4).

RADIOGRAPHY

An effective way to transport and restrain lizards while in the Radiology Department is to wrap them in one or more thick towels, a small blanket, or a comforter, similar to what we do with large birds. Lizards are calmed by such restraint as evidenced by less struggling (Figure 33-5). If a lizard needs to remain in the Radiology Department for more than a few minutes, and the area is cool, we place it on a heating pad and under a heat lamp (Figure 33-6).

Most lizards are radiographed while they are fully conscious, securing them by the tail (Figure 33-7). A conventional vertical x-ray beam is employed to obtain the dorsoventral view (Figure 33-8), and a horizontal beam is used to achieve a lateral projection (Figure 33-9).

Another technique is to first position the lizard on a prewarmed cassette (Figure 33-10), then lightly place a hand on the lizard's pelvic region and a curved wooden spoon alongside the torso (Figure 33-11). Once the animal has settled, quickly remove the hand and make the exposure. The lateral projection is made in the conventional manner by holding the lizard on its side during the exposure (Figure 33-12).

In the case of known or suspected appendicular fractures, the radiographic technique can be adjusted downward so the injured limb is not overexposed, which will result in an underexposed torso (Figure 33-13). When judging bone density in a lizard (or any animal), the radiographic exposure should first be taken into account.

NORMAL RADIOGRAPHIC ANATOMY

The Whole-Body Survey

The great majority of initial examinations in small- and medium-sized lizards include a *whole-body survey*, except any portion of the head or tail required for restraint and therefore concealed by leaded gloves. Subsequent progress examinations are often more focused, according to what specifically is being evaluated. An example of a whole-body survey, including selected enlargements, is shown in Figure 33-14.

The Torso: A Regional Approach to Radiographic Diagnosis

Viewed from above, the torso of a lizard can be conveniently divided into three diagnostic regions: *cranial*, *middle*, and *caudal*.

Cranial Torso. The anatomy of the cranial abdominal region consists of (1) the shoulders, each comprised of four bones: the scapula, coracoid, clavicle, and humerus; (2) the heart, situated between the shoulders; (3) the lung; (4) the spine; and (5) the ribs and sternum (Figure 33-15).

Middle Torso. The middle abdominal region contains (1) the liver and gallbladder, (2) the stomach, (3) the spleen, (4) the pancreas, and (5) a portion of the intestine. The caudal part of the lung may or may not be visible, depending on the size of the liver and the contents of the stomach (Figure 33-16).

Caudal Torso. Elements of the caudal abdominal region include (1) the majority of the small and large intestine, (2) the kidneys, (3) the urinary bladder, and (4) the cloaca. In a female, this portion of the abdomen may be dominated by the ovaries, which may sometimes be

Text continued on p. 387.

Figure 33-1 • An iguana crouched on x-ray table awaiting exposure.

Figure 33-2 • A hooded dragon with its threatening collar unfurled.

Figure 33-3 • A veiled chameleon held to show its unique eye, crest, and hind foot.

Figure 33-4 • A muscular skink maneuvers along the arm of its handler with the aid of its long curled toes.

Figure 33-5 • An iguana is brought to radiology wrapped snugly in a pair of blankets.

Figure 33-6 • An iguana crouches in its enclosure awaiting imaging. Because the room was cool, both a heating pad and a heat lamp were provided to make the animal as comfortable as possible during its brief stay in the Radiology Department.

Figure 33-7 • Illuminated by the collimator light, an iguana crouches quietly on the x-ray table, secured lightly by its tail.

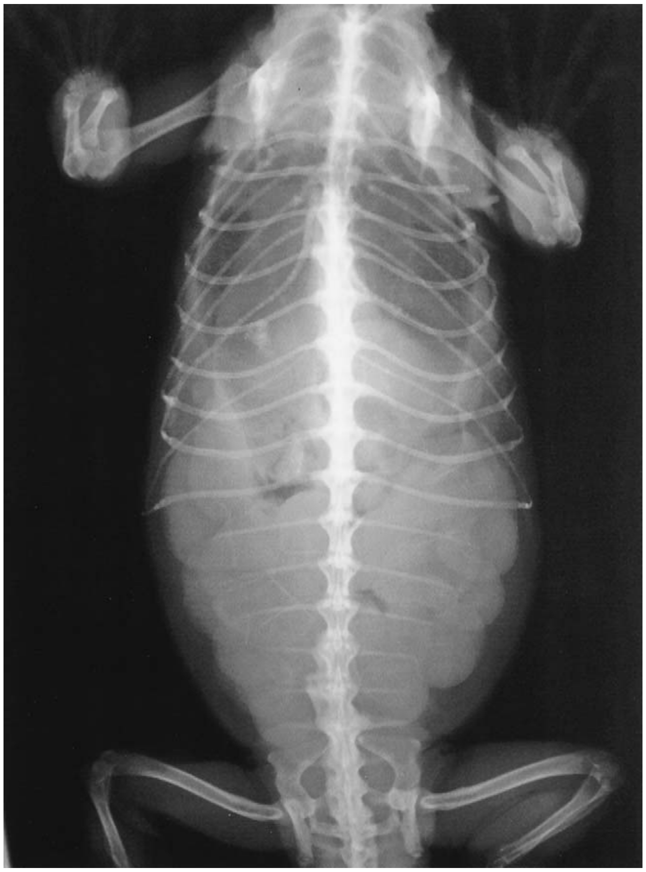

Figure 33-8 • Dorsoventral view of an iguana made with a vertically oriented x-ray beam as the animal crouches on the x-ray table.

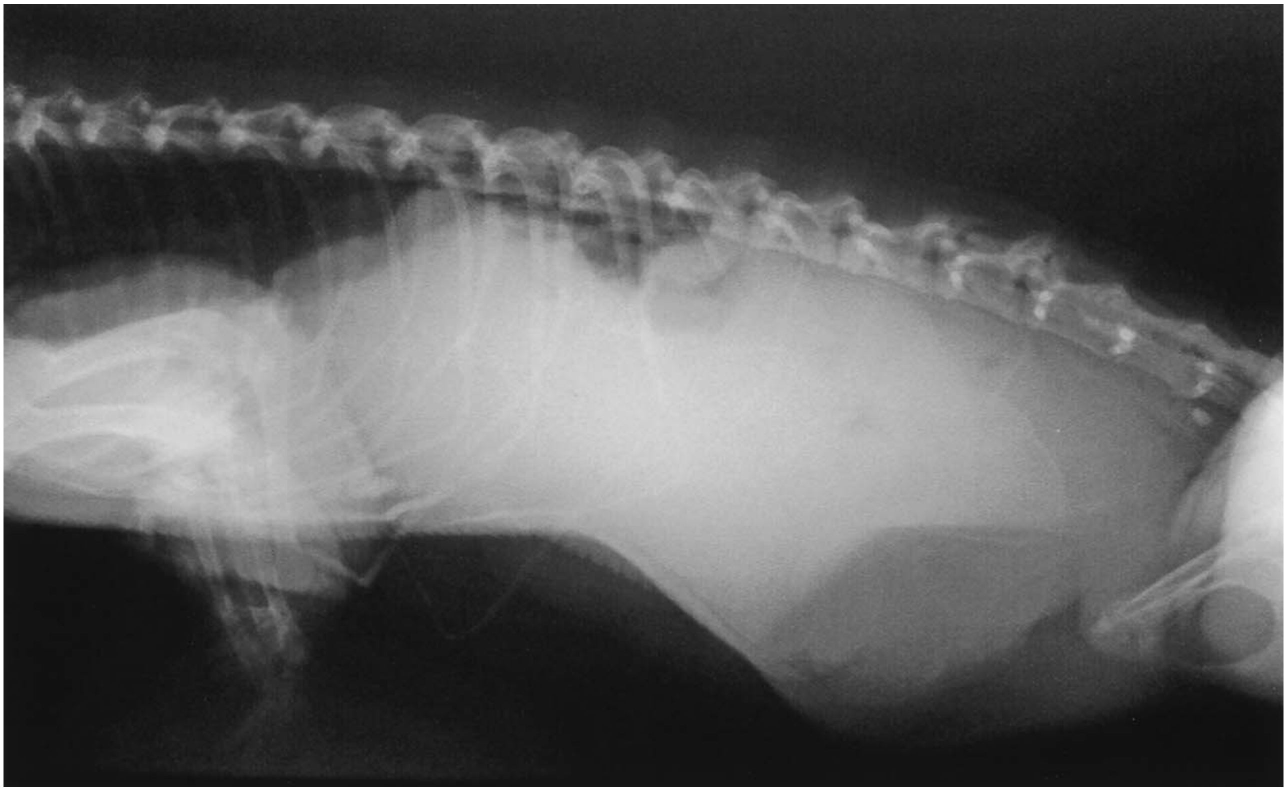

Figure 33-9 • Lateral view of an iguana made with a horizontally oriented x-ray beam, as the animal crouches on the x-ray table.

Figure 33-10 • A Uromastyx is gently placed on an x-ray cassette before being secured and radiographed.

Figure 33-11 • The lizard shown in Figure 33-10 is secured and settled on an x-ray cassette with a combination of gentle hand pressure and a wooden spoon.

Figure 33-12 • One way to obtain a lateral projection of a lizard is to simply place the animal on its side and then restrain in that position long enough to make an exposure.

Figure 33-13 • Flexed dorsoventral view of the right femur of an iguana suspected of having a fracture. Note that although the right hind limb is not optimally positioned, it is adequately exposed, as indicated by a readily distinguishable femoral cortex and medulla. This desired appearance was achieved by reducing the radiographic technique over what would normally be required to adequately expose the torso.

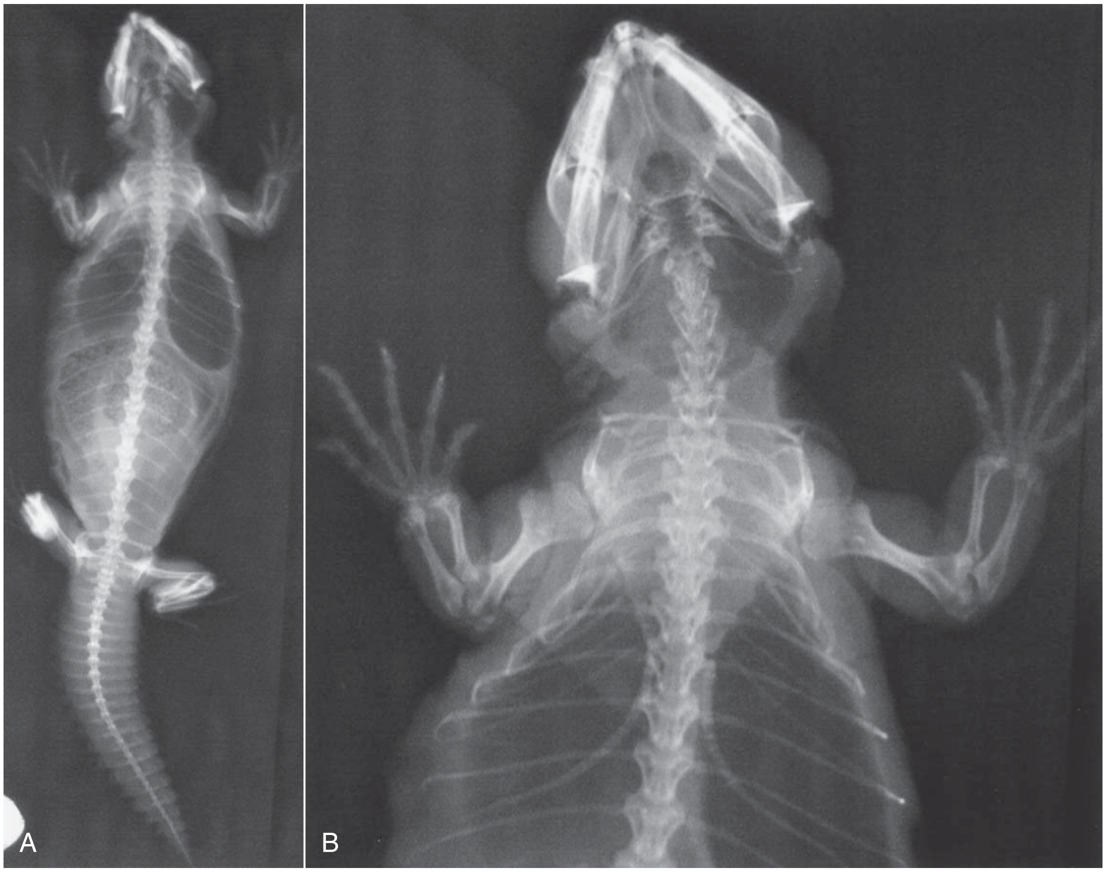

Figure 33-14 • Whole-body radiographic survey examination in a Uromastyx includes full-length dorsoventral view **(A);** close-up dorsoventral view of the head, neck, shoulders, forelimbs, and cranial third of the torso **(B);** dorsoventral view of torso **(C);** close-up dorsoventral view of caudal third of torso, pelvis, hind limbs, and cranial third of the tail **(D);** and full-length lateral view, except for portions of the reptile covered by protective leaded gloves **(E).**

Figure 33-14, cont'd • For legend see opposite page.

Figure 33-15 • Dorsoventral view of the cranial third of the torso of an iguana showing the shoulder bones and portions of the forelimbs, the heart (situated between the shoulder blades), the lungs, the spine, and the ribs.

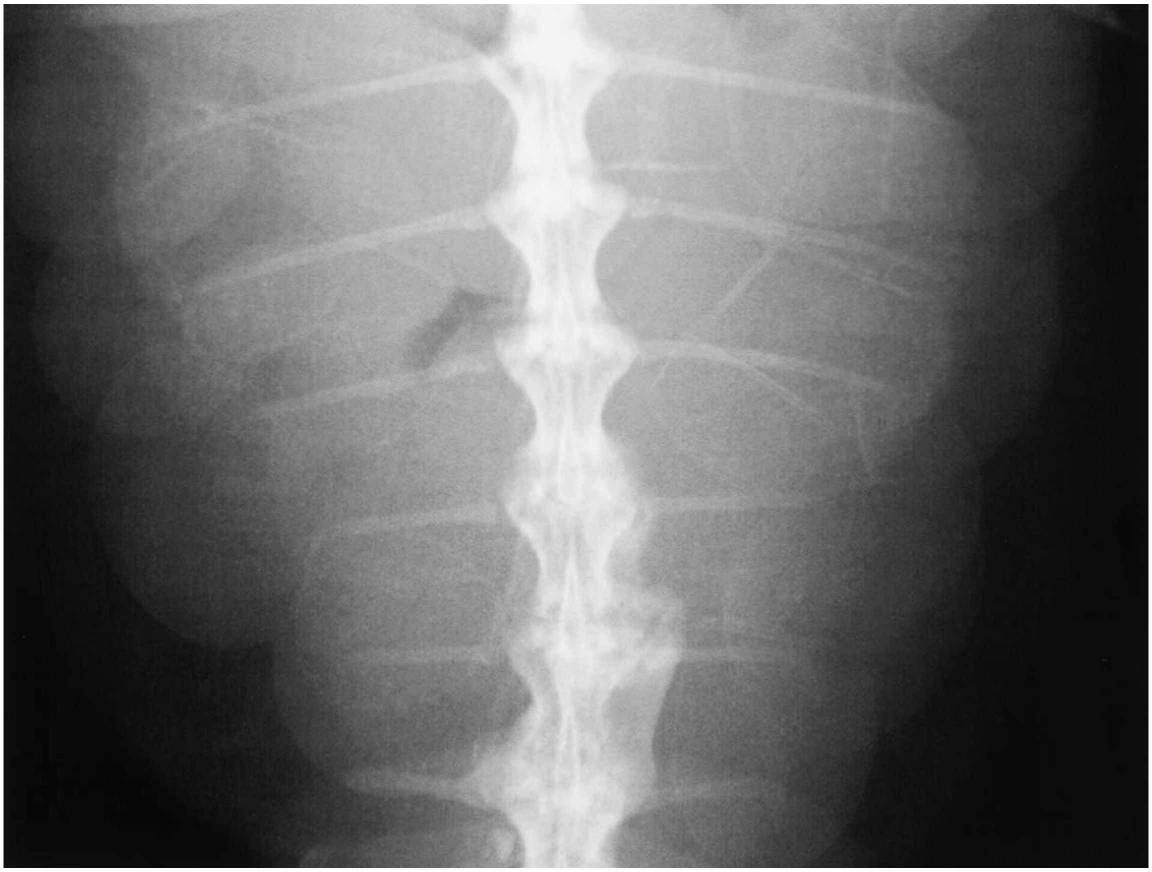

Figure 33-16 • Dorsoventral view of the middle third of the torso of a gravid iguana is dominated by multiple overlapping eggs.

difficult to differentiate from eggs or a full colon. A small square pelvis and hips define the caudal limit of this region (Figure 33-17).

Head and Neck

An outsized facial region and a negligible cranium characterize the head of the typical lizard. Radiographically, this translates into a short, wide triangular head, which is dominated by the upper and lower jawbones in the dorsoventral projection (Figure 33-18). Many lizards have almost no discernible neck, either grossly or radiographically. The tongue of the chameleon, which is nearly twice the length of its torso, is stored in the back of its throat, much like a coil of thick rope (Figure 33-19). Radiographically, it may resemble a mass.

INJURIES

In our practice, the radius and ulna are the bones most often fractured in the forelimb of lizards, while the femur appears most susceptible in the hind limb (Figure 33-20). These injuries are typically caused by the lizard being stepped on or less often by a fall. A lizard's leg or tail is easily broken when caught by a door.

Occasionally, the mandible is fractured (sometimes bilaterally) if an animal is stepped on or crushed in the jaws of a dog. Spinal fractures are usually but not always associated with hind leg paralysis (Figure 33-21).

When small lizards, like water dragons or chameleons, are taken by a cat, they often sustain multiple punctures to the torso, some of which may puncture the bowel and cause leakage and peritonitis. Lizards can also be eviscerated in this manner.

DISEASES

Nutritionally Induced Osteopenia (Nutritional Secondary Hyperparathyroidism)

As might be anticipated, the most common diseases we see in lizards are related to their diets, for example, deficiencies of vitamin D_3 or calcium. This deficiency produces a secondary hyperparathyroidism, causing a generalized mineral depletion, especially to the skeleton, weakening the bones, and a predisposition to *insufficiency fractures*.

Calcium is also withdrawn from the perialveolar bone, causing the teeth to loosen and making eating

Figure 33-17 • Dorsoventral view of the caudal third of the torso of a gravid iguana showing, in addition to multiple eggs, a small, square pelvis and extensive remodeling of the caudal lumbar and coccygeal spinal regions.

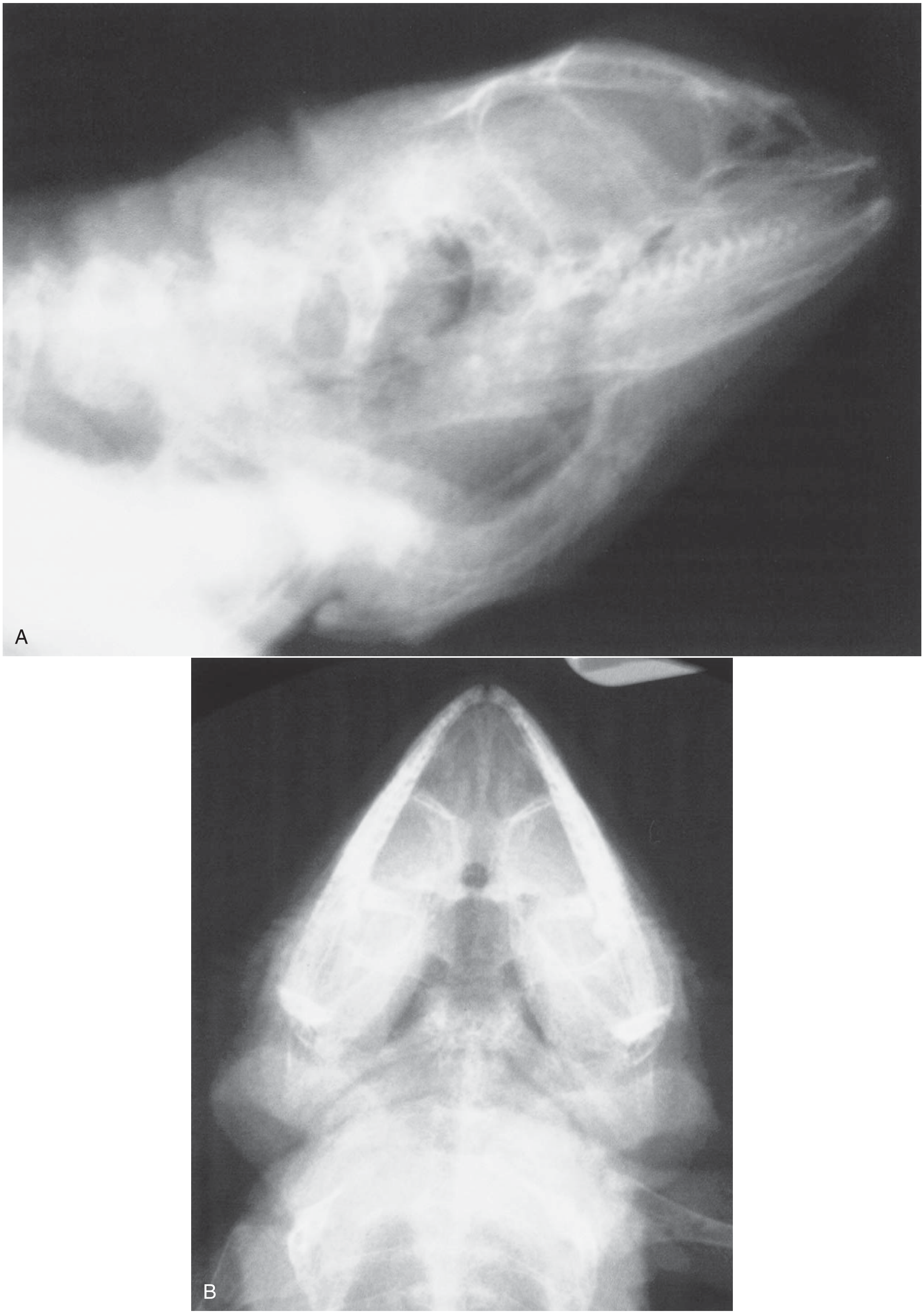

Figure 33-18 • A, Close-up lateral and dorsoventral **(B)** views of the short, wide triangular head and abbreviated throat and neck of a healthy water dragon.

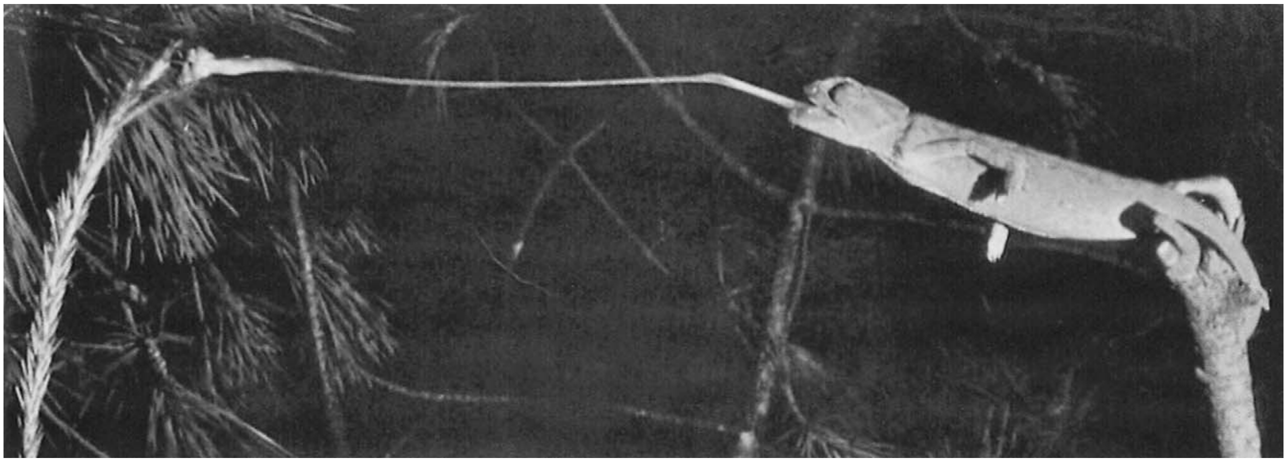

Figure 33-19 • Literally hanging on by its toes and tail, a chameleon launches itself toward its prey, an unsuspecting dragonfly. Its tongue, nearly twice the length of its torso, precedes it, like a living javelin, momentarily fixing the insect before drawing it rapidly back to the waiting jaws. (From Hickman CP, Roberts LS, Larson A, eds: Reptiles. In *Integrated principles of zoology,* ed 9, St Louis, 1993, Mosby.)

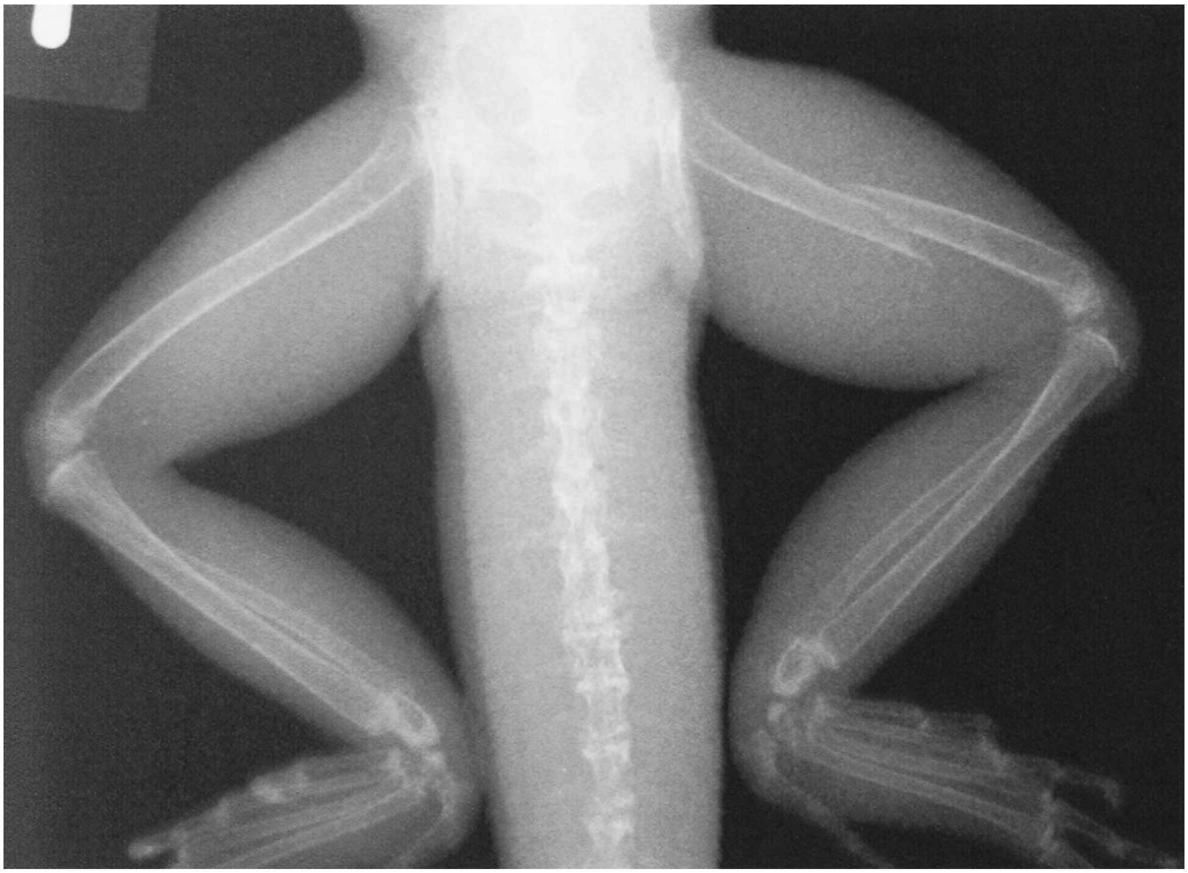

Figure 33-20 • Fresh, displaced left femoral midshaft fracture in a Chinese water dragon. The cause of the old multiple tail lesions is unknown.

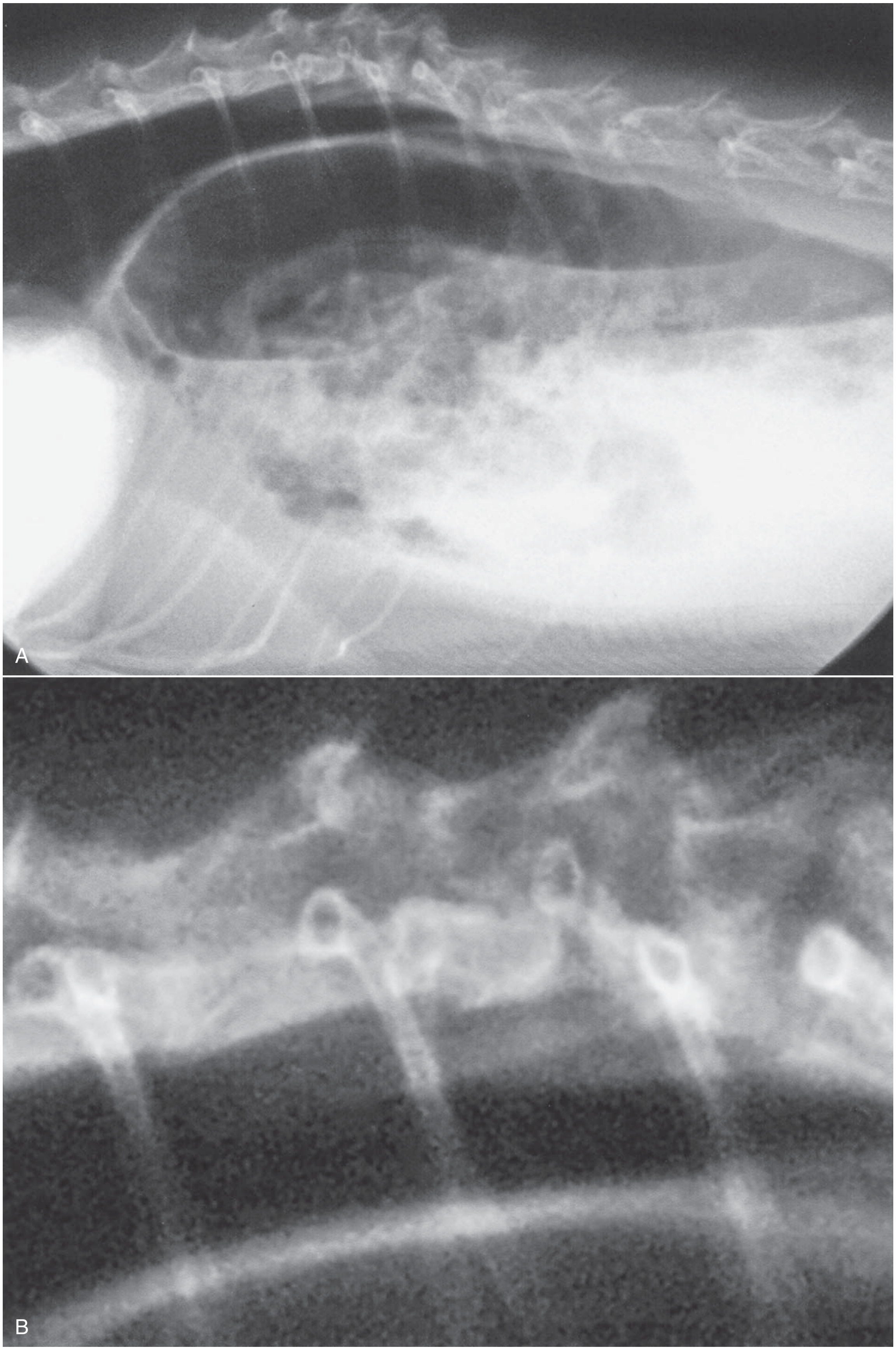

Figure 33-21 • **A,** Lateral orientation, lateral close-up **(B),** and ventrodorsal close-up **(C)** views of the central spinal region of an Iguana show marked biplanar deformity indicative of a fracture. The consolidated appearance of the lesion is consistent with chronicity, and the absence of other lesions supports old trauma.

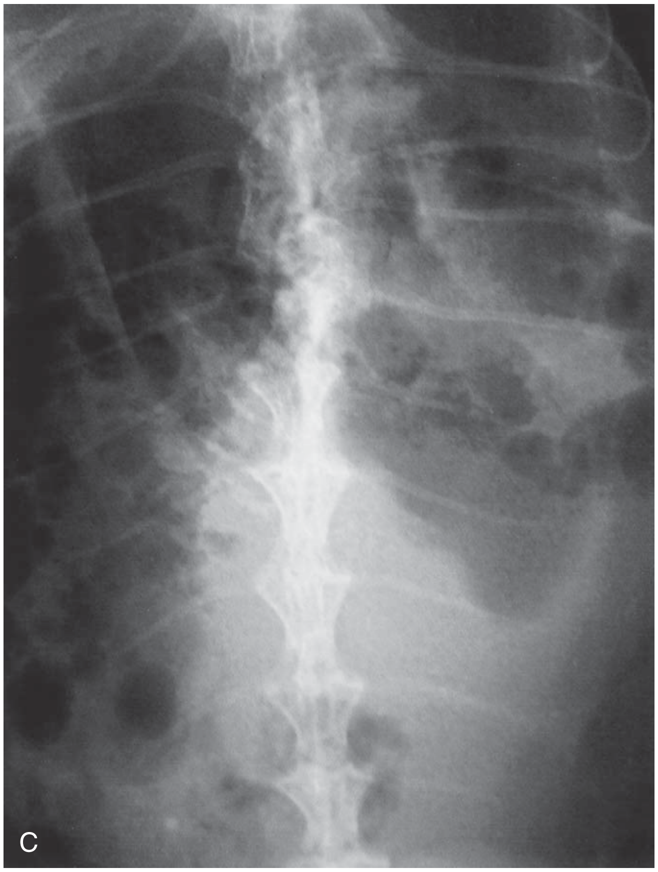

Figure 33-21, cont'd • For legend see opposite page.

Figure 33-22 • Chameleon (seen from above) with multiple insufficiency fractures of its midtail and distal tail.

painful. This pain can lead to a reluctance to eat and a commensurate weight loss. Since the teeth retain their normal density, but the surrounding bone loses its density, the teeth appear to have no visible connection with the associated jaws when viewed radiographically. This ghostly appearance is sometimes described as "floating."

A reduced calcium content also causes bones to soften, particularly the mandible, spine, and pelvis, which can lead to insufficiency fracture and deformity. I have seen some iguanas whose pelvic canal was nearly obliterated to the extent that their hips were situated side-by-side, as seen in a dorsoventral radiograph.

Differentiating Traumatic Fracture from Insufficiency Fracture

The cause of some of these deformities, especially those affecting the spine, is not always clear, but in general, trauma and hyperparathyroidism are the top contenders. These possible causes are based on bone density and the presence of any accompanying skeletal lesions such as long bone fractures or spinal lesions (new or old). If the bone appears osteopenic and there are other spinal deformities or fractures, then it is probably metabolic bone disease (Figures 33-22 and 33-23). If not, fracture becomes the more likely possibility.

Intestinal Impaction and the Perils of Dietary Change

Healthy diets are also capable of causing problems, for example, increasing the amount of food or changing its composition can lead to intestinal impaction. Even altering the frequency of feeding can lead to constipation in lizards and other reptiles.

Some diets cause localized mineral build-ups, known as *enteroliths*, to form in the intestine and eventually block it. These stone-like objects (Figure 33-24) can also lead to intestinal twisting *(volvulus)* or entrapment *(incarceration)*.

Blockage Secondary to Intestinal Foreign Body or Material

Intestinal impaction can also be caused by sand or gravel that the lizard picked up in its enclosure (Figure 33-25). Foreign bodies are also capable of causing blockage of the bowel, as exemplified by an iguana that ate a metal screw accidentally left on the floor near its enclosure (Figure 33-26).

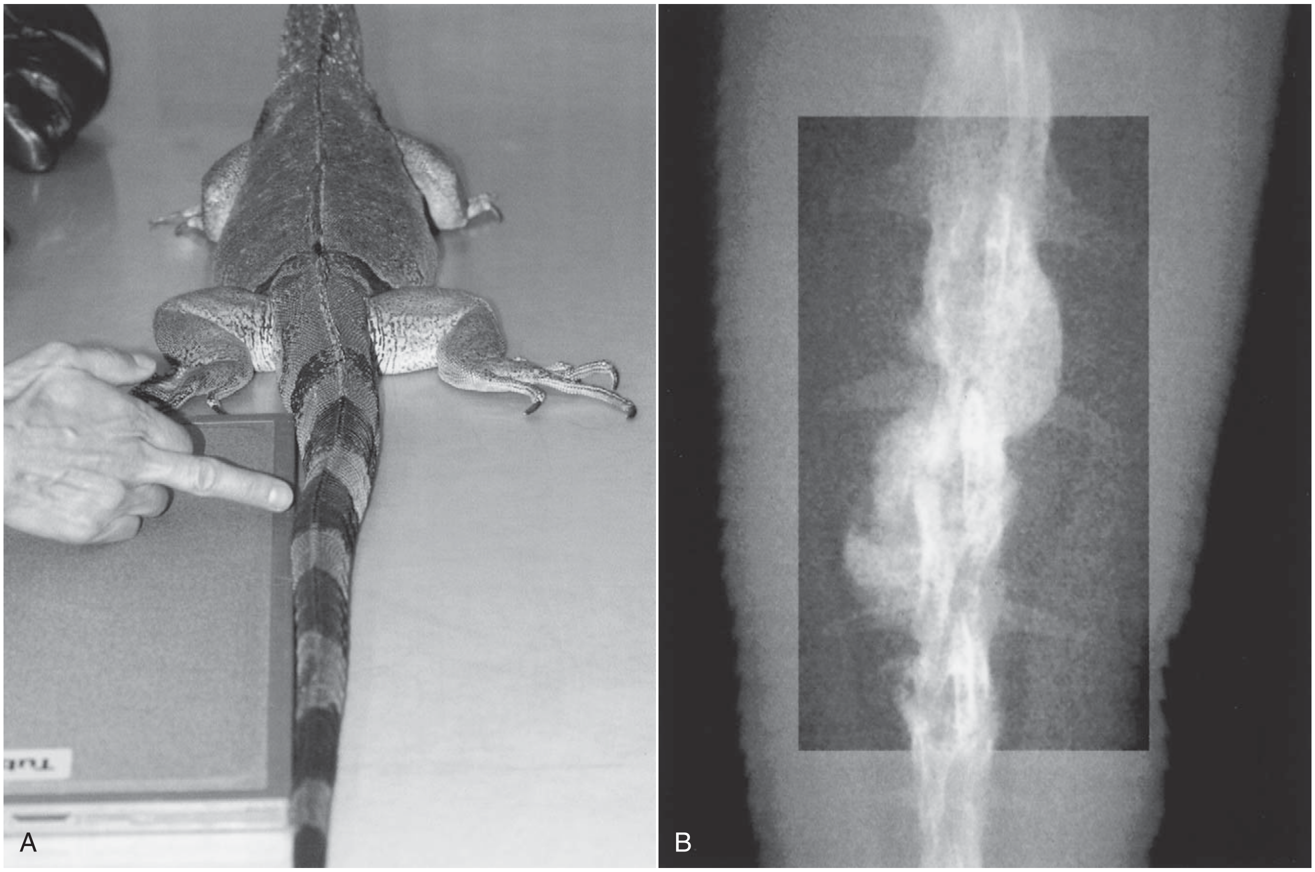

Figure 33-23 • A, Iguana, seen from above rear, has an angular deformity in the cranial third of its tail, the result of multiple insufficiency fractures sustained over a year ago, as seen in a current dorsoventral radiograph **(B).**

Figure 33-24 • Near full-length dorsoventral view of an iguana with a midintestinal enterolith.

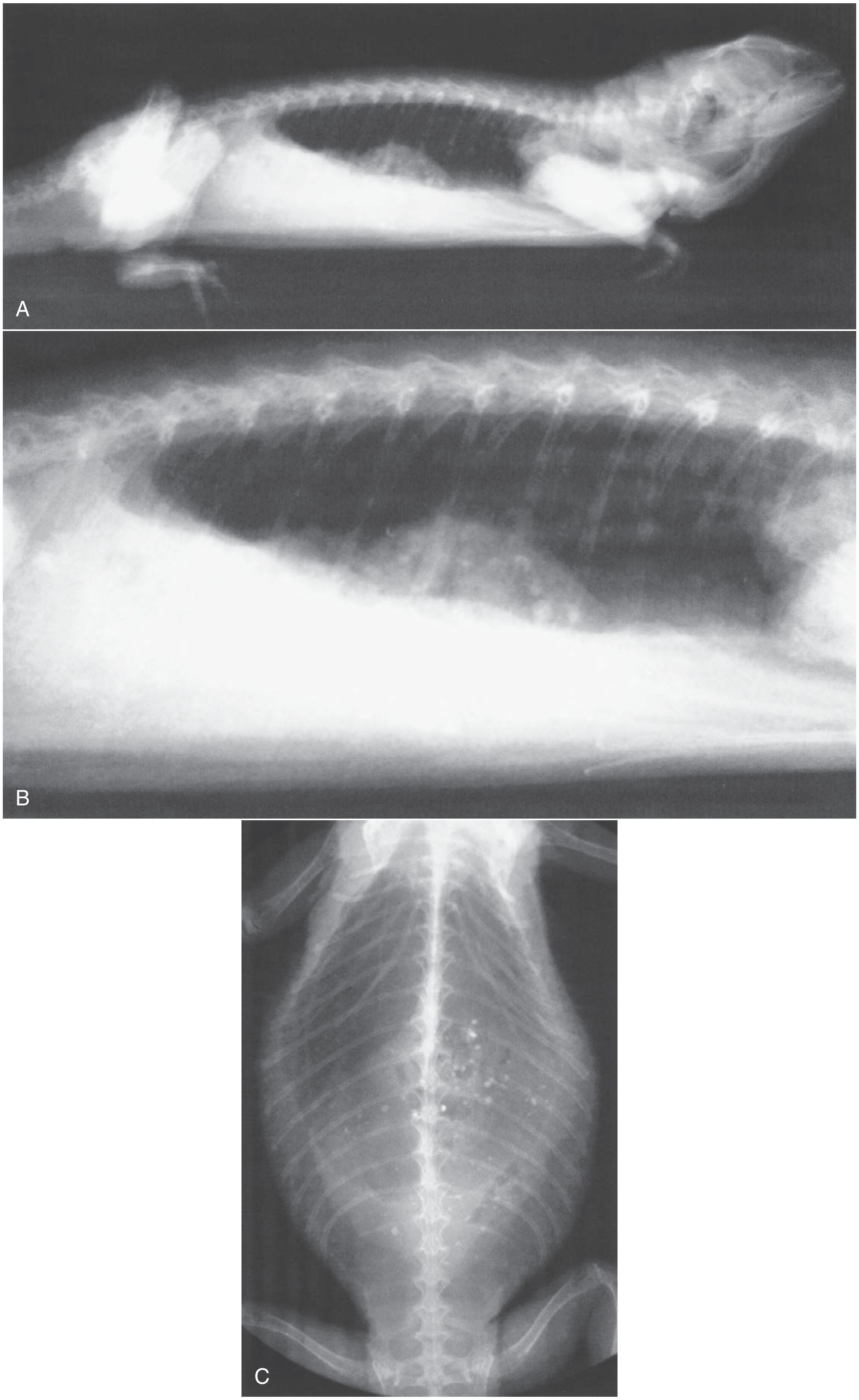

Figure 33-25 • A, Lateral, lateral close-up **(B),** and ventrodorsal **(C)** views of a hooded dragon with intestinal impaction secondary to gravel consumption obtained from the floor of its enclosure. The intestinal blockage site appears as a semicircular, medium-density object in the middle of the torso, interspersed with small bits of gravel.

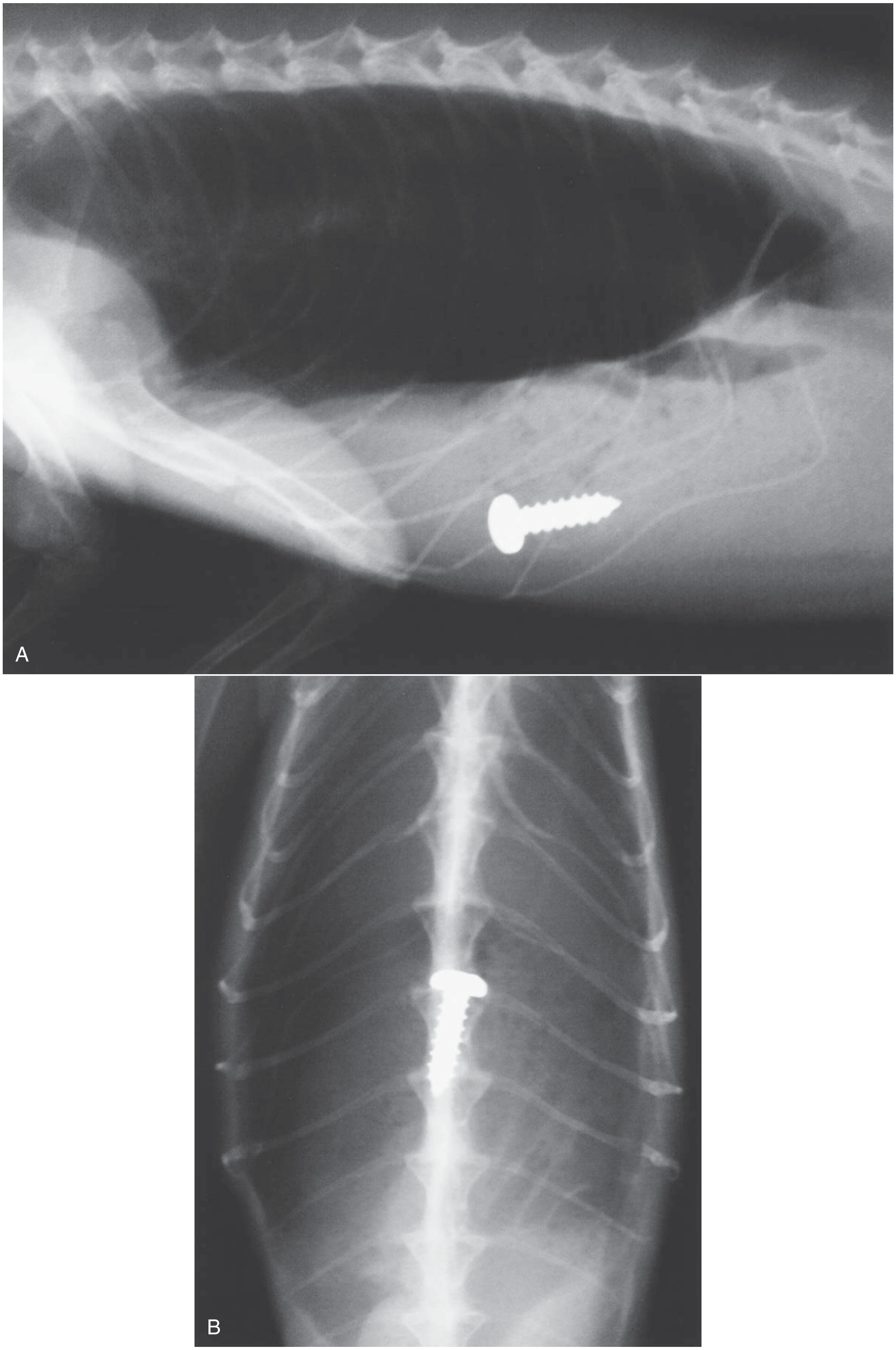

Figure 33-26 • A, Close-up lateral and ventrodorsal **(B)** views of the midtorso of an iguana who has eaten a screw that has blocked its intestine; the latter is confirmed with barium enterography shown in this ultraclose lateral radiograph **(C).**

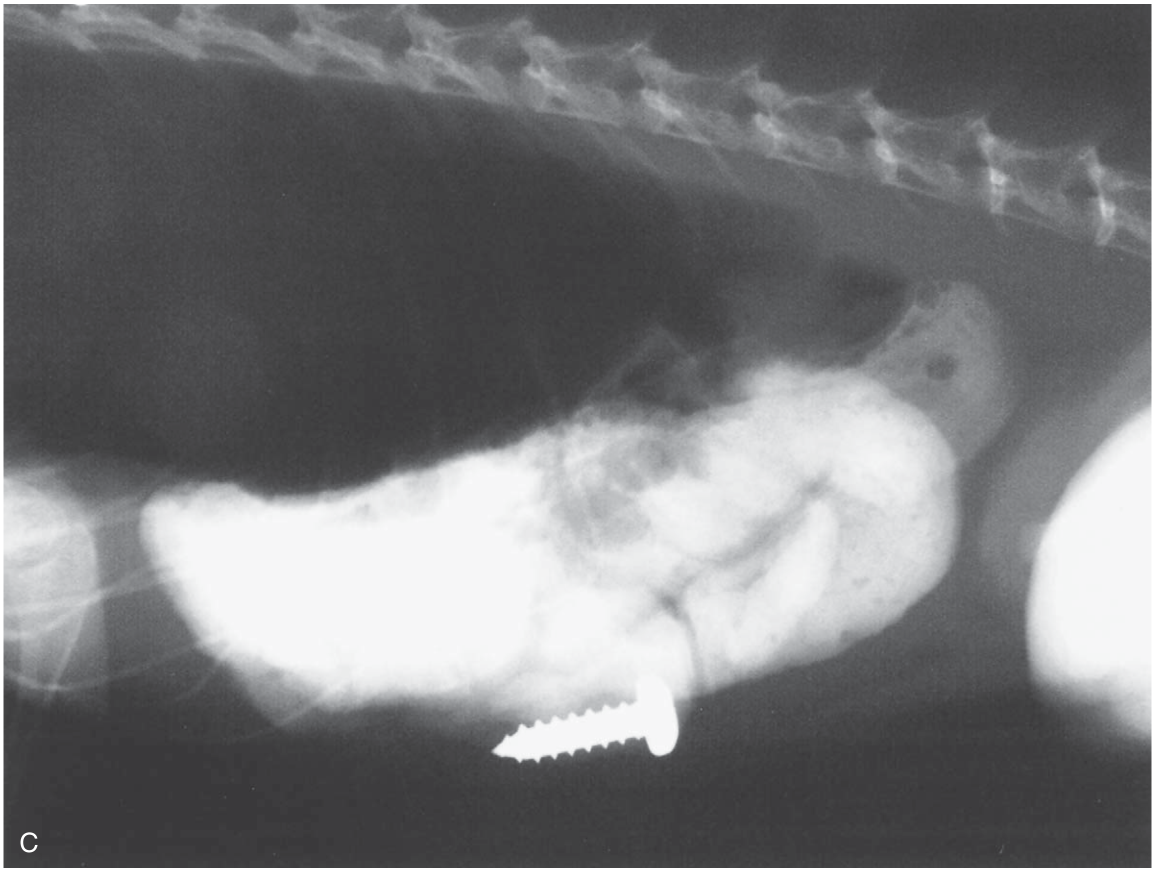

Figure 33-26, cont'd • For legend see opposite page.

Rectal Prolapse

Radiography can prove useful in identifying or eliminating possible causes of rectal prolapse, for example, terminal impactions or foreign bodies. In the following case example, involving a chameleon, the gross and radiographic features of this disorder are shown with some of the unique anatomical features of this fascinating *arboreal* lizard (Figures 33-27 through 33-30).

Face and Jaw Infection

Facial infections are more often than not the result of wounds that become infected. Unchecked, such infections may extend into the soft tissue interior, eventually reaching and infecting the underlying bone.

Localized osteomyelitis in the facial and jaw bones is usually depicted by a fairly consistent group of radiographic disease indicators, including reduced bone density, bone destruction, and in the case of the maxilla and mandible, dental loss. New bone deposition, unlike mammals, is typically scant, especially in the earlier stages of an infection.

In many instances of osteomyelitis, one or more supplementary views are needed to clearly identify the lesion and establish its full extent. Most supplementary and standard views of the head require anesthesia. Figures 33-31 through 33-33 illustrate the case of an iguana with osteomyelitis of its left rostral facial region and show the advantages of various types of supplementary projections compared with standard views.

Figure 33-27 • Rectal prolapse in a chameleon as seen from the right rear side.

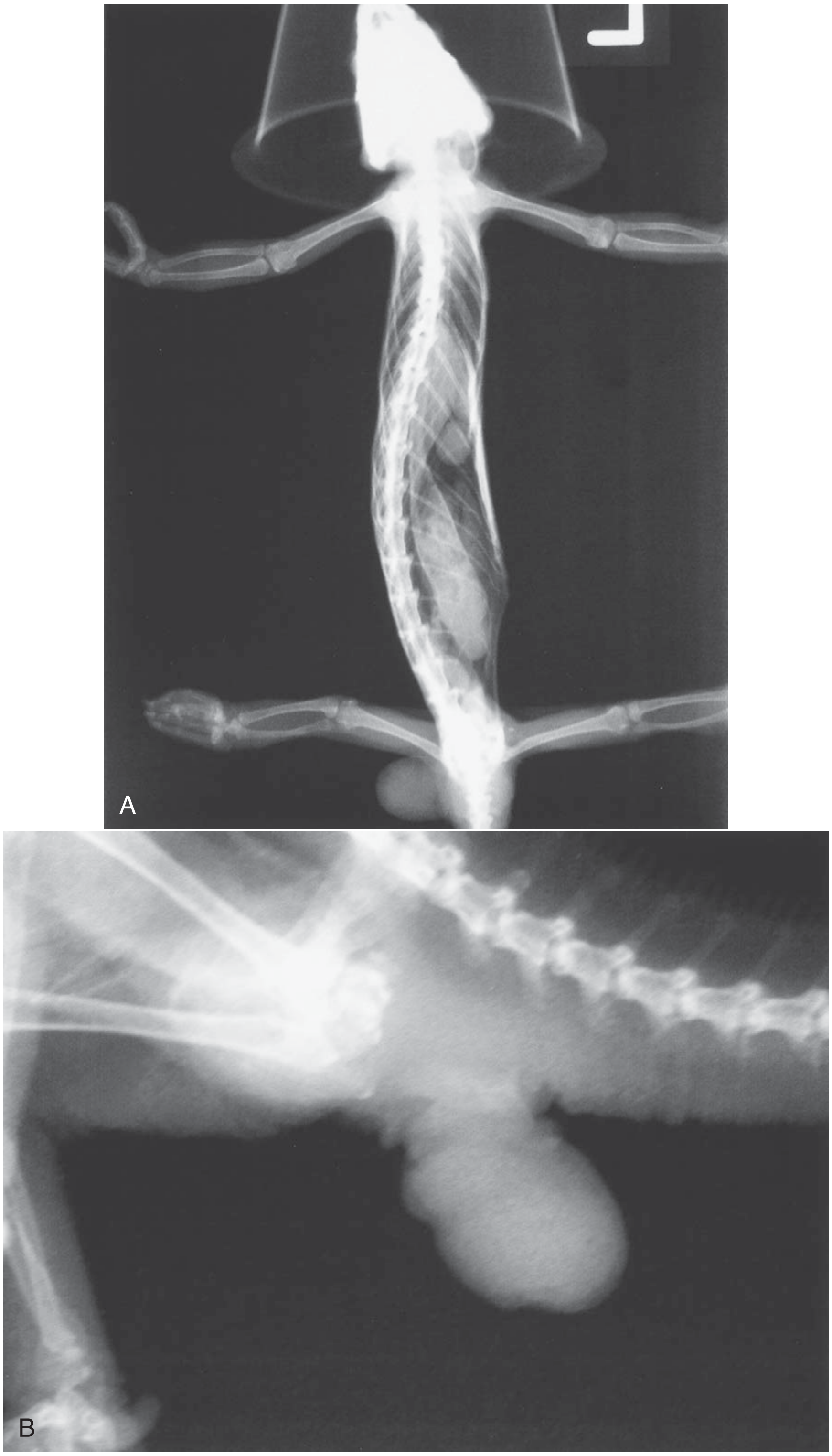

Figure 33-28 • A, Full-length dorsoventral and lateral close-up **(B)** views of the chameleon seen in Figure 33-27. The exteriorized rectum appears as an oval-shaped soft tissue mass just behind and below the right hip.

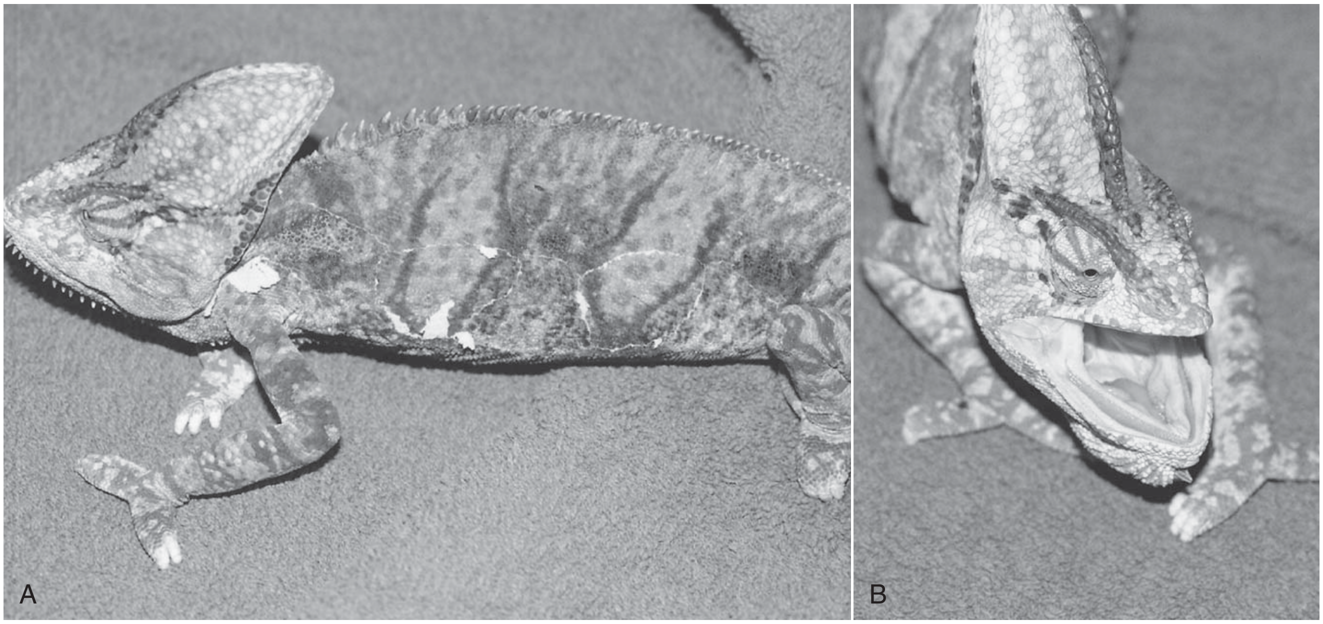

Figure 33-29 • A, Chameleon seen from above right and front **(B)** shows its distinctive *parietal crest* raised into a *casque* and its *zygodactyl* feet featuring a pair of clustered, opposable digits.

Figure 33-30 • A, Lateral and lateral close-up **(B)** views of the chameleon shown in Figures 33-27 through 33-29.

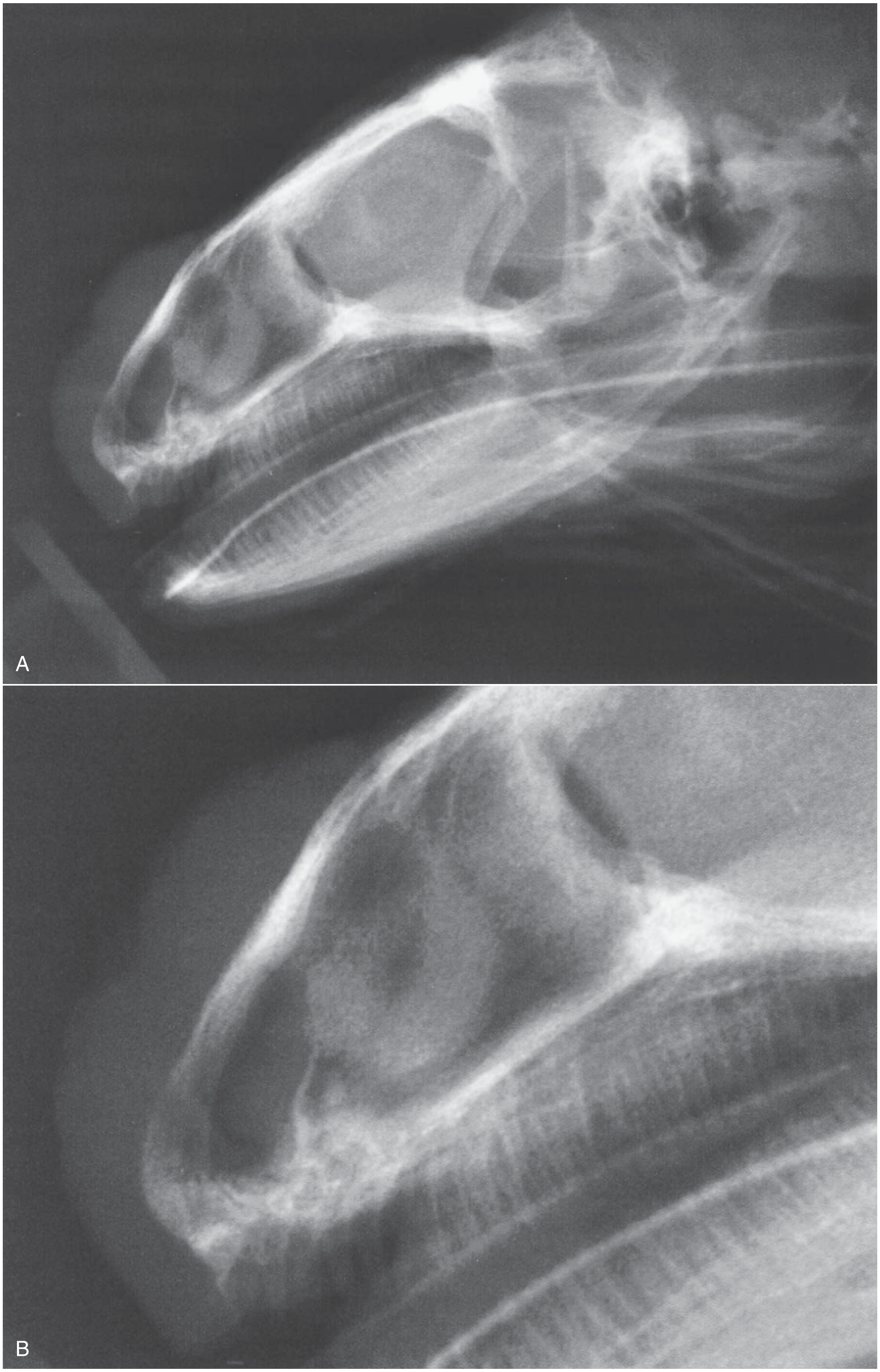

Figure 33-31 • A, Lateral and close-up lateral **(B)** views of an iguana with osteomyelitis of its left rostral facial region show moderate swelling and a subtle but discernible loss of density in the dorsal part of the premaxilla.

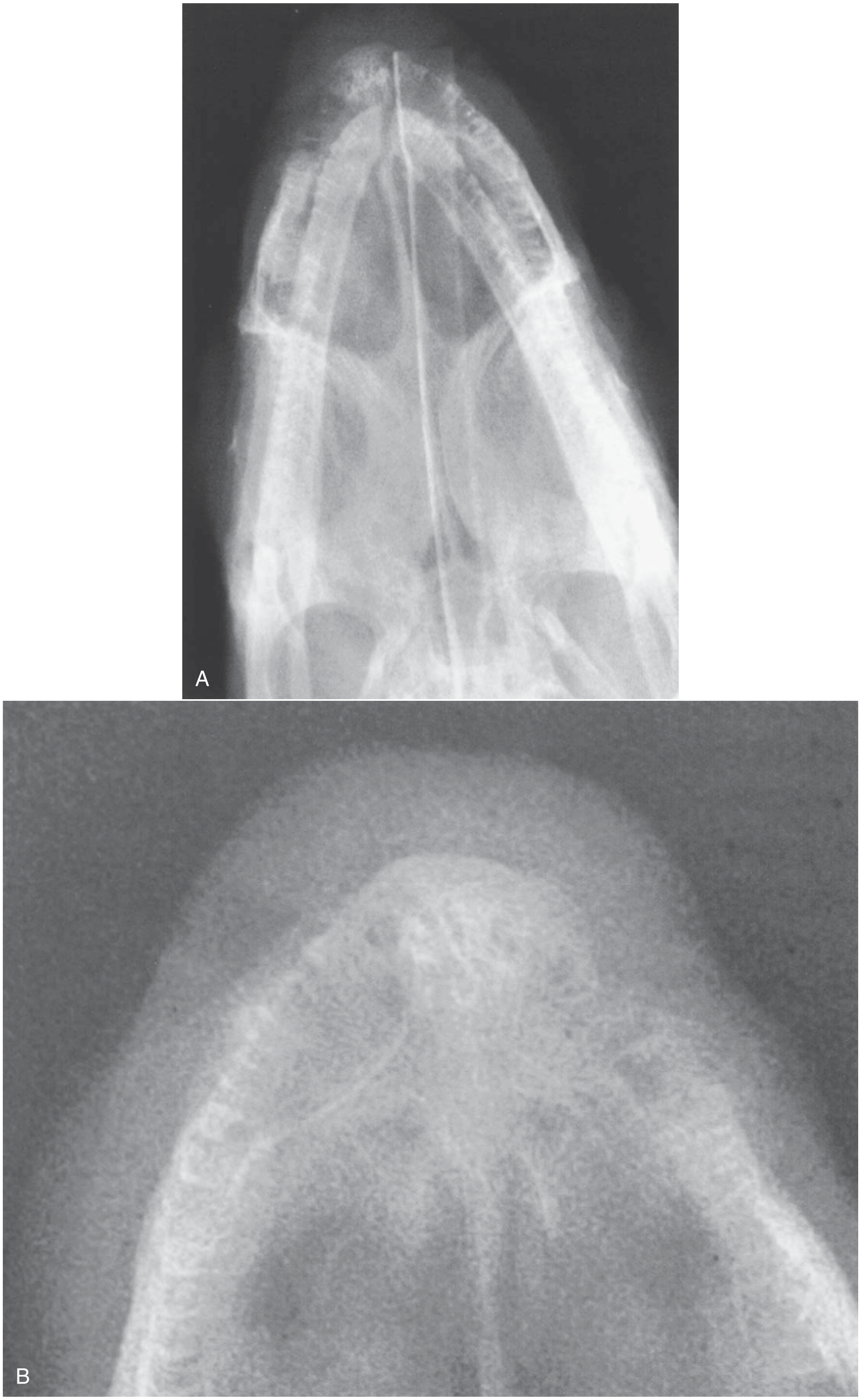

Figure 33-32 • A, Closed-mouth and intraoral **(B)** views of the rostral facial region of the iguana in Figure 33-31 show bilateral loss of normal bone density in the rostral premaxilla, with overt maxillary destruction on the left, including dental loss.

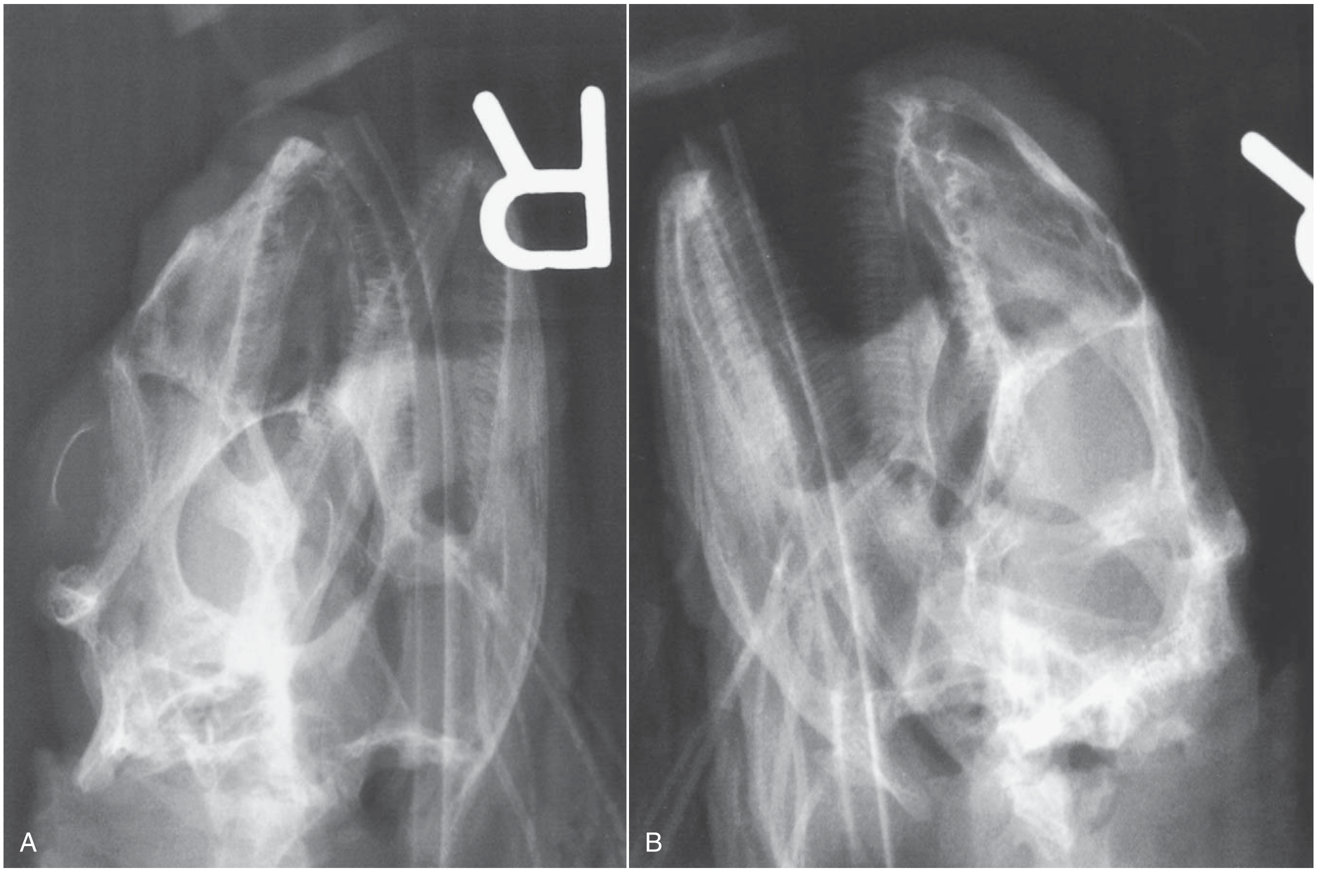

Figure 33-33 • A, Open-mouth left ventrodorsal oblique view of the rostral facial region of the iguana in Figures 33-31 and 33-32 shows complete loss of the upper and lower margins of the left premaxilla as a result of chronic osteomyelitis. A corresponding right oblique view **(B)** shows a subtle density loss in the right premaxilla with surrounding soft tissue swelling.

Chapter 34

Turtles

Turtles are part of a larger taxonomic group of shelled reptiles, the Chelonia, that also includes tortoises and terrapins.

RADIOGRAPHY

We typically image turtles and other reptiles in this group while fully conscious, obtaining three full-body views: dorsoventral, lateral, and craniocaudal. The former image is made with a vertical beam, and the latter two are produced with a horizontal beam (Figures 34-1 and 34-2).

DISEASES

Pneumonia

Pneumonia is one of the most common "turtle diseases" seen in our hospital. Although it may be unilateral or bilateral (double pneumonia), unilateral pneumonia is by far the more common. Turtles suspected of having pneumonia are given a shallow water flotation test. If they cannot maintain their normal surface buoyancy or exhibit asymmetrical flotation (Figure 34-3), then the possibility of consolidative lung disease becomes greater.

Radiographically, pneumonia in turtles and reptiles in this group is characterized by pulmonary consolidation, which depending on severity, increases lung density, sometimes to the point of completely opacifying one side of the chest (Figure 34-4). Although uneven inflation may be caused by pneumonia, it is more often attributed to secondary mechanical deflation caused by the head, neck, and limbs being withdrawn into the lateral recesses, which flank the animal's upper and lower shells, the *carapace* and *plastron*, respectively (Figure 34-5).

Gastrointestinal Obstruction

Turtles and related reptiles occasionally eat stones, which can cause partial or complete intestinal blockage that sometimes is insidious and intermittent. In this latter regard, one or more rocks may be radiographically identified in the stomach or intestinal tract of a sick turtle, tortoise, or terrapin.

Since gastrointestinal foreign bodies may be incidental findings, subsequent progress examinations are often done to determine whether the object or objects in question move or remain static. Those objects that remain fixed in position are usually assumed to be causative, whereas those that gradually move along or are passed are considered innocuous (Figures 34-6 and 34-7).

Reproduction

Turtles lay eggs, either hard- or soft-shelled, depending on the species. The former are the easiest to identify radiographically, typically appearing as multiple, dense, oval-shaped rings with a mild to moderate increase in interior opacity, compared with the surrounding abdominal viscera (Figure 34-8). Care must be taken not to mistake colonic folds for eggs (Figure 34-9).

Gout

Gout produces fairly typical lesions that usually are symmetrical, affect both forelimbs and hind limbs, begin distally, and spread proximally (Figure 34-10). Some infections resemble gout radiographically but rarely are symmetrical.

Figure 34-1 • **A,** Orientation and close-up **(B)** lateral views of a turtle made with a horizontally directed x-ray beam, with the animal elevated on a block.

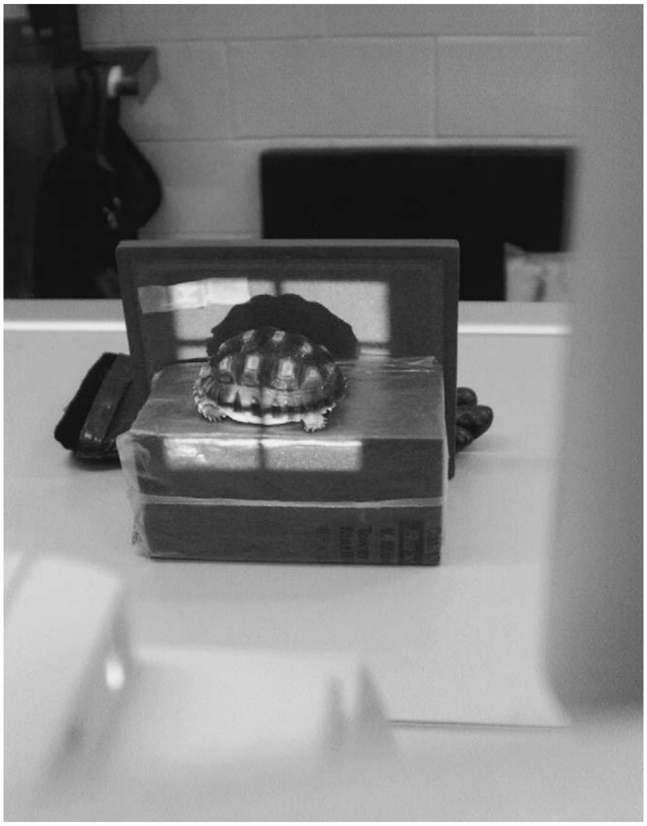

Figure 34-2 • Craniocaudal view of a turtle made with a horizontally directed x-ray beam, with the animal elevated on a block.

Figure 34-3 • A red-eared slider exhibits uneven buoyancy indicative of unilateral pneumonia.

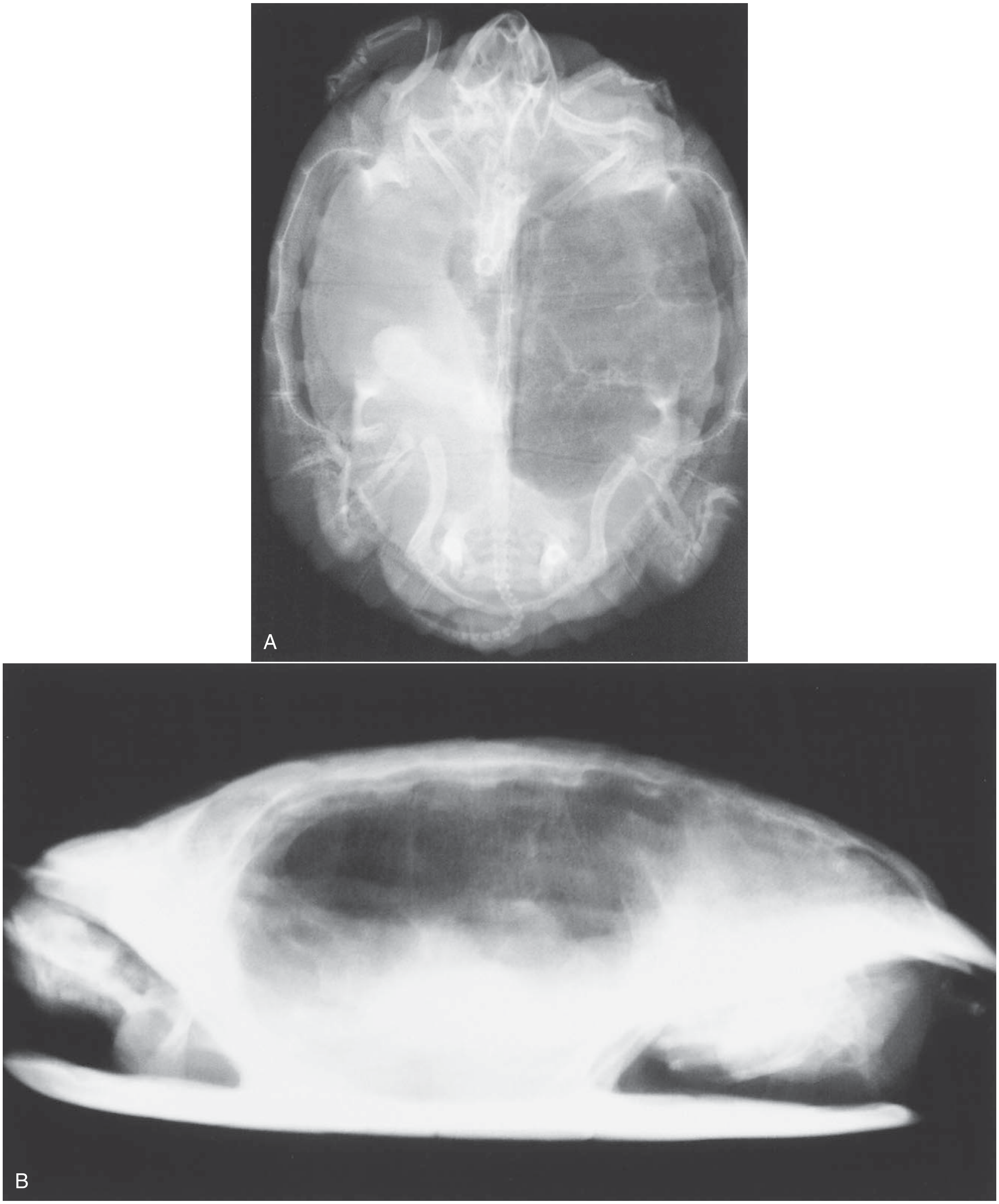

Figure 34-4 • A, Dorsoventral, lateral **(B),** and craniocaudal **(C)** whole-body views of the slider shown in Figure 34-3 show consolidation and volume loss of the right lung as a result of pneumonia. The left-sided pulmonary hyperinflation is compensatory.

Continued

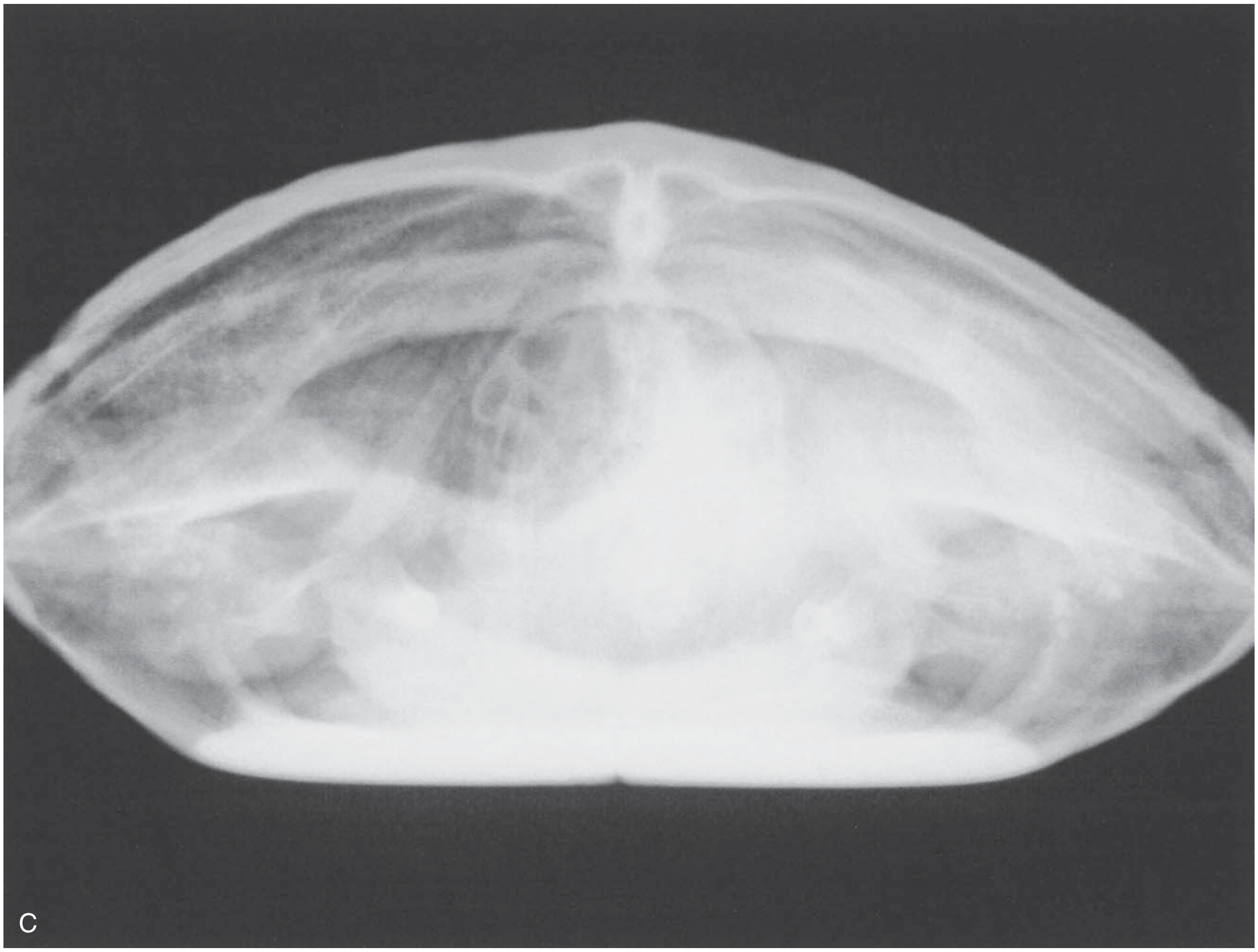

Figure 34-4, cont'd • For legend see p. 405.

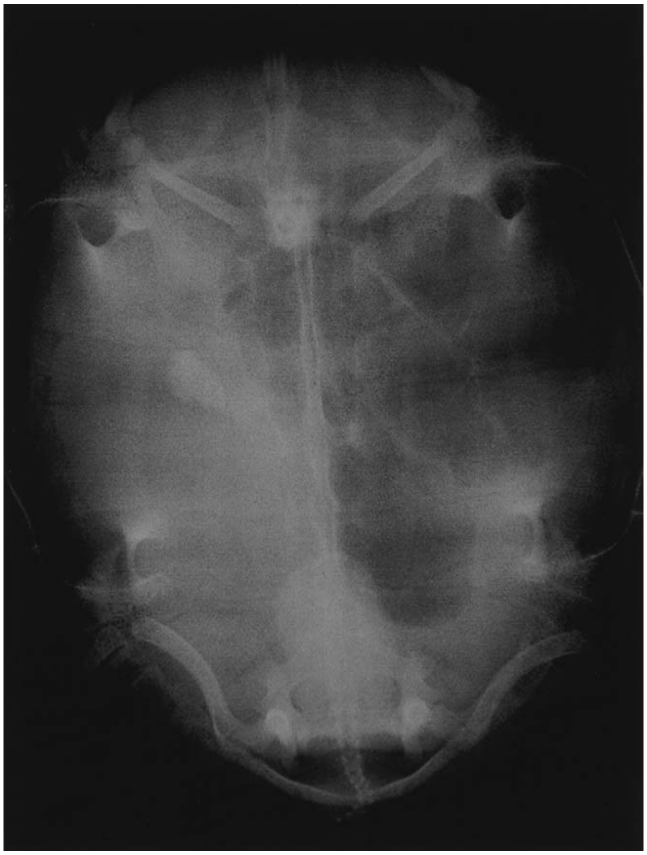

Figure 34-5 • Unilateral pneumonia in the right lung of a box turtle. The subtotal inflation of the right lung *(right)* represents normal mechanical deflation that occurs when the head, neck, and limbs are interiorized.

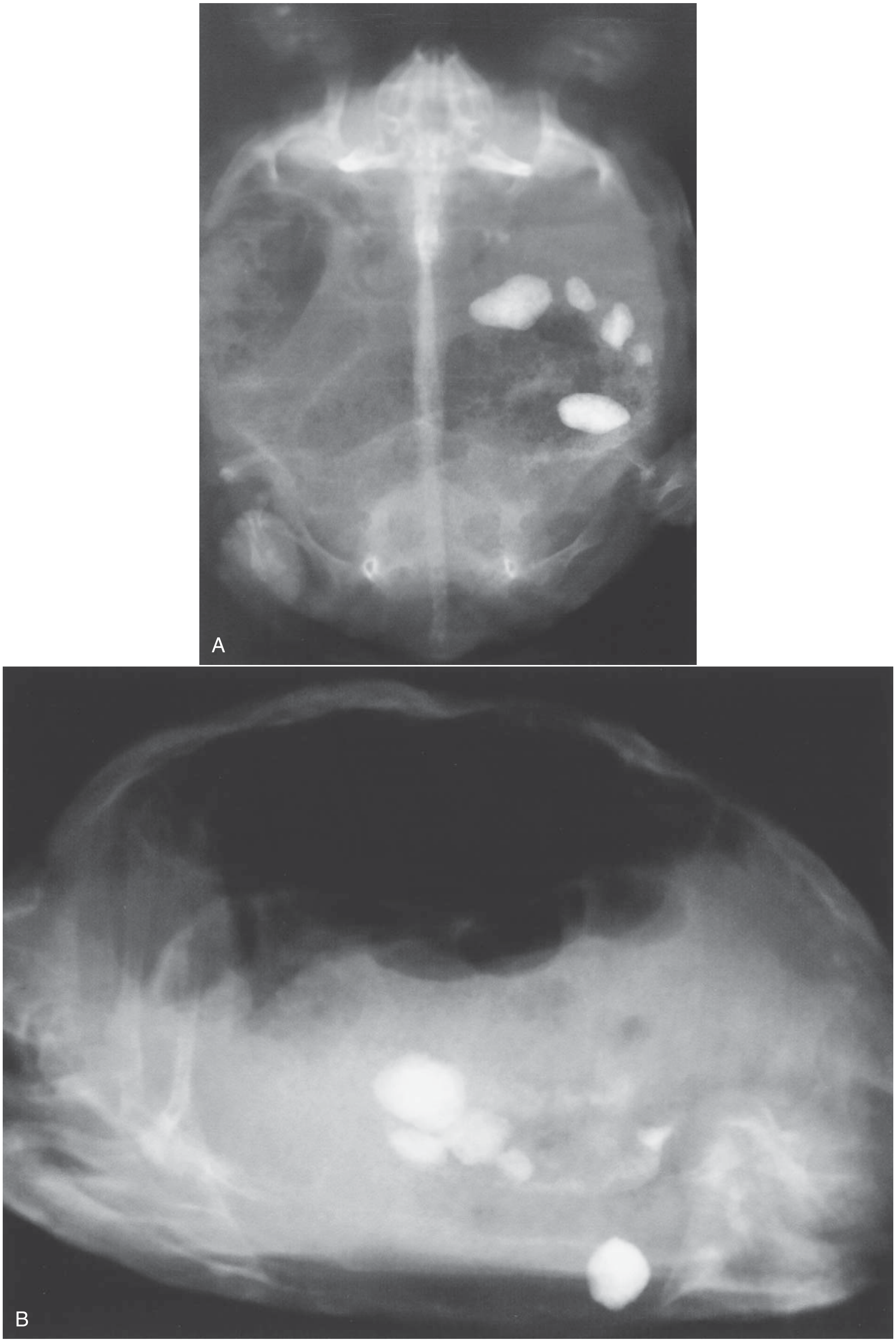

Figure 34-6 • A, Dorsoventral, lateral **(B),** and craniocaudal **(C)** views of a red-eared slider with a history of eating rocks causing constipation show five large- and medium-sized rocks in what is presumed to be a gas- and food-filled colon.

Continued

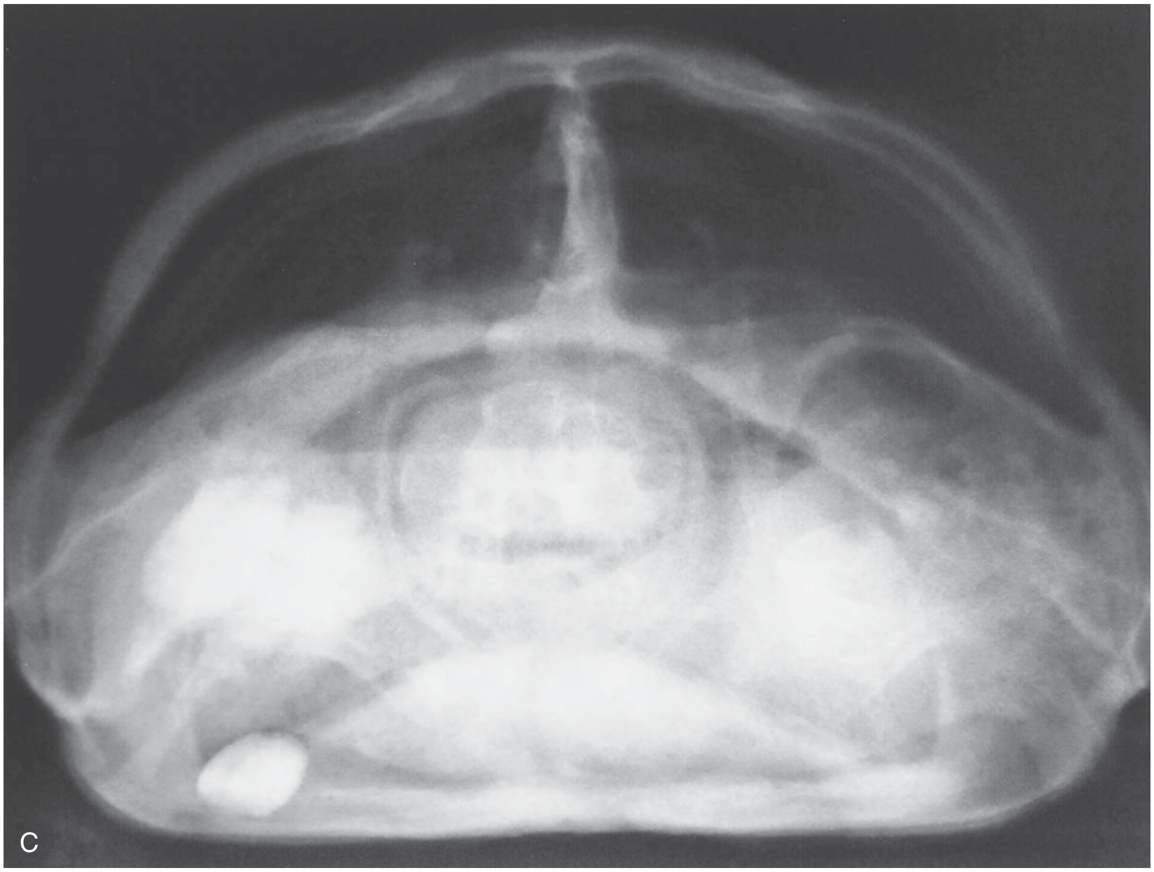

Figure 34-6, cont'd • For legend see p. 407.

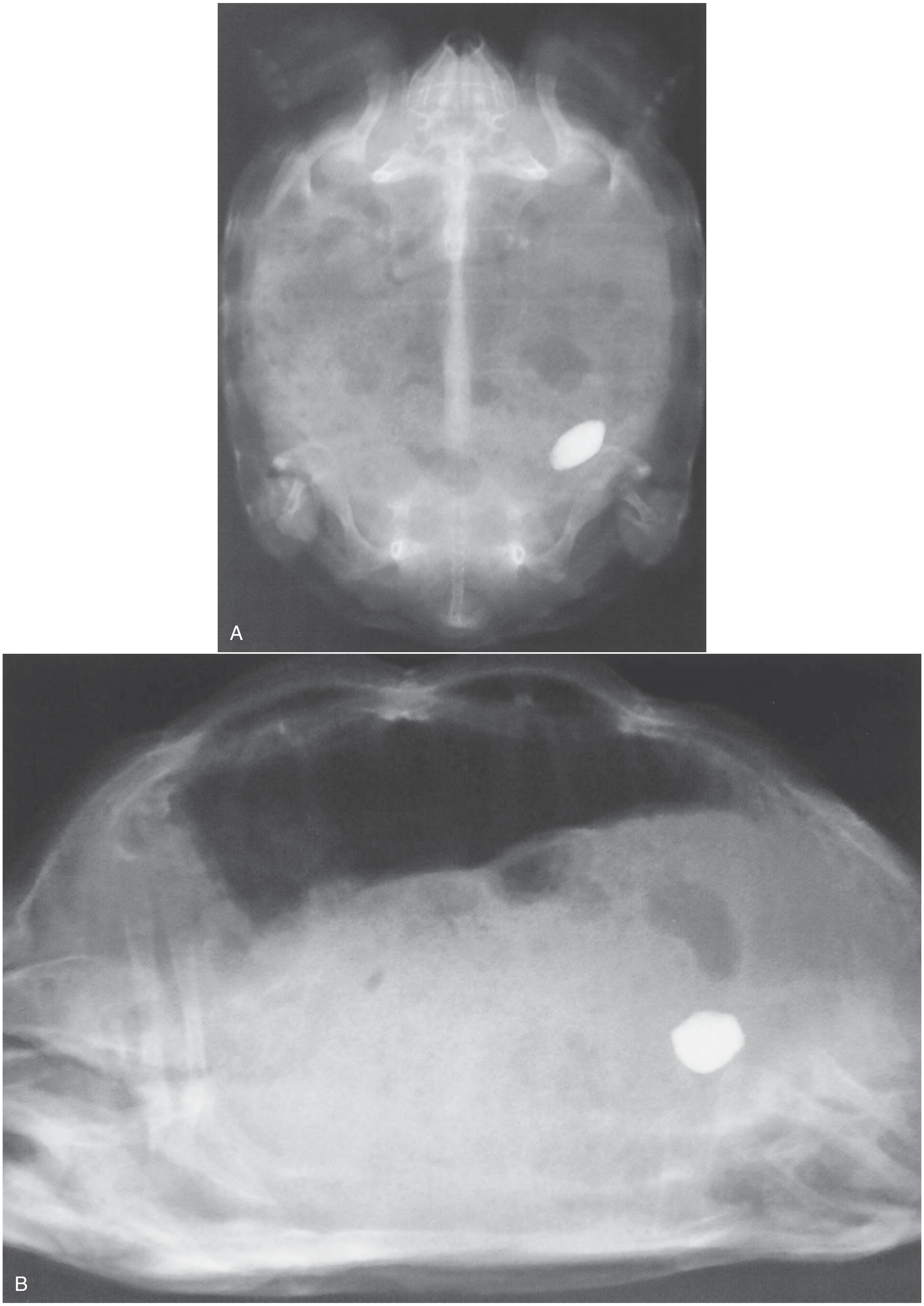

Figure 34-7 • A progress check made a few days later, including dorsoventral **(A),** lateral **(B),** and craniocaudal **(C)** views, shows that all but one of the stones has passed.

Continued

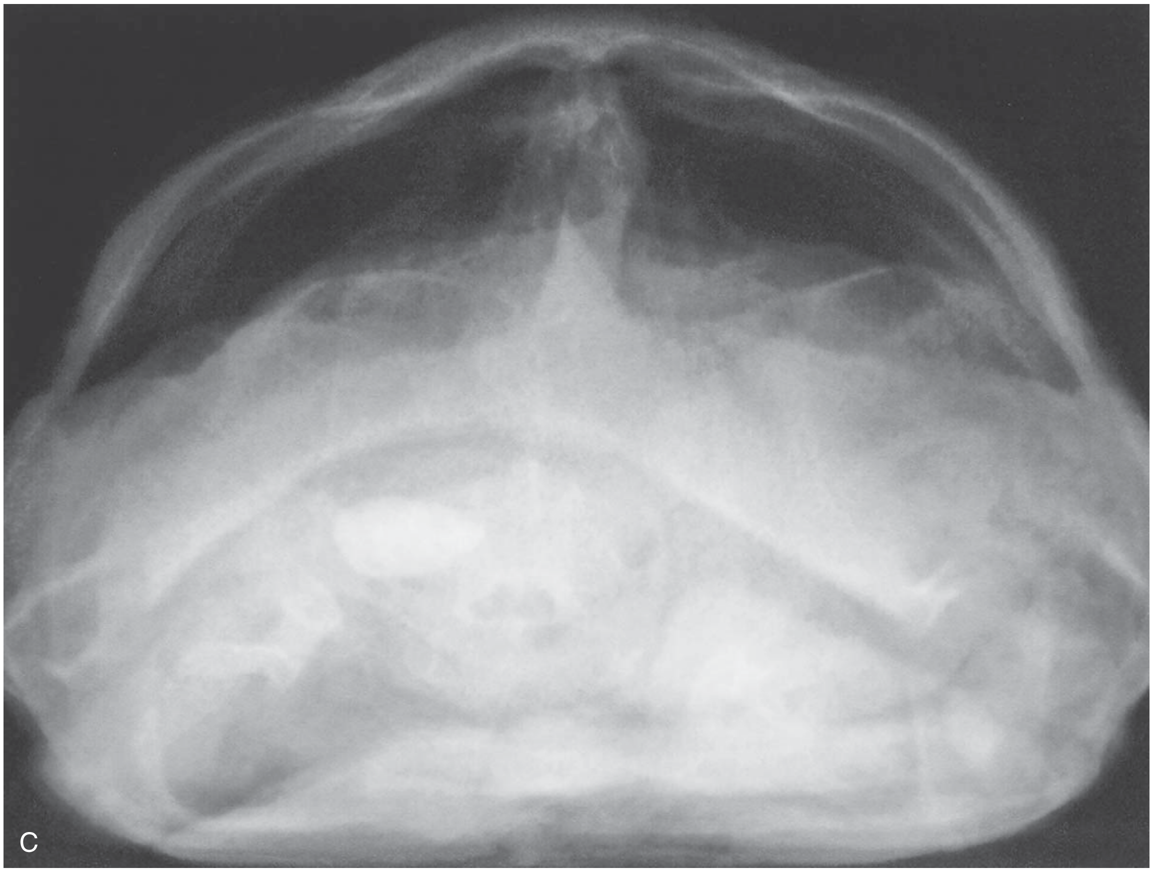

Figure 34-7, cont'd • For legend see p. 409.

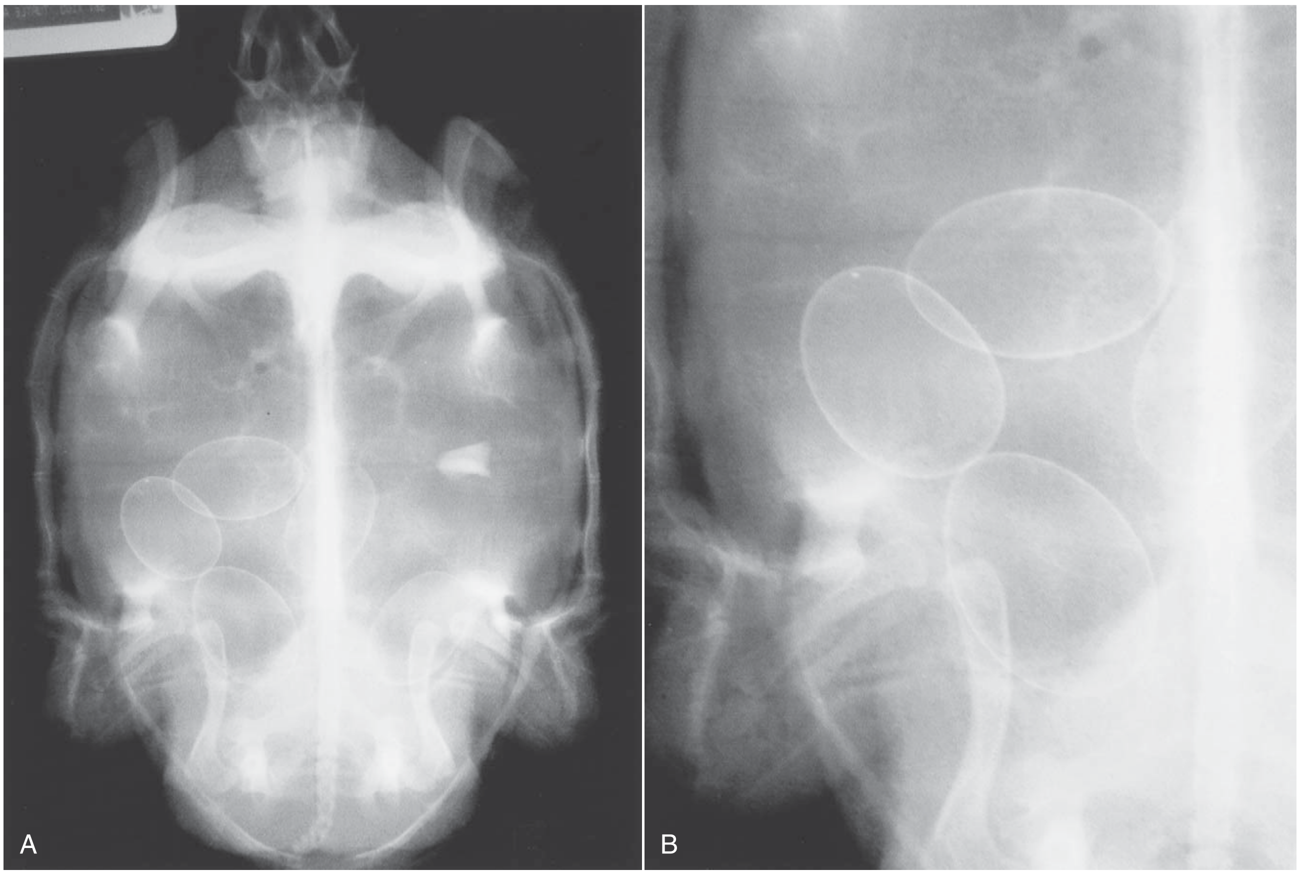

Figure 34-8 • A, Orientation and close-up **(B)** dorsoventral views of multiple eggs in a red-eared slider.

Figure 34-9 • A healthy, nongravid turtle shows distinctive colonic folds (emphasis zone) that should not be mistaken for eggs.

Figure 34-10 • A, Dorsoventral, close-up right forelimb **(B),** and right hind limb **(C)** views of a turtle with symmetrical forelimb and hind limb lesions believed to be caused by gout.

Figure 34-10, cont'd • For legend see opposite page.

Chapter 35

Caimans

Our first caiman, named *Lestat* after the famed vampire, was brought to us for treatment of injuries sustained in a hard fall. Beyond its inherent uniqueness, the creature was notable because it was a demonstration animal owned and shown by a graduate zoology student.

RADIOGRAPHY

Once again, we were able to transport, examine, radiograph (with and without anesthesia), operate, and eventually discharge this caiman because of the able assistance of the owner. Focusing on the imaging (as we must), we first learned how to radiograph a caiman with a minimum of force so that it could be done without chemical or gas restraint. This was accomplished by first muzzling the caiman with a few loops of duct tape (Figure 35-1), having the owner restrain the torso (Figure 35-2) and an assistant secure the tail.

INJURIES

The caiman's jaw was radiographed with a horizontally directed x-ray beam (Figure 35-3) to obtain the lateral projection (Figure 35-4) and a conventional vertical beam to make the dorsoventral view (Figure 35-5). The injured right carpus was examined in a similar fashion and included a comparison dorsoventral view of the opposite left carpus (Figure 35-6).

Although it was possible to clearly identify the dislocated right carpus, the left lower jaw fracture was not completely seen, even when the beam was angled (Figure 35-7). Accordingly, the caiman was anesthetized and radiographed again, but this time on its back, enabling us to use intraoral, nonscreen film (Figure 35-8). The images made under anesthesia showed the fracture more precisely, but they did not alter the earlier radiographic diagnosis.

When a 3-month recheck was performed, we saw that caiman fractures take longer to heal than comparable mammalian injuries, as appears to be the case with most reptiles.

Figure 35-1 • A fully conscious caiman, its jaws held shut by only a few loops of duct tape, calmly remains on the x-ray table awaiting radiography. Note the wound on the lower left midjaw, the result of a fall that also fractured the animal's mandible.

Figure 35-2 • The owner secures the caiman by hugging the torso, cradling the head and neck, and most importantly, preventing the right forelimbs and hind limbs from getting any sort of traction. This is truly a lesson in biomechanics.

Figure 35-3 • With only gentle pressure applied to its back, the caiman quietly awaits having its lower jaw radiographed with a horizontal x-ray beam, which is termed *postural radiography*.

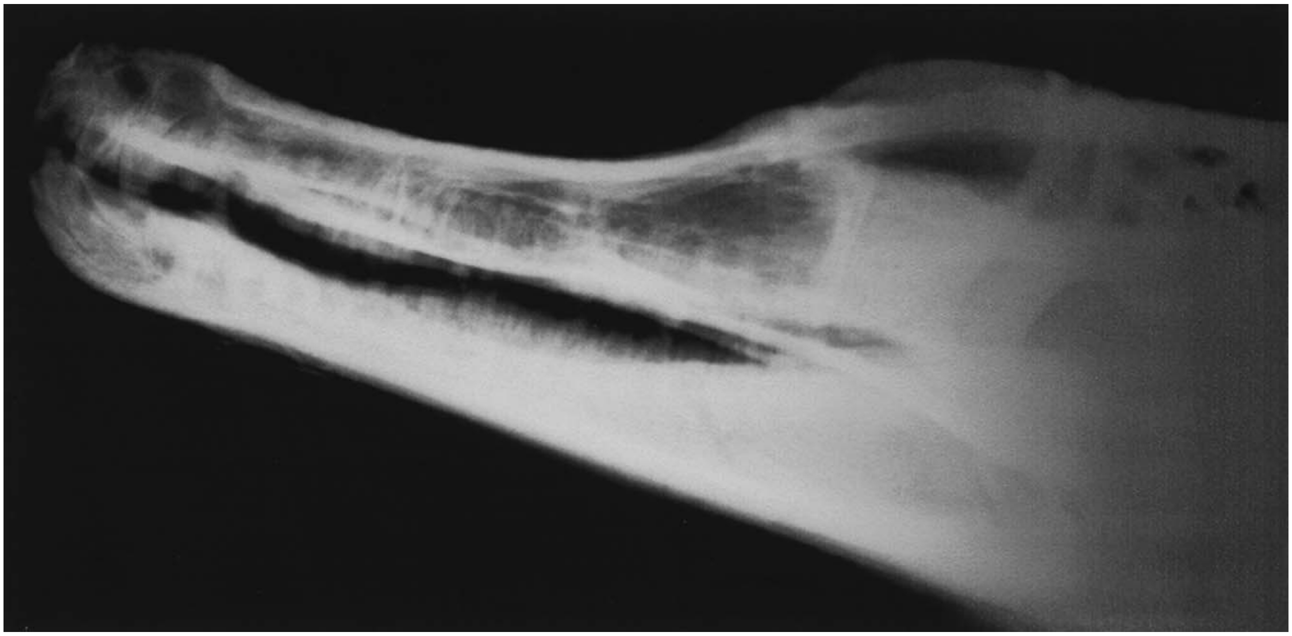

Figure 35-4 • Lateral projection of the skull of a caiman centered on the lower jaw shows a faint, minimally displaced, caudally situated diagonal fracture.

Figure 35-5 • Dorsoventral view of the skull of the caiman seen in Figure 35-4 fails to show the fracture because of superimposition of the jaws.

Figure 35-6 • A, Lateral and dorsoventral **(B)** images of the right midforelimb and distal forelimb of the previously described caiman show a dislocated first digit at the level of the carpometacarpal joint. **C,** A dorsoventral view of the normal left carpus is provided for comparison. An associated third-degree sprain is presumed based on the degree of luxation.

Continued

Figure 35-6, cont'd • For legend see p. 417.

Figure 35-7 • Dorsoventral oblique view of the left central mandible shows a minimally displaced stellite-type fracture, its interior aspect partially concealed by superimposed teeth and bone.

Figure 35-8 • A, A nonscreen film is placed in the open mouth of an unconscious caiman. Once the film is properly positioned, the mouth is closed **(B),** and the x-ray tube is aligned for an exposure **(C).**

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