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Textbook of Hernia

Springer

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ISBN 978-3-319-43043-0 ISBN 978-3-319-43045-4 (eBook)
DOI 10.1007/978-3-319-43045-4

Library of Congress Control Number: 2017930598

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Hernia repairs, both inguinal and ventral/incisional, are some of the most common surgeries performed in the world. Over the last 5 years, the field of hernia surgery has had a significant transformation thanks to a large number of new and innovative surgical techniques as well as an exponential growth in mesh and mesh technology. Increased focus on hernia surgery has led to improved research and outcomes data and has provided strategies to treat both simple and complex hernias. Secondary to the increased complexity of patients and new techniques and mesh products available, there has been a renewed interest in hernia surgery amongst the general and plastic surgery community.

This textbook provides a comprehensive, state-of-the-art review of the field of hernia surgery and serves as a valuable resource for clinicians, surgeons, and researchers with an interest in both inguinal and ventral/incisional hernia. This book gives an overview of the current understanding of the biologic basis of hernia formation as well as lays the foundation for the importance of hernia research and outcomes assessment. Diagnosis and management strategies for inguinal and ventral hernia will be discussed in detail with separate techniques sections for the most widely used procedures in this field as well as emerging technologies such a robotic and single incision surgery. Pertinent associated topics to inguinal hernia surgery such as chronic groin and athletic pubalgia are covered in detail. For incisional hernias, associated topics such as hernia prevention and enhanced recovery protocols are discussed. For both inguinal and ventral/incisional hernias, mesh choices and available mesh technologies are discussed in detail as this remains an often confusing matter for the general surgery. When appropriate, chapters to highlight controversies in care will be highlighted such as the use of synthetic mesh in contaminated surgery and laparoscopic closure of defects in laparoscopic ventral hernia repair. Other topics that are seldom discussed but may be of value to hernia surgeons include a discussion on the use of social media for hernia education and hernia repair in underserved areas.

We hope to give the reader an all-encompassing and wide overview of all types of abdominal wall hernias and highlight common open and laparoscopic techniques and current recommendations for patient management. This textbook provides a concise yet comprehensive summary of the current status of the field that will help guide patient management and stimulate investigative efforts. All chapters are written by experts in their fields and include the most up to date scientific and clinical information.

A book of this scope and breadth is a major undertaking, and we wish to thank all the wonderful authors and Tracy Marton for her assistance in preparing this book.

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The Biology of Hernia Formation

1

Nadia A. Henriksen, Kristian K. Jensen,
and Lars N. Jorgensen

1.1 Introduction

Hernia formation is a multifactorial process involving endogenous factors including age, gender, anatomic variations, and inheritance and exogenous factors such as smoking, comorbidity, and surgical factors (Fig. 1.1) [1]. However, these factors alone do not explain why some develop abdominal wall hernias. Already in 1924, the anatomist Sir Arthur Keith proposed that surgeons should try to perceive tendons and fascia as living structures in order to understand the hernia disease properly [2]. Research on synthesis and breakdown of connective tissue in relation to pathophysiological mechanisms of hernia formation is important to comprehend herniogenesis and to select a proper treatment strategy for the individual patient.

1.2 The Connective Tissue

The connective tissue comprises the extracellular matrix (ECM) and the cells within. The ECM contains proteoglycans and proteins, such as collagen and elastin, which together form a dense network important for tissue stability. In healthy tissue, regeneration of ECM involves a controlled balance between degradation of old and damaged proteins and synthesis of new ones [3]. In hernia patients, this balance may be disturbed leading to altered tissue turnover and impaired tissue quality.

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1.2.1 Collagen

Collagen is synthesized by fibroblasts in a complex process involving extensive modifications before the mature collagen fibril is formed (Fig. 1.2) [4]. The amino acid hydroxyproline is almost unique for collagen and is used for quantitation of collagen in certain tissues. The collagen protein consists of a triple helix, and the enzyme lysyl oxidase (LOX) mediates the formation of both intra- and intermolecular cross-links between the collagen fibrils contributing to the special strength and stability of the collagen protein.

There are 28 genetically different types of human collagen [5]. The skin and fascia consist mainly of type I collagen with smaller amounts of type III and V collagen. The same collagen fiber can comprise both type I and III collagens. The more type III collagen relative to type I collagen, the thinner and weaker the fiber. Type V collagen is essential during collagen maturation, as it is involved in the initiation of fibril formation.

1.2.2 Matrix Metalloproteinases

Matrix metalloproteinases (MMPs) constitute a family of 23 zinc-dependent proteases important for collagen remodeling. The MMPs are divided into groups based on their structure and function. The most important with regard to hernias and collagen are the collagenases (MMP-1, MMP-8, and MMP-13) and the gelatinases (MMP-2 and MMP-9). The collagenases unwind the triple-helical collagens into gelatin, and then the gelatinases cleave the denatured collagen [6].

1.3 Inheritance and Genetics

Some patients seem to be especially susceptible to hernia development [7]. Patients operated on for abdominal aortic aneurysms have a higher risk of developing an incisional hernia postoperatively as opposed to patients operated on for

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_1

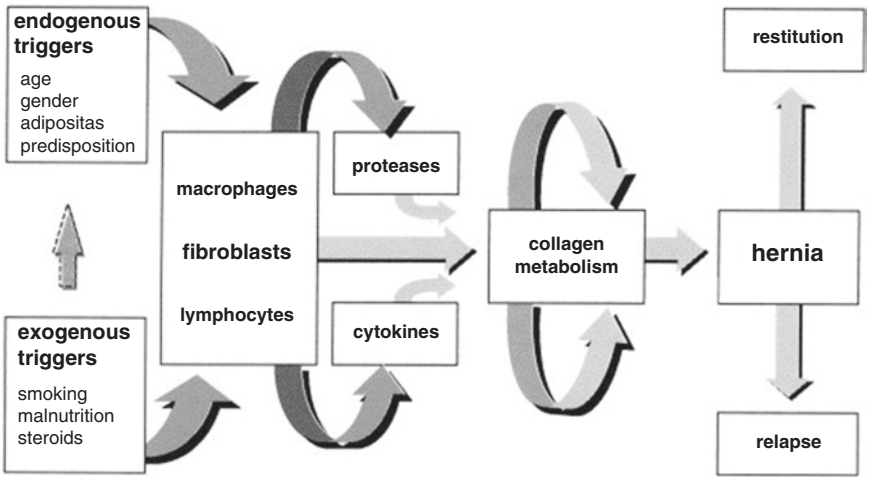

Fig. 1.1 Endogenous and exogenous factors involved in hernia formation (Reproduced with permission from: Jansen PL et al. The biology of hernia formation. Surgery 2004)

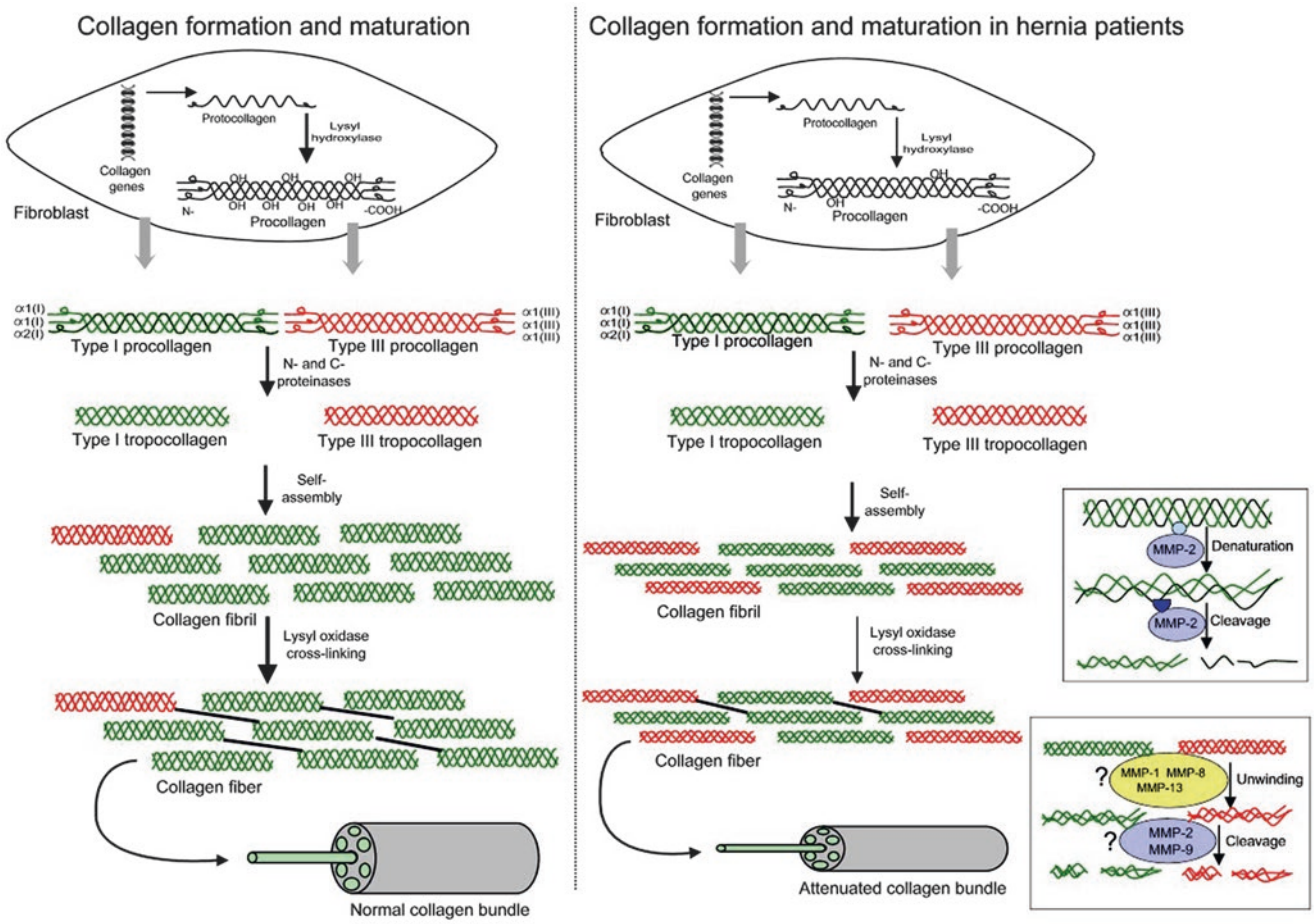

Fig. 1.2 Collagen synthesis and maturation in healthy tissue and in patients with hernias (Reproduced with permission from: Henriksen NA et al. Connective tissue alteration in abdominal wall hernia. Br J Surg 2011)

aortoiliac occlusive disease [8]. Patients with rare connective tissue disorders such as Marfan's syndrome and Ehlers–Danlos syndrome have an earlier onset and a higher risk of hernia development [9–11]. Further, patients with direct inguinal, bilateral inguinal, or recurrent inguinal hernia are at higher risk of ventral hernia formation [12–14], suggesting a systemic predisposition to hernia formation.

Emerging evidence suggests that inguinal hernias represent an inherited disease; however the inheritance pattern remains to be clarified [15]. There is increased risk of developing an inguinal hernia, if a first-degree relative has a history of inguinal hernia repair. Most of the literature on groin hernia inheritance includes hernias in children and does not distinguish between indirect and direct hernias.

Furthermore, the strongest inherited predisposition for hernia disease is found in females with inguinal hernias [16, 17]. As groin hernias in children and females most often are of the indirect type [18, 19], the demonstrated inheritance patterns may be associated with indirect inguinal hernias. Thus, it is possible that it is the anatomic defect of a patent processus vaginalis that is inherited and not a defect in collagen turnover.

It has not yet been possible to identify gene defects involved in hernia formation for clinical use. A polymorphism in the regulatory region of the COL1A1 gene and a missense point mutation in the elastin gene have been demonstrated in a smaller population of patients with both indirect and direct inguinal hernias [20, 21]. A recent genome-wide association study including more than 5000 patients with a history of indirect or direct inguinal hernia repair identified four genetic susceptibility loci for inguinal hernia including *WT1*, *EFEMP1*, *EBF2*, and *ADAMTS6* [22]. WT1 and EFEMP1 may be important in connective tissue turnover through their effect on ECM enzymes including MMPs. The ADAMTS proteins are related to MMPs in structure and function and play a role in ECM homeostasis. A smaller genome profiling study analyzing fascia and skin biopsies of patients with recurrent incisional hernias found an altered expression of the GREM1 gene [23]. GREM1 is a regulator of tissue differentiation and related to fibrosis, which could explain its association to incisional hernia recurrence. Furthermore, altered gene expressions were found for COL1A2, COL3A2, and LOX in patients with recurrent incisional hernias.

1.4 Role of Collagen Turnover in Hernia Formation

Studies on the morphology of the fascial tissue surrounding inguinal hernias found lower total collagen content in patients with inguinal hernias compared with individuals without inguinal hernia [24–29]. Furthermore, the fascial collagen architecture appears altered as described histologically by an uneven distribution of collagen fibers, thinner collagen fibers, inflammation, and degeneration of muscle fibers [24, 30–32].

The collagen quality seems to be more important than the collagen quantity. In fascia from hernia patients, there is less type I collagen relative to type III collagen resulting in a decreased type I to III collagen ratio and thinner collagen fibers with less tensile strength [33, 34]. These alterations are also present at the mRNA level suggesting that the problem appears during collagen synthesis [35]. A decreased type I to III collagen ratio is also present in skin biopsies from hernia patients, suggesting that the connective tissue alterations are systemic [36].

The reason for the altered collagen quality and the decreased type I to III ratio remains to be clarified. It has been suggested that altered activity levels of the enzymes involved in the collagen synthesis and maturation process may play a role. Decreased activity of lysyl oxidase results in decreased cross-linking of collagen fibrils [37], which is essential for collagen strength and stability (Fig. 1.2). In addition, recent studies found systemically decreased turnover of type V collagen both in patients with inguinal hernia and in patients with incisional hernia. Type V collagen is necessary for initiation of collagen fibril formation, and decreased levels of type V collagen may thereby impair the collagen synthesis [38, 39].

Alternatively, the reduced collagen quality may be associated with altered ECM homeostasis. MMP-2 is increased both locally and systemically in men with inguinal hernia, suggesting a higher MMP-2 activity causing increased collagen breakdown [40–42]. No convincing results exist presently with regard to other MMPs or MMP involvement in the development of incisional hernias.

Overall, the collagen alterations found in patients with inguinal hernias are more pronounced in patients with direct hernias as opposed to patients with indirect hernias, suggesting that an imbalance in collagen turnover is especially important in the formation of direct hernias.

1.5 Wound Healing in Hernia Patients

The wound healing process is complex and involves important steps in ECM turnover, which are important in the understanding of secondary hernia formation, that are incisional or recurrent hernias.

First step of the wound healing process includes vasoconstriction and clot formation secondary to activation of both platelets and the coagulation cascade. The following inflammatory phase initiates the immune response in order to eliminate bacteria from the wound. A wound colonized with bacteria at a high tissue concentration will not heal properly as illustrated by the fact that surgical site infection is a well-known risk factor for incisional hernia formation [43]. During the inflammatory response, several growth factors are involved, which among others activate fibroblasts leading to the proliferative phase of wound healing beginning on day 3. This involves fibroblast and myofibroblast proliferation, followed by migration, leading to wound contraction. The fibroblasts produce type I and III procollagens and deposit ECM. In unwounded dermis, there is 80 % type I collagen and 20 % type III collagen, whereas there is 40 % type III collagen in wounded dermis, resulting in thinner collagen fibers with less strength. Lastly, the remodeling phase takes place and may last up to 2 years. During this phase, the immature type III collagen is replaced by the mature and

stronger type I collagen [44]. Any imbalance in this process may lead to hernia formation. Interestingly, the type I to III collagen ratio is even more decreased in patients with secondary hernias as compared with patients with primary hernias, suggesting that hernia recurrence is also associated with collagen imbalance [36].

The final strength of the wound depends on the respective anatomic region, and the duration and quality of the wound healing process. However, surgically traumatized fascial or aponeurotic tissues never regain their original strength, indicating that a midline aponeurotic scar is relatively weak despite uncomplicated healing conditions. It has been demonstrated that minor mechanical stress impacts positively on wound healing in various tissues. Sutured wounds of aponeurosis benefit from mechanical stress in terms of organization and alignment of collagen fibrils as well as enhanced maturation of collagen cross-linking [45].

Apart from infection, other exogenous factors may be involved in the development of secondary hernias. Smoking is a well-known risk factor for both incisional and recurrent inguinal hernias [46, 47]. In smokers, the function of the fibroblasts is compromized and the collagen synthesis is decreased leading to delayed wound healing, possible wound dehiscence, and ultimately hernia formation [48, 49].

Future research on the biology of hernia formation may focus on developing serological markers enabling identification of patients at high risk of developing secondary hernias, thus opening up for preventive measures such as prophylactic mesh placement after elective non-hernia surgery.

1.6 Main Points

- Hernia formation is multifactorial
- Inguinal hernias represent inherited disease, but both the inheritance pattern and involved gene defects remain to be clarified
- Type I to III collagen ratio is decreased in patients with hernias resulting in thinner and weaker collagen fibers
- The connective tissue alterations found in patients with hernias are pronounced in patients with direct and recurrent inguinal hernias as opposed to patients with indirect inguinal hernias

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An Introduction to Complex Systems Science and Its Application to Hernia Surgery

2

Bruce Ramshaw

2.1 Introduction

The scientific paradigm shift from reductionist to complex systems science began over a century ago. Around the beginning of the twentieth century, physicists started to understand the incompleteness of Newtonian physics applied to the real biologic world. During the past century, many other disciplines have begun to make this shift. From the studies of systems biology to behavioral economics, the principles of a reductionist, rational, and static scientific understanding of our world have been found to be inadequate to explain and improve our dynamic and ever-changing world. Even the human genome project, with the unmet potential to discover the blueprint for the cause of and cure for all of our diseases, found that our genome was constantly adapting and changing and the idea that we could make a major impact on our health through only genetic engineering was naïve and misguided. Understanding healthcare as a complex biologic system and applying tools that apply to this reality will result in a global healthcare system that is based on measuring and improving the value of care we provide.

A more complete understanding of our world through the application of complex systems science will allow us to identify the factors that contribute to both positive and negative outcomes from definable patient processes and patient subpopulations. These factors are constantly changing and are interconnected with other factors that contribute to outcomes. If they are tested in isolation, as attempted in a prospective, randomized, *controlled* trial, the potential measurement of the impact of any one factor will be likely inaccurate. It would also only apply to the selected group of people in which that factor was tested and only in the environment in which that experiment was completed. The tools we have used to attempt to discover static truths in healthcare will need to be replaced by tools from complex systems science (also known as information or data science) which should be applied to all patients (no inclusion or exclusion criteria) in many different local environments.

Where the reductionist scientific method, which attempts to prove or disprove a hypothesis, assumes the test environment is static, the complex systems tools for discovery are intended to be applied to a constantly changing world. Basic principles in complex systems science include the assumption that many factors that are constantly changing and interacting can have a variety of impacts on the subject (a person/patient) who is considering a variety of treatment options and will have a variety of potential outcomes based on the interaction of the factors related to the patient, the treatment process in that local environment at one particular moment in time. A change in any one or more of these factors can lead to a similar or potentially different outcome from the same treatment option. Rather than attempting to prove or disprove a hypothesis, tools for discovery in complex systems science are simply designed to improve whatever is measured within a definable process.

These tools for improvement have been applied and matured most famously in manufacturing, the automobile industry, for example. A variety of terms have been applied to improvement tools such as Lean and Six Sigma, but the basic concept is the same—the desire to achieve continuous improvement. One significant point needs to be made about the application of these tools in manufacturing compared with healthcare. In manufacturing, these tools are typically applied to one manufacturing process that is producing one specified product, a 2016 Ford Mustang, for example. In a manufacturing process, the steps and factors involved can be controlled and improved by eliminating variation. Statistical tools include process control charts to identify inappropriate or unexpected variation. In a biologic process, such as

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_2

healthcare, it is impossible to control the variation. Instead, the process can be managed through iterative measurement and improvement of value-based outcomes and through the identification of patterns and subpopulations. The optimal variety of options for various subpopulations can be determined with nonlinear complex systems tools such as factor analysis and predictive analytics. Currently, many reductionist tools for improvement (like a single "best practice," for example) are being applied to healthcare as if healthcare was composed of static, mechanical processes instead of the realty that we are dealing with complex biologic processes in healthcare.

Another way improvement tools have been generally misapplied in healthcare is their application to subproccesses without attention to the impact on the value of whole patient processes. It should be well accepted that the most important processes to improve are the entire cycles of patient care for the many definable patient processes. The concept of a whole patient process includes the time from the moment of first symptom to the return to a full quality of life (for acute, curable disease) and in some cases for the entire life of the patient (for chronic, not currently curable disease). The ultimate outcome measure for the entire cycle of care is value, a combination of costs, quality measures, and outcome measures from the perspective of the patient, such as patient and family satisfaction with the care process. Until now, essentially all process improvement attempts in healthcare, like decreasing central line infection or improving safety in the operating room, have been attempts at improving a subprocess, not the entire cycle of care for a definable patient care process. In a complex process, when a subprocess is improved without attention to the whole process, the result is suboptimization—improvement of a subprocess will not lead to improvement of the whole process and will predictably have unintended consequences.

The application of complex systems science to hernia disease is demonstrated in applying the principles of value-based clinical quality improvement (CQI) principles to the whole cycle of care for a definable patient care process. This ideally requires a multidisciplinary team to determine the appropriate factors (patient and treatment variables) that are most likely to impact the outcomes that would measure value for a specific care process. By identifying what data points and outcome measures should be collected, the team is providing the programming for what goes in to the computing—a computer program providing data analysis and data visualization. That same team then attempts to interpret the significance of the analysis and data visualizations to generate ideas to improve outcomes that measure value. This example of a team providing the programming of data, a computer program providing a variety of data analytics and visualizations from the data entered, and that same human team then interpreting the output and using that to generate ideas for improving the patient care process is an example of the human–computer collaboration that can be termed artificial intelligence (Fig. 2.1). Computers have become immensely powerful at beating human beings in competitions if rules and answers are known and do not change. IBM's successful demonstration of their computer capabilities at beating the world's best chess player (IBM's Deep Blue vs. Garry Kasparov) and Jeopardy's greatest champions (IBM's Watson vs. Ken Jennings and Brad Rutter) demonstrate that computing capabilities have overtaken even the greatest human minds in these areas. But this was never meant to be the greatest potential application of artificial intelligence. The true potential for artificial intelligence is in the discovery of new ideas, innovations, and applications that have yet to be applied to improve the value of a particular process. In the case of hernia disease, we have generated many examples of attempts to improve the value of care for patients who have a ventral hernia. We will demonstrate the method and impact of having a dedicated team (including input from patients and family members) who determine what factors and outcome measures to use for the computer analytics and how to interpret the output of the data analyses and data visualizations to generate value-based ideas in an attempt to improve outcomes. This is one application of artificial intelligence, a symbiosis between human teams and computing capabilities, to healthcare. This complex systems science approach to healthcare will become more and more important as the pace of change in our world continues to accelerate.

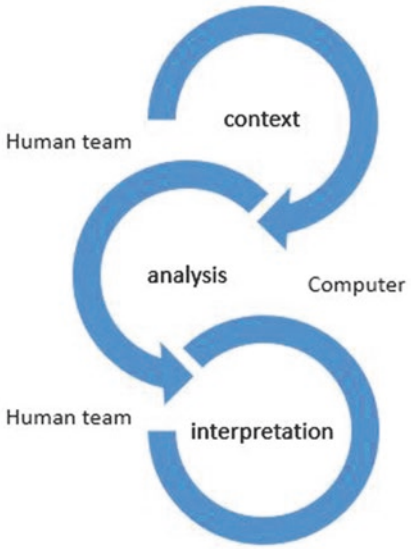


Fig. 2.1 Illustration of the human–computer symbiosis for artificial intelligence applied to healthcare. The human team identifies the context (patient care process) and programs what data and outcomes to analyze, the computer can perform a variety of analyses and produce visualizations, and the human team then interprets the analyses and visualizations to generate ideas for process improvement

2.2 Examples of CQI Applied to Ventral Hernia Disease

2.2.1 A Patient Centered Idea for Improvement (Eliminating the Use of Abdominal Wall Drains)

As a part of our Hernia CQI program, we have regularly obtained feedback and input from hernia patients and their family members to get ideas for improvement. A couple of years into applying CQI for the patients who underwent an abdominal wall reconstruction (AWR), we recognized that many patients had very negative experiences with the abdominal wall drains we often placed during an AWR. Patients did not like the irritation, discomfort, and hassle of drains, especially when they had to manage them outside of the hospital. We even had one patient who developed an infection at the site where the drain tubing exited the skin, with no problem at the actual incision site. In an attempt to apply a process improvement, our hernia team did a literature search and found techniques that had been developed by plastic surgeons in abdominoplasty operations that led to the elimination of abdominal wall drains which demonstrated better rates of wound complications such as infection, hematoma, and seroma.

We were already moving toward techniques to minimize the elevation of skin flaps—first using endoscopic approaches for external oblique component separation and then the transversus abdominus release (TAR) approach. We added the techniques of wide skin and soft tissue excision including excision of the umbilicus, and the use of layered quilting (also known as tension reduction) sutures to eliminate the dead space and tension on the skin closure. In some cases, this included an inverted T (fleur-de-lis) incision. Although this did increase the operative time (a new improvement opportunity), the rate of wound complications has decreased significantly without using a single drain over the past 3 years.

The primary data analytics tool we used to evaluate the impact of eliminating drains is called a factor analysis. In general, a factor analysis produces a number between positive one and negative one. The more positive the number, the more positive the correlation is between the factor and what is being measured. If the number is negative, the closer the number is to negative one the stronger the negative correlation is between that factor and whatever is being measured. A factor analysis produces weighted correlations and attempts to identify which factors contribute the most to identified outcome measures that determine the value for a particular process, ventral hernia disease in this example. In a factor analysis performed to determine what factors contributed to poor outcomes, the use of drains had a highly weighted correlation (+.875) to poor outcomes (increased LOS, increased opioid use, and increased incidence of postoperative complications). This factor analysis supported the continued practice of not using drains in our AWR patient process after applying the technical process improvements described above.

2.2.2 Minimizing Pain and Enhancing Recovery (A Multimodal Effort)

The problem of opioid-related complications and chronic opioid use and addition is now a national epidemic and the dialogue has made it to the public press with reports of many tragic deaths related to prescription opioids. It has been estimated that approximately 1 in 12 elective surgery patients may become addicted to opioids due to the use of their postoperative prescription for pain medication.

With this motivation and the patient's perspective that it is not a good experience to feel pain from a major operation, or to feel nausea and vomit as a side effect from postoperative opioid use, our hernia team implemented many attempts at process improvement with the focus being perioperative pain management and enhanced recovery minimizing the use of opioids. Working with an anesthesiologist, we implemented preoperative transversus abdominus plane (TAP) blocks with a variety of medications including long-acting local anesthetics (liposomal bupivacaine) and short-acting local anesthetics (bupivacaine). In addition, other anti-inflammatory medications were also used as a part of the block and intraoperatively through an intravenous route. Over time, for large abdominal wall reconstruction patients, we added an intraoperative block with liposomal bupivacaine, and for laparoscopic ventral hernia repair patients, we instituted a low pressure pneumoperitoneum system to address visceral pain which would not be adequately addressed with the abdominal wall blocks which were used to address the somatic pain. Other process improvement ideas in this area included a more aggressive attempt to prepare the patient for surgery including weight loss, smoking cessation and nutritional, physical, medical and even psycho/social/spiritual and emotional optimization. The perception of pain is a very complex biologic interaction and a subpopulation of patients may experience less pain if their fears and emotional problems (like PTSD) are addressed preoperatively. We also try to do a better job at setting expectations of postoperative pain and the appropriate attempt to minimize opioid use. Most patients understand when we explain the potential downside of using opioids as the sole or primary method for postoperative pain control. Our hernia patient care manager does the majority of this counseling and has many of examples from prior patients to help patients understand why we would want to implement these concepts in an attempt to improve outcomes.

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Age	-0.040	-0.040	-0.818	-0.024	0.207	0.209
BMI	-0.136	-0.137	0.230	-0.001	-0.806	0.037
Frequent Cough	-0.193	-0.604	-0.036	-0.529	-0.143	-0.106
Frequent Constipation	0.137	-0.774	0.048	0.104	-0.013	0.264
Prostate Enlargement	0.007	0.129	-0.449	-0.002	0.142	-0.049
Strain to Urinate	-0.143	-0.726	0.029	0.075	0.059	-0.214
Frequent N/V	0.030	0.067	0.034	-0.879	0.027	0.029
Pre-OP Pain	0.106	0.059	-0.134	-0.287	0.231	-0.686
C Medically	0.137	-0.212	-0.669	0.014	-0.465	-0.248
C Emotionally	0.741	0.037	0.345	-0.051	0.057	-0.286
C Surgically	0.846	0.093	-0.074	0.168	-0.205	-0.047
Recurrence	0.832	-0.115	-0.106	-0.029	0.103	0.155
Previous Infection	0.353	0.293	0.096	-0.014	-0.613	0.029
Smoke	0.014	-0.076	0.115	0.181	-0.142	-0.794
Previous Repair	0.628	0.207	-0.156	-0.519	-0.016	-0.075

Fig. 2.2 A factor analysis demonstrating the patients emotional complexity (C Emotionally) has a highly positive correlation (Factor 1 row +0.741) to poor outcomes such as increased length of stay complications and higher total opioid use

It was actually our patient care manager who identified that a patient's preoperative emotional state may be impacting the outcomes for our hernia program. Almost 5 years ago, we started to subjectively assess the emotional state of our patients—low, medium or high emotional complexity. Patients with minimal or no emotional issues were graded low, those with moderate issues as medium, and those with significant issues, such as a documented diagnosis or demonstrating severe anxiety or PTSD, were considered high emotional complexity. About a year later, when we did a factor analysis, we learned that the emotional state of our patients preoperatively was the highest weighted modifiable factor that correlated with bad outcomes, contributing much greater to those outcomes than BMI, smoking, or diabetes (Fig. 2.2). Since then, we have been implementing preoperative counseling, psychological assessments, and therapy and addressing social support needs for this subpopulation of patients. We have also worked with social scientists and other social services professionals to refine and make our preoperative tools more objective to better identify and classify these patient groups.

Through these many multimodal attempts at process improvement for opioid sparing pain control and enhanced recovery, we have seen a significant decrease in the time in PACU, the length of stay and the total use of opioids in the PACU and for the total hospital stay. The percentage of patients not requiring opioid pain medication in the PACU has risen to about 33 % for patients who undergo abdominal wall reconstruction (AWR) and over 60 % for patients who have a laparoscopic ventral hernia repair. Similarly, a much larger percentage of patients is now discharged on the day of surgery or postoperative day 1 after laparoscopic ventral hernia repair and almost 40 % of patients are now discharged in 3 days or less (all without drains) after AWR. Prior to implementing these attempts at process improvement, only one patient went home on postoperative day 3 (less than 5 % were discharged in 3 days or less) after an AWR. As we continue to apply linear and nonlinear analytics tools, such as factor analysis, we can continue to see which factors contributed the most (or least) to the outcomes. In a recent factor analysis, several of the attempts at process improvement, such as long-acting local anesthetic blocks, the elimination of drains and low insufflation pressure had highly weighted positive correlations to the improvement of outcomes over time.

2.2.3 Understanding the Cost Component of Value (The Challenge of Measuring Real Costs)

The most difficult outcome measure to collect when attempting to define a measurement of value for a hernia patient care process has been the costs for the entire cycle of care. The majority of costs for a hernia process are typically around the operation and hospital stay. It would be ideal for the hospital to collect costs for the patient care process during the entire hospital stay (known as activity-based accounting). But hospitals use a method called cost accounting, where the costs are allocated by hospital departments, not by the patient care process. In cost accounting, the hospital will typically pool all costs into direct (actual costs of care for all patients) and indirect (nonclinical-related costs like overhead and nonclinical salaries). Hospitals will have a variety of formulas to assign direct and indirect costs to each patient for internal purposes, but the actual costs of care for each patient are not actually collected or known. The hospital bill that a patient receives after a hospital stay actually has little or nothing to do with the actual costs of care. The bill is generated from a chargemaster that generates a bill from an itemized attempt at documenting the patient's hospital stay. The patient's hospital bill is notoriously inaccurate and often lists charges for items that seem ridiculous. It is important to know that hospital charges are not related to the actual costs of care and should not be used as one of the measurement of costs to determine the value of a patient care process.

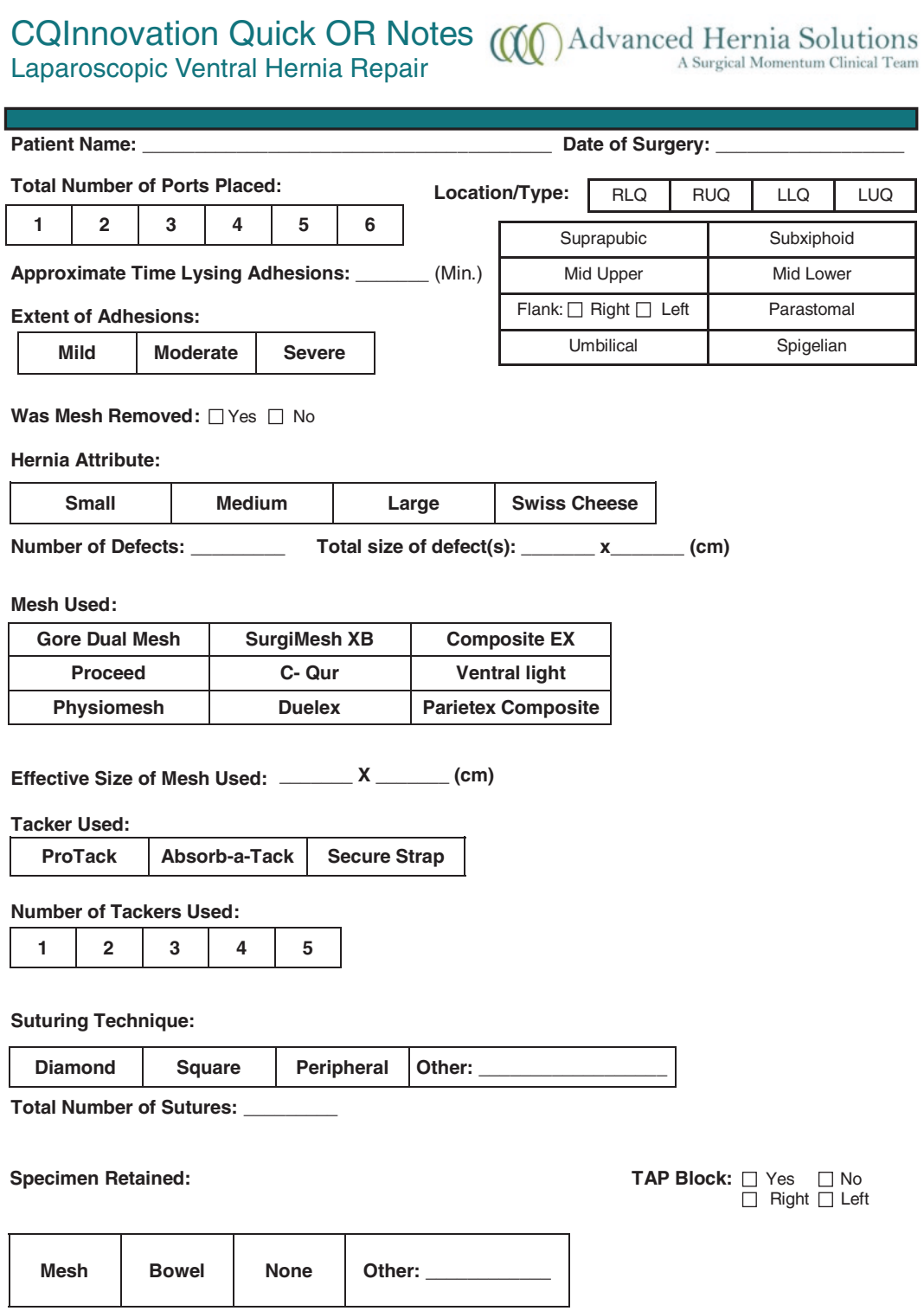
To get a true measurement of value, some reasonable estimate of costs of care will be necessary to go along with quality and patient perspective measures. Until activity-based accounting is available, the easiest way to measure costs is to combine the estimates of direct and indirect costs that a hospital assigns to each patient's hospital stay. Although costs are a challenge to obtain, a true measurement of value cannot be obtained without knowing (or at least having a reasonable estimate of) real costs. When the actual reimbursement is known and a total cost estimate is known the hospital profit margin can be calculated for a specific patient care process. For most hernia processes, the hospital margin will be negative due to the low reimbursement of hernia procedures compared to other surgical procedures and due to the costs of some hernia meshes and a relatively high rate of complications for complex ventral hernia repairs. We have found that including the measurement of hospital margin and making attempts at process improvement to improve the financial outcomes for the hospital in addition to the value for the patient can help engage the hospital administration in the CQI effort. Some people chose to look only at direct costs and not apply the nonclinical overhead (indirect) cost estimates. The measurement of direct costs subtracted from the total hospital reimbursement is called contribution margin. We have chosen to use total costs and total margin when applying the financial measures to our CQI projects in an attempt to better partner with the hospital and recognize that all hospital costs will need to be accounted for if we are to have financial sustainability in healthcare.

2.3 Application of These Tools to a Local Hernia Program

The application of these concepts for any hernia team requires some time to meet, some understanding of where the data exists (if it exists), and some commitment on the part of the hospital to help with access to data and to allow the people who contribute to the whole cycle of care for hernia patients at each local environment (operating room staff, floor staff, etc.) to be available from time to time to look at outcomes and help contribute ideas for attempted process improvement. As discussed above, ideally the hospital will work with the hernia team to get better and better estimates of real costs for each patient within each process. This might be more realistic collecting data prospectively although if data for patients who have been cared for in the past is available, that can be a good dataset as a starting point to stimulate the first set of ideas for attempted process improvement.

Our current general method for applying these principles includes an initial multidisciplinary meeting where we define the care process we will work on, define the factors in the process that we think will contribute to the outcomes, and define the outcomes that will be a good measurement of value for each specific patient care process. For a ventral hernia process, we look at patient demographic factors, such as gender, BMI, number of prior hernia repairs, presence of an active wound, and the emotional state of the patient, for example. We also identify process or treatment factors that we believe will potentially impact outcomes such as use of local anesthetic block, type of mesh, use of an intraoperative local anesthetic block, and the pressure of carbon dioxide gas used for laparoscopic cases. Outcomes that measure value for a ventral hernia process include costs, length of stay, opioid use, wound complications, recurrence, return to quality of life, etc.

When the data points are identified, we go to all of the data repositories where they might be found—the physician and hospital EMR, the anesthesia record, the hospital financial system, etc. We typically do a 1-month dataset test to see if we think the mechanism of data collection is generating the correct patient group and produces reasonably accurate data. Usually, there are some gaps to fill in, particularly in data collected for the specific data points from the actual surgical procedure and for data from the long-term follow-up. To specifically address these two gaps, we developed forms, OR quick forms and follow-up forms, to make documenting



CQInnovation Quick OR Notes
Laparoscopic Ventral Hernia Repair

Advanced Hernia Solutions
A Surgical Momentum Clinical Team

Patient Name: _____ **Date of Surgery:** _____

Total Number of Ports Placed:

1	2	3	4	5	6

Location/Type:

RLQ	RUQ	LLQ	LUQ

Suprapubic	Subxiphoid
Mid Upper	Mid Lower
Flank: ☐ Right ☐ Left	Parastomal
Umbilical	Spigelian

Approximate Time Lysing Adhesions: _____ (Min.)

Extent of Adhesions:

Mild	Moderate	Severe

Was Mesh Removed: ☐ Yes ☐ No

Hernia Attribute:

Small	Medium	Large	Swiss Cheese

Number of Defects: _____ **Total size of defect(s):** _____ x_____ **(cm)**

Mesh Used:

Gore Dual Mesh	SurgiMesh XB	Composite EX
Proceed	C- Qur	Ventral light
Physiomesh	Duelex	Parietex Composite

Effective Size of Mesh Used: _____ **X** _____ **(cm)**

Tacker Used:

ProTack	Absorb-a-Tack	Secure Strap

Number of Tackers Used:

1	2	3	4	5

Suturing Technique:

Diamond	Square	Peripheral	Other: _____

Total Number of Sutures: _____

Specimen Retained:

TAP Block: ☐ Yes ☐ No ☐ Right ☐ Left

Mesh	Bowel	None	Other: _____

Fig. 2.3 OR quick form for laparoscopic ventral hernia repair—a method to collect gaps in data from the actual surgical procedure

data in these two areas more efficient (Fig. 2.3). After the dataset test looks good, we will collect data for a defined previous time period, 1 year or more depending of the volume of cases for each process. Meaningful insight begins to occur after analyzing as few as 20–30 cases so obtaining hundreds of past cases is not usually necessary. Finding the data and putting it in context does require time and some resources, so getting a minimum amount of cases and data that generates actionable insight to improve value is the goal. Once the ideas for process improvement have been generated from the analysis of previous cases, then data is collected as new patients go through the process and as new ideas for

potential process improvement are implemented. Meetings to go over the outcomes and the computer-generated data analysis and visualization are held periodically to generate new ideas for improvement. Typically, we have had our meetings monthly, with a deeper study of the data through nonlinear analytics and data visualization each quarter. We will periodically also invite additional people to attend meetings and give their perspective and ideas to attempt to improve our care processes. Groups from former patients and family and industry partners that produce and sell drugs and devices that are factors in the patient care process typically attend one or two of these meetings each year. The application of CQI principles from complex systems science applied to healthcare never ends. Theoretically, there can always be improvement and change is occurring at a faster and faster pace. So it will become more and more important to understand and apply these principles in the future. When applied to hernia disease and across our entire healthcare system, the potential for a sustainable healthcare system that is based on measuring and improving value, not based on volume, will be achievable.

2.4 Summary

The application of complex systems science to hernia disease and to healthcare in general is in its infancy. But the understanding that we cannot continue to use the same methods to care for patients that we have in the past and expect to achieve a sustainable global healthcare system is growing fast. It is becoming evident that we will need to transition from a healthcare system based on volume to one that is based on value. To do this, we will need to learn how to measure and improve value in the context of definable patient care processes. The complex system science principles applied to hernia disease described in this chapter, including the use of human–computer artificial intelligence to generate and apply ideas to improve value-based outcomes, can lead to a sustainable healthcare system.

Suggested Reading

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Evaluating Outcomes and Evidence in Hernia Repair

3

Filip Muysoms

3.1 Introduction

Interpretation of the outcomes of abdominal wall surgery is difficult and obscured by the large number of variables included in this surgery. As illustrated in the Triple P-triangle of abdominal wall hernia repair (Fig. 3.1), many *patient* variables, characteristics of the *prosthesis* used, and the details of the surgical *procedure* will influence the outcome for the patients [1]. The variables of the upper part of the triangle will be described in the many chapters of this book. In this chapter we will focus on the lower part of the Triple-P triangle, the outcome parameters and variables. How will we measure and describe the results of our surgery? The recurrence rate, the number of complications, and the Quality of Life of the patients postoperatively.

3.2 Recurrences

The number of patients who develop a recurrent abdominal wall hernia has been and still is considered by many the *Holy Grail* to measure the success of our surgery. But the recurrence rate measured will depend on many factors and on the quality of the research done. The weakness of the recurrence rate as primary outcome measure of our surgery lies in that it is a dichotomous variable. It is either Yes or No. But in reality some patients might have a small asymptomatic recurrent hernia and be very satisfied with the outcome. While others who have no recurrence, but have chronic pain interfering with their daily live, might be very dissatisfied with their outcome of surgery. So recurrence rate is an important, but certainly not the only outcome parameter to judge the success of our hernia repair surgery.

3.2.1 Importance of Study Methodology

The methodological quality of a study will have an important influence on the outcome parameters and the level of evidence it will provide [2]. Prospective studies and registration of data is of primordial importance to diminish the risk of bias in determining the recurrence rate. A clear description of the population studied is needed to assess the relevance of the outcome results found. Retrospective studies are often unreliable in the outcome data they provide.

3.2.2 Importance of Length of Follow-Up

It has been shown in many studies that the number of incisional hernias or recurrences will increase over time [3–6]. Most studies in abdominal wall surgery have a follow-up below 24 months and thus the recurrence rate they provide are an important underestimation of the true total number of patients that will develop a recurrence at some time postoperatively. The European Hernia Society guidelines on the closure of abdominal wall incisions strongly recommend for studies that have incisional hernia as their primary outcome parameter, to include follow-up of at least 24 months and preferably 36 months [7].

3.2.3 Importance of Outcome Assessment

How was the recurrence rate assessed? In the studies by the Danish hernia databases the reoperation rate for recurrence is their primary outcome parameter [8]. It is a surrogate for the recurrence rate and it was shown that it will underestimate the true clinical recurrence rate by four- or fivefold [9].

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_3

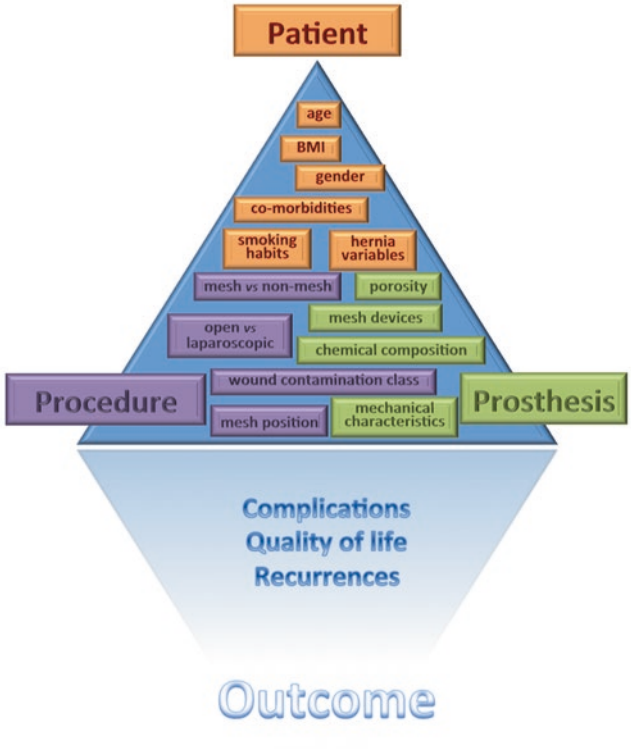

Fig. 3.1 Triple P-triangle of abdominal wall hernia repair [1]

The clinical examination by a surgeon is probably the most accepted manner of determining the presence or absence of recurrence. Including medical imaging like ultrasound or CT scan evaluation will increase significantly the level of evidence for the recurrence outcome in a study [10–12]. This was demonstrated in some studies on the prevention of parastomal hernias with mesh [13, 14]. Both studies showed a significant preventive effect of mesh based on the clinical evaluation alone, but when systematic CT scan evaluation was considered, the difference was no longer significant.

3.2.4 Importance of Follow-Up Percentages

It is inevitable that some patients will be lost to follow-up when we seek to get long-term results. The number of patients and the reasons for lost to follow-up has to be reported. Ideally the authors will include a patient flow diagram within their manuscript. A follow-up rate below 80 % makes the estimate of effect less reliable.

3.2.5 Importance of Outcome Reporting

Another, less often highlighted important determinant of the recurrence rate is the method used to report the outcome. Most often the recurrence rate will be reported at a specific time point during follow-up based on the *Intention To Treat* (ITT) population. But there is uncertainty about the status of the patients that are lost to follow-up: recurrence or no recurrence. A specific study population does not have a fixed recurrence rate over time. Therefore, recurrence rate should only be reported including the length of follow-up and 95 % confidence intervals. A more appropriate method of reporting the recurrence outcome is *time-to-event analysis* of the freedom of recurrence (Kaplan Meier curves). This method will account for the patients that are lost to follow-up and for the differences in length of follow-up of the individual patients. This was nicely demonstrated in a study on the long-term 10 year incidence of incisional hernias from the Aachen University [4]. Of 2983 patients, 129 developed an incisional hernia, giving an incidence of 4.3 % with a mean length of follow-up of 21 months. But with the Kaplan–Meier method, the incidence was calculated as 9.8 % at 21 months follow-up and was 18.7 % at 10 years.

3.3 Complications

Complications are an inherent part of surgery and an important outcome parameter to evaluate hernia repair. Clavien et al. defined in 1992 a negative outcome after surgery in three groups [15]:

- Complication: "*any deviation from the normal postoperative course*"
- Sequela: "*an after-effect of surgery that is inherent to the procedure*"
- Failure to cure: "*if the original purpose of the surgery has not been achieved*"

It is clear that to determine exactly the number of complications following these definitions it is of primordial importance to describe what is the normal postoperative course of your patients and what will be considered sequelae. Hernia-specific adverse events like postoperative seroma, hematoma and pain, need to be defined either as a sequela or a complication. This is highly relevant when we compare studies across the literature. Some studies will report every seroma detected postoperatively, but some will only report those needing treatment. This will obviously be reflected in the overall reported complication rate. Postoperative pain is inherent after surgery, but when it is much higher than expected it might be considered a complication. What is the expected normal duration of hospital stay for the patients and when will it be considered a complication? Recurrence after hernia repair is a clear *"failure to cure"* and thus should be reported separately and is not considered a complication.

3.3.1 General Surgical Complications: Clavien–Dindo Classification

We strongly recommend using the Clavien–Dindo classification of surgical complications [15]. They are defined in Table 3.1. By using this classification we change from the dichotomous variable (Yes or No complication) to categorical variable according to the severity of the complications. Kaafarani et al. reporting on the results of a randomized study comparing laparoscopic and open ventral hernia repairs demonstrated the added value of the classification [16]. Overall, open repair had significantly more complications than laparoscopic repair: 47.9 % versus 31.5 %, $P = 0.026$. However, complications of laparoscopic repair were more severe than those of open repair.

From the definitions of Grade I and II complications, it is clear that retrospective studies based on review of patient charts is very unreliable and likely to underestimate the number of complications. It seems useful to group the complications in minor (Grade I, II, and IIIa) and major (Grade IIIb, IVa, IVb, and V) complications in comparing outcome results.

3.3.2 Hernia-Specific Complications

Some complications are more relevant and specific after hernia repair to evaluate the outcome, because they might have direct implications to the proposed surgical techniques and mesh devices used.

3.3.3 Seroma

As mentioned above some surgeons might consider a seroma an inevitable sequela after surgery and others as a complication. Morales et al. proposed a classification of postoperative seroma, as shown in Table 3.2 [17]. We propose to consider a seroma type I or II (asymptomatic; <6 months) as a sequela, and seroma type III or IV as a complication.

Table 3.1 Classification and grading of surgical complications as proposed by Dindo et al. [15]

Grade 0	No complications
Grade I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications. Blood transfusion and TPN are included
Grade III	Requiring surgical, endoscopic, and radiological interventions
Grade IIIa	Intervention not under general anesthesia
Grade IIIb	Intervention under general anesthesia
Grade IV	Life-threatening complication requiring IC/ICU management
Grade IVa	Single organ dysfunction
Grade IVb	Multi-organ dysfunction
Grade V	Death of the patient

Table 3.2 Classification of postoperative seroma after ventral hernia repair as proposed by Morales-Conde [17]

Seroma type	Definition	Clinical significance
0	No clinical seroma	No clinical seroma
I	Clinical seroma lasting <1 month	Incident
II	Clinical seroma lasting >1 month	
III	Symptomatic seroma that may need medical treatment: minor seroma-related complications	Complication
IV	Seroma that need to be treated: major seroma-related complications	

Clinical seroma: Those seromas detected during physical examination of patients which do not cause any problem, or just a minimum discomfort that allows normal activity
Minor complication: Important discomfort which does not allow normal activity to the patient, pain, superficial infection with cellulitis, esthetic complaints of the patient due to seroma or seroma lasting more than 6 months
Major complication: Infection, recurrence, mesh rejection or need to be punctured

3.3.4 Surgical Site Infections

Wound infections after hernia repair is a very relevant complication that might induce significant morbidity and treatment costs and compromise the repair at longer term. Surgical Site Infection (SSI) is classified categorically for severity by the Centre of Disease Control (CDC) as superficial SSI, deep SSI, or organ space SSI. There is a correlation to the degree of wound contamination during surgery, stratified as: clean/clean–contaminated/contaminated/dirty [1].

3.3.5 Surgical Site Occurrences

The Ventral Hernia Working Group introduced Surgical Site Occurrence (SSO) as a new combined complication variable after hernia repair [18]. This is a combination of SSI, seroma, hematoma, wound dehiscence, and enterocutaneous fistula. Several authors have used SSO as outcome parameter, but I see two important issues related to its use. Firstly the SSO definition as used by the several authors is different from the original five components (Table 3.3). Some use the same five component definition [19]. Some have not included hematoma [20]. Others have also not included seroma and enterocutaneous fistula, leaving only SSI and wound dehiscence as part of their SSO [21]. Others have added to SSI and wound dehiscence, *return to the operating room*, as part of SSO [22]. So there is need for a consensus on the definition of SSO to use it as a standard outcome measurement. Second issue with

Table 3.3 Inclusions in the definitions of Surgical Site Occurrence (SSO) according to different authors and publications

Reference	SSI	Seroma	Hematoma	Wound dehiscence	Entero cutaneous fistula	Reoperation needed
Kanters et al. [18]	X	X	X	X	X	
Baucom et al. [20]	X	X		X	X	
Fischer et al. [21]	X			X		
Regner et al. [22]	X			X		X
Petro et al. [19]	X	X	X	X	X	

SSO is that it reduces postoperative complications again into a dichotomous variable, not taking into account the variation in severity of the SSO. It is clear that a superficial SSI is very different from a wound dehiscence needing reoperation, but they will both be classified similarly as a SSO.

3.4 Patient Reported Outcomes Measurement and Quality of Life

The time that the success of abdominal wall repair was solemnly measured by the rate of recurrences has gone. Although the recurrences rate is still an important outcome measure, many researchers nowadays consider *patient reported outcome measurement* (PROM) of at least equal importance to evaluate the quality of our surgery [23]. This is most relevant when we operate on oligo- or asymptomatic patients. By implantation of a permanent foreign body in the abdominal wall we run the risk of inducing chronic pain or restriction of the patients' activities and thus impair the patients' Quality of Life (QoL).

3.4.1 Generic Quality of Life Scores

Although the Short-Form 36 (SF-36) is a frequently used QoL score in studies on abdominal wall surgery, it is considered too generic to use for evaluation of QoL after abdominal wall repair [24]. Nevertheless, some studies have used SF-36 successfully to demonstrate benefits on QoL by performing hernia repair, both in inguinal hernia repair and in incisional hernia repair [25, 26].

3.4.2 Visual Analogues Scale (VAS) for Pain

The VAS score is often used routinely in hospitals for measuring postoperative pain and manage the pain medication. The VAS score is recorded by asking the patient to mark on a calibrated line of 10 cm long the amount of pain experienced [27]. The left side of the line is mentioned to be "No pain" and the right side as "The worst imaginable pain." It is a good measurement in the immediate postoperative period, but less valuable to asses late chronic pain.

3.4.3 Verbal Rating Scale (VRS)

The patient is asked to grade the level of pain experience in four levels defined by Cunningham et al. [28]: "*No pain*" = no discomfort experienced; "*Mild pain*" = occasional pain or discomfort that did not limit activity, with a return to pre-hernia lifestyle; "*Moderate pain*" = pain preventing return to normal preoperative activities, or "*Severe pain*" = pain that incapacitated the patient at frequent intervals or interfered with activities of daily living. For assessing chronic pain, the VRS seems a better tool than the VAS for pain for assessment [27].

3.4.4 Carolina Comfort Scale™ (CCS™)

The CCS™ has been developed as a questionnaire to assess the QoL of patients that had a hernia repair using a prosthetic material [24, 29]. The questionnaire contains 23 questions with a 6-point scale from 0 to 5 that report sensation of the mesh, pain, or movement limitation for eight different activities. Added to the numerical scale is a descriptive scale: 0 = no symptoms, 1 = mild but not bothersome symptoms, 2 = mild but bothersome symptoms, 3 = moderate and/or daily symptoms, 4 = severe symptoms, 5 = disabling symptoms. The total score ranges from 0 to 115 .in 3 sub-scales: "Sensation" (range 0–40), "Pain" (range 0–40) and "Movement" (range 0–35). The questionnaire is shown in Fig. 3.2. The CCS™ was used successfully to demonstrate QoL improvement after hernia repair [30]. Because many questions of the CCS™ are related to the sensation of the implanted mesh, it is not applicable for preoperative assessment. Some authors have used a Modified Carolina Comfort Scale (MCCS™) with a range from 0 to 75, by omitting the questions on mesh sensation, because they wanted to evaluate patients also preoperatively [25, 31]. The use of the CCS™ needs approval of the Carolina Medical Centre and a fee has to be paid for using it.

3.4.5 Inguinal Pain Questionnaire (IPQ) and Ventral Hernia Pain Questionnaire (VHPQ)

Fränneby et al. validated the Inguinal Pain Questionnaire (IPQ), evaluating pain and difficulties in performing activi-

Carolinas Comfort Scale ™

NOT FOR USE WITHOUT SCORING ALGORITHM AND LICENSE AGREEMENT

Carolinas Medical Center

Division of Gastrointestinal and Minimally Invasive Surgery

Name: _____

Date of Surgery: _____

Date of Survey: _____

0= No Symptoms
1= Mild but not bothersome symptoms
2= Mild and bothersome symptoms
3= Moderate and/or daily symptoms
4= Severe symptoms
5= Disabling symptoms

Please answer ALL questions for each of the 8 activities. Use N/A if an activity was not performed.

1. While laying down, do you have							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
2. While bending over, do you have							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
c) movement limitations	0	1	2	3	4	5	N/A
3. While sitting up, do you have							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
c) movement limitations	0	1	2	3	4	5	N/A
4. While performing activities of daily living (i.e. getting out of bed, bathing, getting dressed**), do you have**							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
c) movement limitations	0	1	2	3	4	5	N/A
5. When coughing or deep breathing, do you have							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
c) movement limitations	0	1	2	3	4	5	N/A
6. While walking, do you have							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
c) movement limitations	0	1	2	3	4	5	N/A
7. When walking up the stairs, do you have							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
c) movement limitations	0	1	2	3	4	5	N/A
8. While exercising, do you have							
a) sensation of mesh	0	1	2	3	4	5	N/A
b) pain	0	1	2	3	4	5	N/A
c) movement limitations	0	1	2	3	4	5	N/A

Fig. 3.2 Example of the Carolina Comfort Scale™ in English [24]

ties after groin hernia repair [32]. The same Swedish group from the Karolinska Institute published and validated in 2011 the Ventral Hernia Pain Questionnaire (VHPQ) to evaluate QoL after ventral hernia repair [33].

3.4.6 Hernia-Related Quality-of-Life (HerQles)

Krpata et al. proposed another hernia-specific QoL questionnaire, HerQles [34].

3.4.7 European Registry for Abdominal Wall Hernias QoL Score (EuraHS-QoL Score)

The EuraHS-QoL score is a short hernia-specific questionnaire with nine questions that can be scored by the patient in an 11-point scale from 0 to 10. The questions were chosen in consensus between the 14 members of the EuraHS working group coming from nine different countries trying to ask those questions that seemed most relevant for QoL before and after hernia repair [1]. The EuraHS-QoL questions are divided in three domains: "Pain" (range 0–30), "Restriction of activities" (range 0–40), and "Esthetical discomforts (range 0–20). An example in the English language for preoperative assessment is shown in Fig. 3.3. The total score ranges from 0 to 90, with the lower scores being the most favorable outcome. The EuraHS QoL score was recently validated for laparoscopic inguinal hernia repair and a validation study for ventral hernia repair is ongoing [35].

EuraHS

EuraHS QoL

version: English

EuraHS Quality Of Life scale **Pre-operative**

1. Pain at the site of the hernia												
	0 = no pain										**10 = worst pain imaginable**	
Pain in rest (lying down)	0	1	2	3	4	5	6	7	8	9	10	
Pain during activities (walking, biking, sports)	0	1	2	3	4	5	6	7	8	9	10	
Pain felt during the last week	0	1	2	3	4	5	6	7	8	9	10	
2. Restrictions of activities because of pain or discomfort at the site of the hernia												
	0 = no restriction										**10 = completely restricted**	
Restriction from daily activities (inside the house)	0	1	2	3	4	5	6	7	8	9	10	X
Restriction outside the house (walking, biking, driving)	0	1	2	3	4	5	6	7	8	9	10	X
Restriction during sports	0	1	2	3	4	5	6	7	8	9	10	X
Restriction during heavy labour	0	1	2	3	4	5	6	7	8	9	10	X
	X = If you do not perform this activity											
3. Cosmetic discomfort												
	0 = very beautiful										**10 = extremely ugly**	
Shape of your abdomen	0	1	2	3	4	5	6	7	8	9	10	
Site of the hernia	0	1	2	3	4	5	6	7	8	9	10	

Fig. 3.3 Example of the EuraHS QoL score [1] (printed with permission from the EuraHS working group represented by Dr. Filip Muysoms)

The reason to develop a new QoL instrument instead of using an existing one is fourfold: we want to develop an instrument that can be used both pre- and postoperative which none of the existing scores can; we want our EuraHS platform and thus the QoL score to be free of charge for the users; we want to develop a PROMS that is considerably shorter in number of questions; and we wanted to create an instrument that can be used both in groin and in ventral hernia patients.

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Inguinal Hernia Epidemiology

4

Kristian K. Jensen, Nadia A. Henriksen,
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4.1 Introduction

Inguinal hernia is the most common abdominal wall hernia and consequently inguinal hernia repair ranks among one of the most often performed surgical procedures [1]. It is estimated that more than 20 million groin hernia repairs are performed every year worldwide. Of these, nearly 800,000 are inguinal hernia repairs performed in the USA [1]. Epidemiologic data on inguinal hernias originate from either large-scale population-based studies or register studies revealing that the disease is multifactorial and affects individuals of all ages and both gender.

As many as 30 % of the patients presenting with an inguinal hernia are asymptomatic and up to 50 % of the patients are unaware of their inguinal hernia [2]. Less than 3 % of patients diagnosed with inguinal hernia experience incarceration, if a nonoperative strategy is chosen [3]. Emergency procedures account for 5–10 % of all inguinal hernia repairs, and are almost solely performed due to incarceration [4]. In women, femoral hernias account for 15 % of elective groin hernia repair, whereas 53 % of emergency groin repairs are femoral [5]. In men, the same trend is observed, as elective femoral hernia repair make up less than 1 % of all groin hernia repairs, compared to 7 % in an emergency setting [5]. Importantly, emergency femoral hernia repair is associated with a sevenfold increased 30-day mortality compared to the background population [5].

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Different types of groin hernias exist. An indirect inguinal hernia protrudes through the deep inguinal ring lateral to the inferior epigastric vessels—often as a consequence of a patent processus vaginalis. Indirect inguinal hernias account for more than 50 % of inguinal hernias in adults. A direct inguinal hernia protrudes through a defect in the posterior wall of the inguinal canal, medial to the inferior epigastric vessels. A pantaloon or saddle bag hernia is a combined direct and indirect hernia with protrusion on both sides of the inferior epigastric vessels. Lastly, femoral hernias protruding through the posterior wall of the femoral canal are often described along with inguinal hernias under the common name groin hernias.

On the following pages, the established knowledge about risk factors for primary inguinal hernias in adults will be presented. Since recurrent inguinal hernias account for 13–17 % of all inguinal hernia repairs, this chapter will touch upon recurrent inguinal hernias as well [6, 7].

4.2 Age and Gender

Increasing age is a well-established risk factor for inguinal hernia occurrence. Age-induced degradation of the elastic fibers in the deep inguinal ring has been proposed as a contributing factor [8]. The incidence of inguinal hernia repair is lowest in early adulthood, and rises until the incidence peaks between the age of 70 and 80 years for both genders (Fig. 4.1) [9]. The cumulative prevalence of inguinal hernia in males aged 25–34 years is 5 %, rising to 10 % for age 35–44 years, 18 % for age 45–54 years, 24 % for age 55–64 years, 31 % for age 65–74 years, and finally 45 % for males of age 75 years or more [10]. Increasing age is associated with a higher occurrence of direct hernias, illustrated by the fact that 20 % of males aged below 40 years undergoing inguinal hernia repair have direct hernias as opposed to more than 40 % in males aged above 60 [11].

Inguinal hernias occur eight times as often in men as in women, and consequently approximately 90 % of all inguinal hernia repairs are performed in male patients [12].

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_4

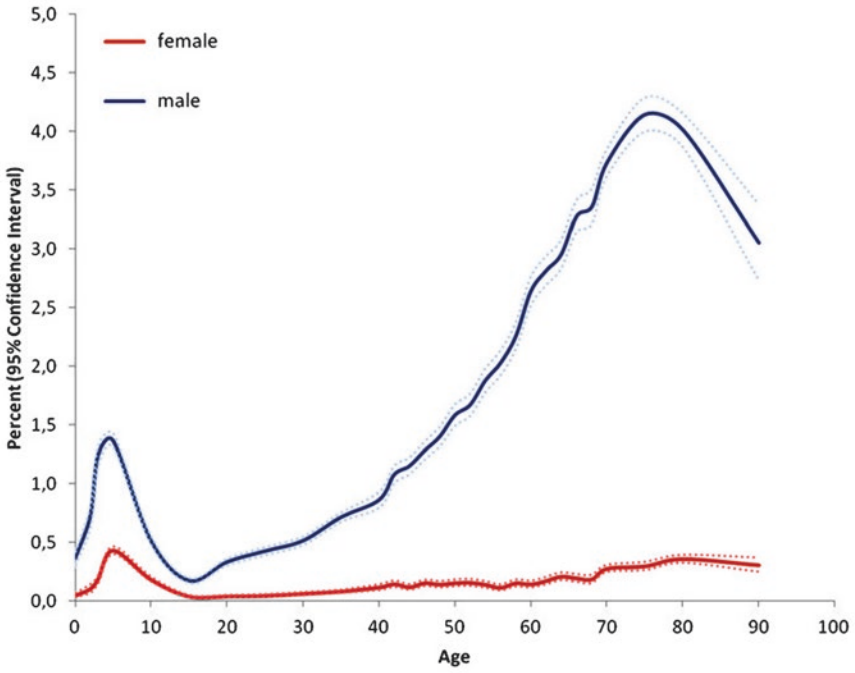

Fig. 4.1 Incidence of inguinal hernia repair in male and female (Reproduced with permission from: Burcharth J, Pedersen M, Bisgaard T, Pedersen C, Rosenberg J (2013) Nationwide Prevalence of Groin Hernia Repair. PLoS ONE 8:e54367)

This is due to the weakness in the inguinal canal through which the testicle descends in early life. As stated, studies suggest that almost one in two men will have an inguinal hernia at some point during their lifetime if they live to become more than 75 years old, and the lifetime risk of inguinal hernia repair for men is 25 % [4, 10, 12]. Contrary, the lifetime risk of inguinal hernia repair in women is <5 % [4]. The incidences of inguinal hernia repair increase almost exponentially for men during their third decade and onward, whereas the corresponding incidence for women exhibits a slow increase with increasing age [9]. The distribution of the types of groin hernia varies by gender. In women, femoral hernia is the second-most common type of groin hernia, followed by direct and pantaloon inguinal hernia [13]. In men, direct hernia is the second-most common, followed by pantaloon hernia, while femoral hernias are rare (Fig. 4.2) [13].

4.3 Inheritance

Several studies have reported a positive family history of inguinal hernia to be associated with an increased incidence of inguinal hernia, as reflected by adjusted odds ratios as high as 4–8 compared with families without a history of inguinal hernia [14, 15]. Whether this is partly due to increased patient awareness remains unknown. Furthermore, there seems to be an increased risk of inguinal hernia regardless of which family member has a positive history (parents or siblings). Of note, twin studies on inguinal hernias of mono- and dizygotic twins have led to conflicting results regarding a potential genetic element. One study found that hernias occurred more often in both monozygotic than in both dizygotic twins, whereas another study reported no difference between the twin types [16, 17]. Thus, it cannot be ruled out that the apparent hereditary element in inguinal hernia is due to environmental factors.

4.4 Occupation

Several studies on the association between inguinal hernia and a physically demanding occupation have been conducted. Most of these studies include only men, due to the low incidence of inguinal hernia in women. A Spanish case-control study reported increased risk of inguinal hernia in men holding occupation of medium to high physical effort [18], a finding confirmed by a large-scale American cross-sectional study in which sanitation workers were compared to non-sanitation workers [19]. Contrary, a prospective cohort study did not find any association between self-reported non-recreational physical activity and inguinal hernia [12]. One reason for these conflicting results may be the pooling of direct and indirect hernias, as a recent register study differentiating between the types of hernia found that indirect hernias are more frequent after exposure to lifting activities and prolonged standing/walking at work [20]. However, until further literature on this potential association emerges, no association between occupation and the risk of inguinal hernia development can be confirmed.

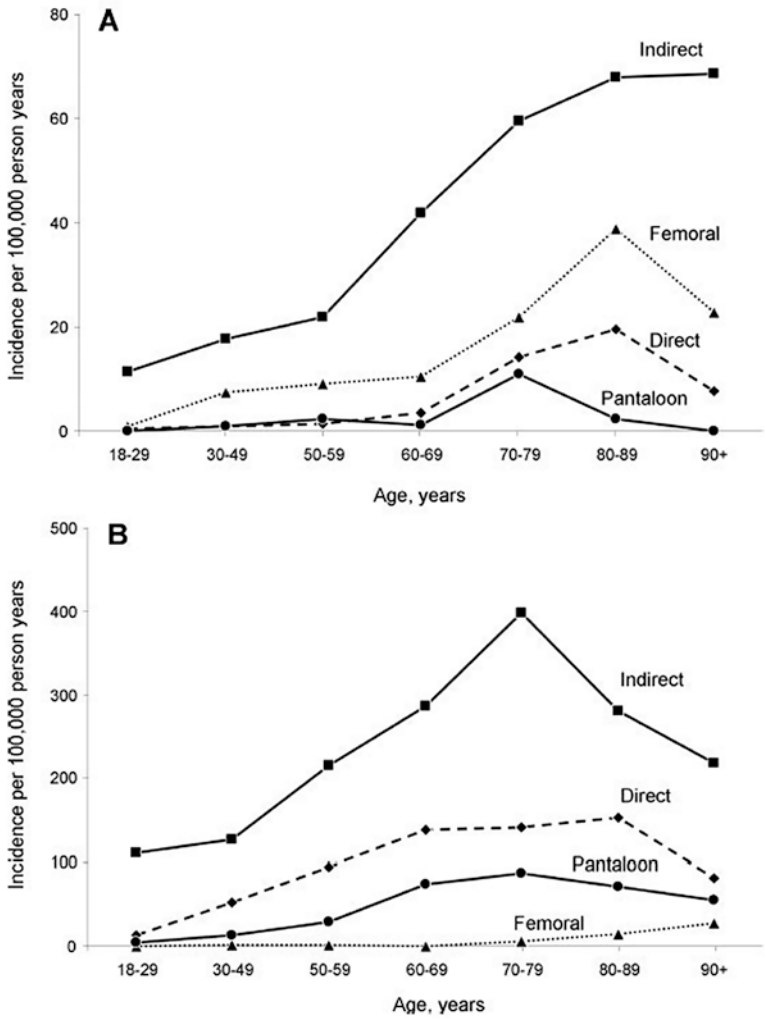

Fig. 4.2 Age-specific incidence of inguinal hernia repairs per 100,000 person-years by type of hernia in women (**a**) and men (**b**) who experienced an initial, unilateral inguinal hernia repair (Reproduced with permission from: Zendejas B, Ramirez T, Jones T, Kuchena A, Ali SM, Hernandez-Irizarry R, et al. Incidence of inguinal hernia repairs in Olmsted County, MN: a population-based study. Ann Surg. 2013;257:520–6)

4.5 Obesity

Contrary to what may seem intuitive, obesity is protective against inguinal hernia. Several studies have confirmed this finding using different methods of follow-up [10, 12, 21, 22]. Non-obese individuals (body mass index <25 kg/m^2) have twice the risk of acquiring an inguinal hernia compared to obese individuals (body mass index >30 kg/m^2) [21]. One hypothesis for this phenomenon is that the intraabdominal visceral fat prevents the hernia from occurring. Moreover, the clinical diagnosis of an inguinal hernia in the obese patient is more challenging resulting in lower diagnostic sensitivity.

4.6 Comorbidities

Several comorbidities, some of which are associated with altered collagen metabolism, have been proposed to be associated with inguinal hernia formation. It has been suggested that patients diagnosed with aortic abdominal aneurism or thoracic aortic disease are predisposed to inguinal hernia formation, but the evidence on this is inadequate [23, 24]. Ehlers–Danlos syndrome, characterized by altered collagen metabolism, increases the risk of inguinal hernia by a factor 4–5 depending on gender [25].

Prostatic hypertrophy, diagnosed by physical examination, proposedly increases the risk of inguinal hernia in men [10]. While this has only been reported sparsely, it seems certain that prostatectomy increases the risk of subsequent inguinal hernia repair three- to fourfold [26]. Interestingly, the indirect inguinal hernia is more common after prostatectomy [26]. Historical studies have reported right-sided groin hernias to be more frequent after appendectomy, supporting the hypothesis of a trauma-related etiology of the increased risk of inguinal hernia after prostatectomy [27].

Smoking does not alter the risk of a primary inguinal hernia [12, 15, 21]. Conditions resulting in increased intraabdominal pressure have been reported to increase the risk of developing an inguinal hernia. In one study it was found that

chronic obstructive pulmonary disease is a risk factor for direct inguinal hernia [14], and in another, that chronic coughing is associated with a higher risk of inguinal hernia [28]. It is, however, still unclear whether coughing and chronic obstructive pulmonary disease associates with inguinal hernia, due to conflicting published results. Chronic constipation seems to be associated with development of inguinal hernia [25, 29]. Lastly, supporting the link between increased intraabdominal pressure and inguinal hernia, it has been suggested that peritoneal dialysis is associated with the development of inguinal hernia [30], however to date this association cannot be confirmed.

4.7 Inguinal Hernia Recurrence

Up to 17 % of inguinal hernia surgery is due to recurrence, thus making it a relevant aspect of inguinal hernia epidemiology [7]. After inguinal hernia repair 3–8 % of patients develop recurrence of the hernia [31, 32]. Sutured repair as opposed to mesh repair leads to higher recurrence rates [33]. Surgeon volume and experience also impacts on the risk of recurrence. Surgeons with less than five inguinal hernia repairs per year have higher recurrence rates compared to those with higher volume [34], and inexperienced surgeons have higher recurrence rates than those with advanced surgical experience [35, 36].

Patient-related factors influence on the risk of recurrence as well. After primary repair, direct inguinal hernias have a higher risk of recurrence compared to indirect hernias; however, the size of the hernia has no association to the risk of recurrence [37]. Overall, women are at higher risk of recurrent groin hernia compared to men [38, 39]. A potential explanation for this finding is that a femoral hernia may be missed when using an open approach for repair [40]. Obese patients have a higher risk of recurrence compared to non-obese patients [37, 41]. Smoking seems to be a risk factor for recurrence in both genders, whereas increasing age and inheritance have no impact on the risk of recurrence [37, 42, 43]. The risk of recurrent inguinal hernia in association with socio-occupational factors, alcoholic intake, and pregnancy remains unknown.

In summary, several risk factors for development of primary and recurrent inguinal hernia exist, although there is discrepancy between factors associated with primary and recurrent hernias. Future research in inguinal hernia epidemiology might focus on identifying the patients best suited for a tailored surgical approach according to recognized risk factors.

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Inguinal Anatomy

5

Charles D. Procter Jr.

5.1 Overview

The inguinal region is an often discussed and seldom understood region of the abdominal wall. Ebers Papyrus wrote the earliest recorded reference to hernias in 1552 BC: "When you judge a swelling on the surface of a belly…what comes out…(is) caused by coughing" [1]. Since then the anatomy of the groin and the pathophysiology of the groin hernia has been studied and recorded by many of the greatest scholars of anatomy and surgery. Still it remains an area that is confusing even to most seasoned surgeons today.

The inguinal, or "groin" area of the human abdominal wall, is bound by the thigh inferiorly, the pubic tubercle medially, and the anterior superior iliac spine (ASIS) superolaterally. The "watershed" area of weakness of the inguinal region is the acquired inguinal canal. The inguinal canal is an oblique passage connecting the peritoneal surface of the abdomen to the scrotum or, in females, the labia majoris. It is bound by a pair of openings called the deep (or posterior) inguinal ring and the superficial inguinal ring anterior and external to the abdominal cavity. The inguinal rings are thought to overlie each other at birth and separate in a superolateral to inferomedial orientation by adulthood. In the average adult, the inguinal canal is 4–5 cm long. The boundaries of the inguinal canal, discussed later in this text, become important in understanding surgical approaches to hernias formed in this region. The structure central to the anatomy and repair of this region is the inguinal ligament, otherwise known as the Poupart ligament, which is formed from the external oblique aponeurosis as it folds over and inserts from the ASIS to the pubic tubercle.

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5.2 Embryology

Central to the understanding of inguinal hernias is an understanding of the creation of the inguinal canal. This passageway, formed by the confluence of several aponeurotic and fascial planes and devoid of muscular fibers fosters a natural area of weakness in the anterior abdominal wall. Formation of the inguinal canal in males occurs concurrently with testicular descent prior to birth. In utero, the testis descend from their position in the posterior abdominal cavity, through the inguinal canal and, eventually, come to rest in the scrotum. This descent is led by the gubernaculum which will eventually become the anchoring structure which maintains the position of the testicles. Failure of this process results in cryptorchidism or nondescent of the testis. This descent of the testis in males creates an inherent weakness in the abdominal wall at the inguinal canal. In his 1959 text, *Hernia*, Ogilvie noted that the descent of the testicles into the scrotum made "a mess" of the three-layered abdominal wall [1]. This weakness is important in the development of inguinal hernias.

In their 1997 adaptation of *Hollinshead's Textbook of Anatomy*, Dr. Cornelius Rosse and Dr. Penelope Gaddum-Rosse summed up this developmental process:

> *Concomitant with the differentiation of the abdominal wall musculature, the fascial covering of the spermticord develop around the gubernaculum in the region of the inguinal canal. At this stage, the future inguinal canal is essentially vertical…From the lateral inguinal fossa, a tubular extension of the peritoneal sac grows into the mesenchyme of the gubernaculum and forms the processus vaginalis. The processus vaginalis extends through the inguinal canal into the scrotum, forming, with the layers of the spermatic cord, what is called the inguinal bursa… Presumably guided by the gubernaculum, the testis slides down from the posterior abdominal wall, through the inguinal canal, to pass retroperitoneally outside and behind the processus vaginalis, but within the sleeve of the internal spermatic fascia* [2].

At this point, the gubernaculum will shorten and eventually become indistinguishable and will persist only as the tunica vaginalis.

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Persistence of the processus vaginalis leads to fluid accumulation in the scrotum and around the testis. The amount of fluid present depends on the patency of the processus vaginalis. A communicating hydrocele occurs when there remains an opening between the abdominal and scrotal cavities. This type of hydrocele can increase and decrease in size with gravity and throughout the day. This is remedied by surgical excision of the hydrocele/hernia sac and repair of the hernia defect, if necessary [3]. A noncommunicating hydrocele will occur when fluid is trapped within a section of the processus vaginalis that is sealed at both ends. On physical exam, this is often mistaken as a nonreducible hernia or mass within the scrotum or inguinal canal. It is treated with groin exploration and drainage or excision.

In the female, the round ligament of the uterus, or ligamentum teres uteri, is a fibromuscular band that represents the caudal portion of the gubernaculum as it lies within the inguinal canal. It does not contain any significant structure.

5.3 Gross Anatomy

5.3.1 The Layers of the Lower Anterior Body Wall in the Inguinal Region (Adapted from Skandalakis)

1. Skin.
2. Subcutaneous tissue or superficial fasciae (Camper's and Scarpa's) containing fat.
3. Innominate fascia (of Gallaudet). This is the superficial or external layer of fascia of the external oblique muscle. It is not always recognizable and its absence is of no surgical importance.
4. External oblique aponeurosis, including the inguinal (Pourpart's), lacunar (Gimberat's), and reflected inguinal (Colles') ligaments.
5. Spermatic cord in the male; round ligament in the female.
6. Transversus abdominis muscle and aponeurosis, internal oblique muscle, falx inguinalis (Henle), and the conjoined tendon (when present).
7. Transversalis fascia and aponeurosis associated with the pectineal ligament (Cooper's), the iliopubic tract, falx inguinalis, and transversalis fascia sling.
8. Preperitoneal connective tissue with fat.
9. Peritoneum.
10. Superficial and deep inguinal rings.

Inguinal region anatomy is illustrated in Fig. 5.1.

As stated previously, the inguinal canal is bordered by two openings: the deep (internal) inguinal ring and the superficial (external) inguinal ring. The boundaries of the canal are as follows [2]:

- Posterior wall (floor)—Formed laterally by the aponeurosis of the transversus abdominis muscle and the transversalis fascia laterally in three-fourths of subjects; in a quarter of subjects, the posterior wall is formed by the transversalis fascia only. Medially, the posterior wall is formed by the internal oblique aponeurosis or conjoint tendon.
- Anterior wall—Internal oblique muscle laterally and aponeurosis of external oblique muscle. There are no external oblique fibers in the inguinal area; only aponeurotic fibers.
- Superior (Roof)—formed by the lower edge of the internal oblique muscle and transversus abdominis muscle and aponeurosis.
- Floor—Inguinal (Poupart's) ligament and medially by the lacunar (Gimbernat's) ligament.

The superolateral margin of the inguinal canal is the internal (deep) inguinal ring. It is formed as a defect of the transversalis fascia. The external (superficial) inguinal ring, which forms the inferomedial margin, is an opening in the aponeurosis of the external oblique muscle.

The male inguinal canal contains several structures of importance:

- The ilioinguinal nerve which enters the abdominal wall by piercing the posterior surface of the transversus abdominis just above and medial to the anterior superior iliac spine. It extends into the inguinal canal between the external and internal obliques. In the canal, it can be found traveling along the inferior aspect of the spermatic cord. Care must be taken to identify and protect this nerve during anterior hernia repairs as it can often be entrapped in mesh causing hyperesthesia or hypoesthesia of the skin of the upper medial thigh, scrotum, penis, or labia majora.
- The spermatic cord which contains structures that pass from the deep to superficial inguinal rings. The cord is bound by coverings that are extensions of the layers of the anterior abdominal wall. The structures contained within the spermatic cord are as follows:
  - The ductus deferens
  - Three arteries
    The testicular artery
    The deferential artery
    The cremasteric artery
  - A venous (pampiniform) plexus

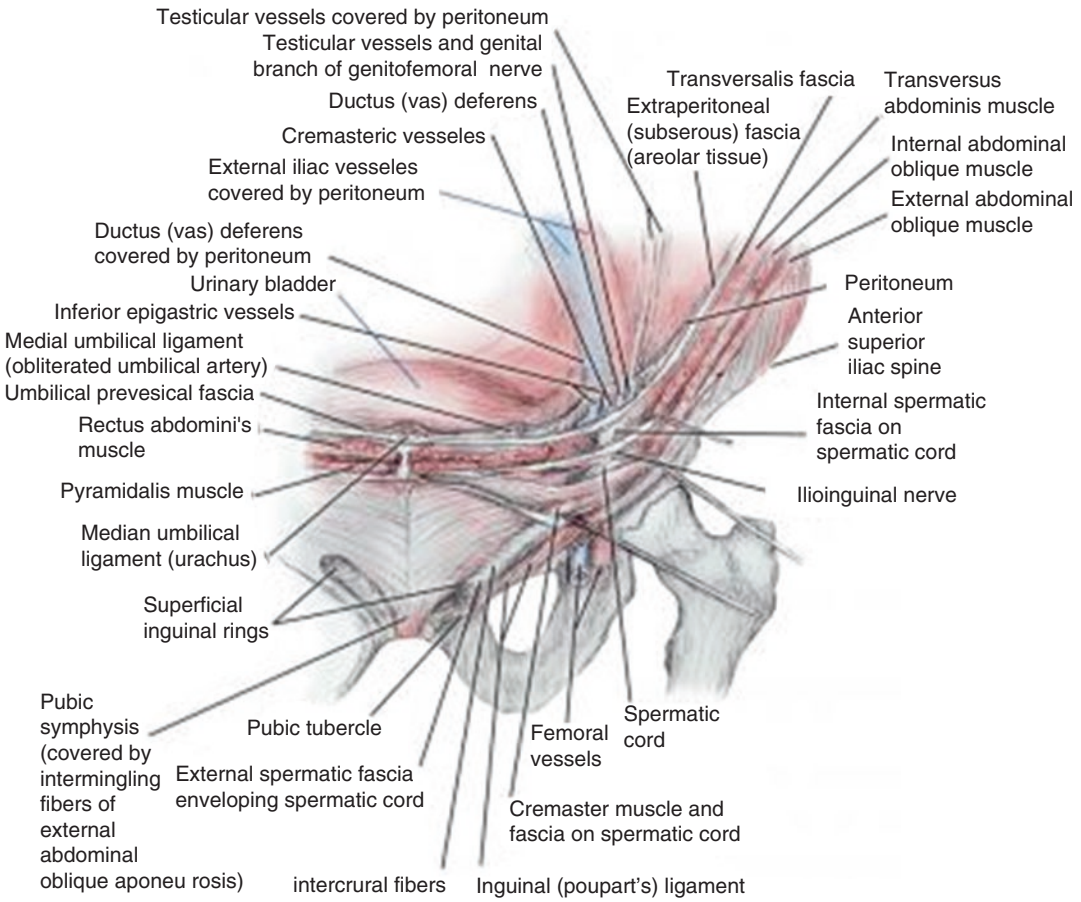

Fig. 5.1 Inguinal region anatomy

– Three nerves
  Genital branch of the genitofemoral nerve
  Ilioinguinal nerve
  Sympathetic fibers from the hypogastric plexus
– Three layers of fascia
  The external spermatic fascia
  The middle, or cremasteric layer, continuous with the internal oblique muscle and fascia
  The internal spermatic fascia, an extension of the transversalis fascia

The Female inguinal canal consists of:

- The round ligament (ligamentum teres) of the uterus
- The genital branch of the genital femoral nerve
- Cremasteric vessels
- Ilioinguinal nerve
- The same, albeit less distinct, fascial coverings as described for the male

Testicular anatomy is illustrated in Fig. 5.2.

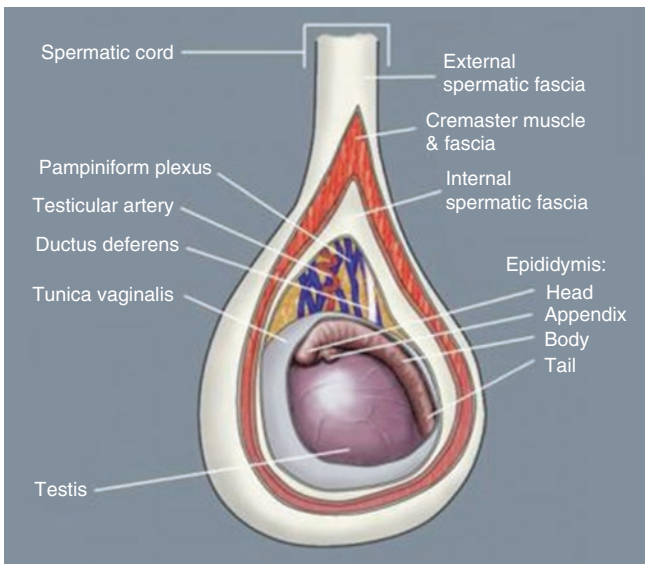

Fig. 5.2 Testicular anatomy

5.3.2 The Anatomical Entities of the Groin Defined

5.3.2.1 Superficial Fascia

The superficial fascia is divided into the superficial (Camper's) fascia which extends upward over the abdominal wall and downward over the penis, scrotum, perineum, thigh and buttocks, and deep (Scarpa's) fascia. This extends upward on the abdominal wall and downward over the penis. The deep (Scarpa's) layer of the superficial fascia extends from the abdominal wall to the penis (Buck's fascia), the scrotum (dartos), and perineum (Colles' fascia). Buck's fascia is attached to the pubic arch, the ischiopubic rami, and posteriorly, to the posterior aspect of the urogenital diaphragm forming the superficial perineal pouch.

5.3.3 Inguinal (Poupart's) Ligament

The inguinal ligament is the thickened lower part of the external oblique aponeurosis. It passes from the anterosuperior iliac spine laterally to the superior ramus of the pubis. The middle one-third has a free edge. The lateral two-thirds is attached strongly to the underlying iliopsoas fascia.

5.3.4 Lacunar (Gimbernat's) Ligament

This is the most inferior portion of the inguinal ligament and is formed from external oblique tendon fibers arising at the anterior superior iliac spine. It attaches to the pectineal ligament and sometimes forms the medial border of the femoral canal.

5.3.5 Pectineal (Cooper's) Ligament

The pectineal ligament is a strong tendinous band formed principally by tendinous fibers of the lacunar ligament and aponeurotic fibers of the internal oblique, transversus abdominis, and pectineus muscles, and, with variation, the inguinal falx. It is fixed to the periosteum of the superior pubic ramus and, laterally, the periosteum of the ileum. The tendinous fibers are lined internally by transversalis fascia.

5.3.6 Conjoined "Tendon"

The conjoined area is a fusion of the fibers of the internal oblique aponeurosis with similar fibers from the aponeurosis of the transversus abdominis muscle just as they insert on the pubic tubercle, the pectineal ligament, and the superior ramus of the pubis. This arrangement is found in fewer than 5 % of subjects.

5.3.7 Hesselbachs Triangle

As described by Hesslelbach in 1814, the base of the triangle was formed by the pubic pectin and the pectineal ligament. The boundaries of this triangle as usually described today are.

- Superolateral: The inferior (deep) epigastric vessels
- Medial: The rectus lateral border of the rectus sheath
- Inferior: The inguinal ligament

Most direct inguinal hernias occur in this area.

5.3.8 Fossae of the Anterior Abdominal Wall

Posterior surface of the anterior body wall has gained surgical significance since the introduction of the laparoscopic posterior hernia repair. This region, above the inguinal ligament and below the umbilicus, is divided into three fossae by which inguinal hernias are defined. From lateral to medial, these fossae are:

- The lateral fossa, bound medially the inferior epigastric arteries. It contains the internal inguinal ring. Hernias which are formed lateral to the epigastric arteries through the internal (deep) inguinal ring are defined as indirect inguinal hernias.
- The medial fossa, between the inferior epigastric artery and the medial umbilical ligament (remnant of the umbilical artery). This is the site of direct inguinal hernia.
- The supravesical fossa, between the medial and median umbilical ligaments. It is the site of external supravesical hernia.

A hernia through either the supravesical or the medial fossa, is for all practical purposes, a direct inguinal hernia. A direct hernia may thus be inguinal, in the medial fossa, or supravesical, in the supravesical fossa [4].

5.3.9 The Femoral Sheath and Femoral Canal

The inguinal ligament, as it traverses a plane from the anterior superior iliac spine medially to the pubic turbercle, lies somewhat anterior and just inferior to the superior ramus of the pubis. This positioning creates a space for the passage of several structures below the inguinal ligament into the thigh. On cross section, this passage way is divided into two sections or lacunae.

The most compartment or lacuna musculorum, bordered by the lateral confluence of the inguinal ligament with the ASIS and the iliopectineal arch medially, houses the psoas

and iliacus muscles with the femoral nerve traveling between these two structures. The medial compartment, between the iliopectineal arch laterally and the free edge of the lacunar ligament medially, is known as the lacuna vasorum and houses the iliac artery as it passes into the thigh as the superficial femoral artery, and the external iliac vein as the extension of the femoral vein. The transversalis fascia forms a thickened band behind the inguinal ligament and creates two septae which divide the lacuna vasorum into three compartments. The first two compartments house the femoral artery laterally and the femoral vein medially. The most medial compartment, which is bordered by the lacunar ligament and (in some instances) the conjoint tendon, is a potential space about 1 cm in diameter with only a thin covering of aureolar tissue separating it from the peritoneal cavity. It is this potential area of weakness that a femoral hernia may form. Femoral hernias, by definition, pass below the inguinal ligament and into the thigh.

5.4 Pathophysiological Variants

5.4.1 Hernias

An inguinal hernia is the protrusion of intra-abdominal contents through a defect in the abdominal wall. It can be fat, bowel, or, in some cases, the genitourinary tract. The two types of inguinal hernias are direct inguinal hernias and indirect inguinal hernias.

An indirect inguinal hernia forms as a result of the failure of the processus vaginalis to fully obliterate. When it remains open, the potential for herniation occurs. Thus, it is referred to as a congenital hernia. This hernia lies lateral to the inferior epigastric artery. It passes through the deep (internal) inguinal ring and may pass through the entire inguinal canal and into the scrotum, depending on the patency of the processus vaginalis.

The second type of inguinal hernia is the direct hernia. This hernia forms as a result of weakening of the posterior wall of the inguinal canal. It typically occurs as a result of increased abdominal pressure. Thus, it is known as an acquired hernia. The herniation is found to be medial to the inferior epigastric artery [1].

5.4.2 Hydrocele

Hydrocele, like an indirect inguinal hernia, is the result of persistence of the processus vaginalis, and they may exist together. In this case, the persistence of the processus vaginalis leads to excessive fluid accumulation in the scrotum and around the testis. The amount of fluid present depends on the patency of the processus vaginalis [2]. If the processus vaginalis remains open, the hydrocele is termed communicating because persistent communication exists between the abdominal and scrotal cavities. The hydrocele can increase and decrease in size with gravity and throughout the day. This needs to be corrected with surgical excision of the hydrocele/hernia sac and repair of the hernia defect, if necessary.

5.4.3 Cryptorchidism

Cryptorchidism refers to a testis that has not completely descended and, as such, is not found in the scrotum. Prior to birth, the testes reside within the abdomen in the fetus. The testis then begins to migrate towards the internal inguinal ring. Between 28 and 40 weeks' gestation, the testes begin transinguinal migration, which ultimately leads to placement within the scrotum. For patients with cryptorchidism, it is recommended that the testis be placed in the scrotum if it has not migrated on its own within 6 months. By surgically correcting the problem, the patient has an increased chance of fertility and is able to perform testicular self-examinations to check for cancer. It is important for the patient to be able to examine himself because patients with cryptorchidism have a significantly increased risk of testicular cancer [5].

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Diagnostic Considerations in Inguinal Hernia Repair

6

Shirin Towfigh and Yasmine Shafik

6.1 Introduction

The diagnosis of an inguinal hernia largely depends upon (a) a suggestive history and (b) the presence of a bulge during physical examination. However, physical examination for an inguinal hernia is at most 74.5 % sensitive and 96.3 % specific. Thus, imaging is a necessary tool to help confirm the diagnosis of inguinal hernia. In addition, imaging may help diagnosis alternative causes for inguinodynia and pelvic symptoms. Lastly, in the postoperative patient, imaging plays a vital role in the algorithm for working up post-herniorrhaphy chronic pain.

There are a limited number of imaging modalities for evaluation of an inguinal hernia. Each has its indications, risks, and benefits. These include herniography, ultrasonography (US), computed tomography (CT), and magnetic resonance imaging (MRI). Understanding how and when to order these studies will improve the diagnosis and treatment plan for patients with possible inguinal hernia.

6.2 Herniography

Herniography, also referred to as focused peritoneography, was first introduced in the 1960s as a technique for diagnosing contralateral inguinal hernias in the pediatric population. It involves percutaneous injection of non-ionic iodinated contrast into the peritoneal space. The patient then performs maneuvers and lies in a series of positions to promote the contrast material to fill the myopectineal orifices. Herniography is now more commonly applied to adults. It is most useful to help evaluate inguinodynia of undetermined etiology among athletes, females, and obese patients. It was reported to have a sensitivity of at least 81 % and specificity of at least 92 %. Low false positive rates (0–18.7 %) and low false negative rates (2–7.9 %) are also noted in the literature. False negative studies occur in those with preperitoneal fat occluding a hernia orifice. One study that claims that herniography successfully detects more than 67 % of missed inguinal hernias from ultrasonography. Another has supported its superiority over the MRI.

Despite these values, herniography has slowly falled out of favor in the USA. All but a few specialized centers have stopped offering this technique, as it is widely accepted that multi-planar imaging is superior and less invasive than herniography. The risks of the procedure include colonic perforation, peritonitis, anaphylactic reactions, and hemorrhage in 0.19 % of patients. Minor complications can be seen in up to 80 % of patients, which is mostly a deep pain during the injection of contrast material.

6.3 Ultrasonography

Ultrasonography (US) is readily available in most centers and is an inexpensive modality for the evaluation of the abdominal wall and inguinal hernias. Thus, it is often the first diagnostic image used for evaluation of inguinal hernias. It is non-invasive, poses no risk of radiation, and can be performed with the ability to capture real-time images. This is the greatest strength of the US.

To maximize the sensitivity of this study, the ordering physician should clearly order a “hernia ultrasound,” aimed at meticulously looking for content within the hernia orifices. As per protocol, the typical “abdominal” or “pelvic US” will overlook the abdominal wall and inguinal region, resulting in inadequate evaluation of the patient. A correctly performed hernia US has the patient perform dynamic

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_6

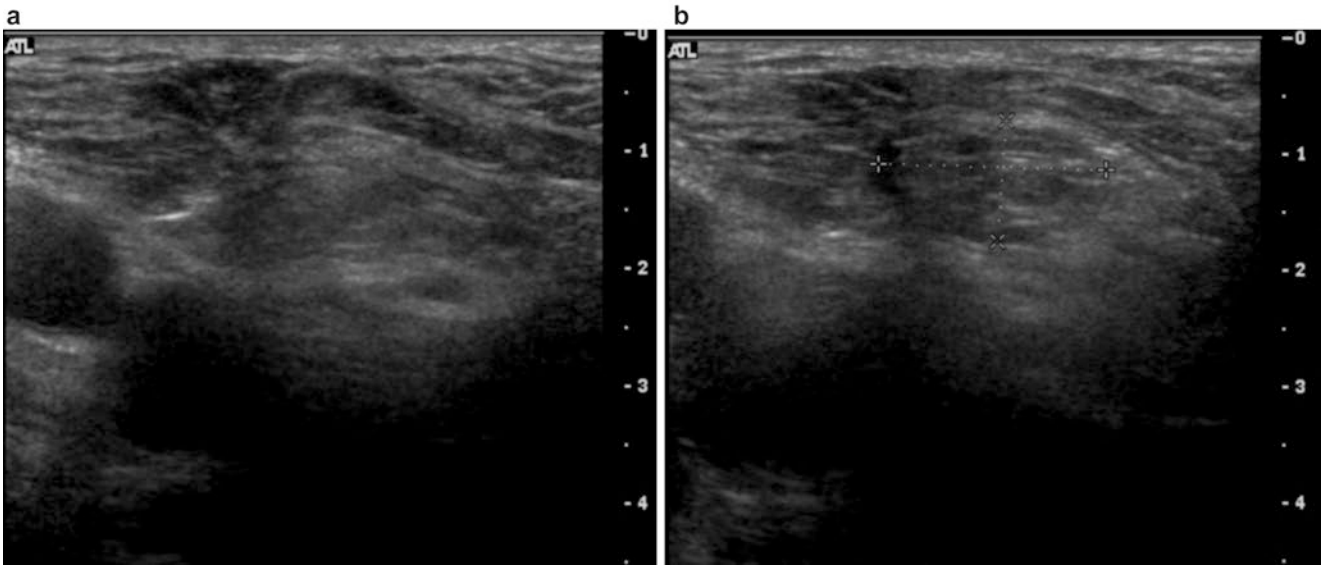

Fig. 6.1 Ultrasound of right inguinal hernia in transverse plane (**a**) at rest and (**b**) with valsalva

Table 6.1 Comparison of imaging modalities for all inguinal hernias ($N=76$)

Study	Sensitivity	Specificity	Positive	Negative
			Predictive value	
Ultrasonography	0.56	0	1.00	0
Computed tomography	0.77	0.25	0.96	0.04
Magnetic resonance imaging	0.91	0.92	0.97	0.79

Source: From Miller J, Cho J, Michael MJ, Saouaf R, Towfigh S. Role of imaging in the diagnosis of occult hernias. JAMA Surg. 2014;149(10):1077–80

Table 6.2 Comparison of imaging modalities for occult inguinal hernias ($N=36$)

Study	Sensitivity	Specificity	Positive	Negative
			Predictive value	
Ultrasonography	0.33	0	1.00	0
Computed tomography	0.54	0.25	0.86	0.06
Magnetic resonance imaging	0.91	0.92	0.95	0.85

Source: From Miller J, Cho J, Michael MJ, Saouaf R, Towfigh S. Role of imaging in the diagnosis of occult hernias. JAMA Surg. 2014;149(10):1077–80

maneuvers during the ultrasonography. Activities such as standing, bending, and valsalva can increase the chance of identifying a small hernia. Criteria for diagnosing an inguinal hernia via US include (a) visualization of a hernia sac with content, such as intestinal peristalsis or echogenic omental fat or (b) visualization of a defect in the fascia with bulging or widening upon dynamic maneuvers (Fig. 6.1).

The US can also help diagnose differential causes of inguinal swelling or pain, such as hydrocele, encysted hydrocele of the canal of Nuck, hematoma, aneurysm, varicocele, abscess, ovarian and testicular torsion or mass, ectopic pregnancy, fibroids, epididymo-orchitis, lymphadenopathy, and so on. US is a poor option in the groin of a morbidly obese patient, in a patient incision in the area, and in an area with prior implantation of mesh. Due to tissue density or distortion due to scar or mesh, US is unable to adequately visualize the myopectineal orifices.

Unlike other modalities, the value of US is highly operator dependent. Most US are performed by technologists who follow a protocol, as defined by the physician orders. The captured images are then interpreted separately from the procedure, removing the radiologist from patient interaction. As a result, an inadequate study may be performed, which will affect its sensitivity (Table 6.1). US is most reliable in the setting of clinically palpable inguinal hernias. One can argue the necessity of such a study if the hernia is already diagnosed on physical examination. However, the sensitivity of US in detecting occult hernias can be as low as 33 % (Table 6.2). In such a situation, a positive ultrasound is predictive of inguinal hernia; however, negative ultrasound has no predictive value. The US serves as a valuable adjunct to physical examination; however, a negative US should always prompt further investigation if there remains a clinical suspicion for inguinal hernia.

6.4 Computed Tomography

Computed Tomography (CT) scans are the most readily available modalities in the USA and have the least variability based on the operator. It is affordable and rapid. All radiologists and most surgeons are comfortable reading CT images with accuracy.

For the typical non-occult inguinal hernia, the CT sensitivity, specificity, positive predictive value, and negative predictive value can reach as high as 83 %, 83 %, 94 %, and 96 %, respectively. The highest value of CT scan is when the reader actively looks for inguinal hernia. Most CT scans, however, miss inguinal hernias due to underappreciation of the finding of hernia or no mention at all that the pelvis was even evaluated for inguinal hernia. In our study, we noted 78 % of all imaging missed inguinal hernia, i.e., there was no mention of inguinal hernia or it was misdiagnosed as negative for inguinal hernia. Thus, practically speaking, CT scan often miss subtle inguinal hernia findings, resulting in low specificity (25 %) and negative predictive value (4 %) (Table 6.1). The results are even worse for occult nonpalpable inguinal hernias (Table 6.2).

For best chance at diagnosing an inguinal hernia, the physician should order a CT pelvis with valsalva and with oral contrast (Fig. 6.2). IV contrast is not necessary for most evaluations, as the IV contrast is useful in the evaluation of neoplasia, infection, or inflammation.

Undergoing CT scanning does expose the patient to ionizing radiation, and so such a study must be performed judiciously. For example, CT has been shown to be a very insensitive study for patients with occult nonpalpable inguinal hernias; ultrasound and MRI are better choices in these situations. Also, CT is a poor study to evaluate a secondary hernia or an area with prior incision and/or mesh, as the Hounsfield units of muscle and most mesh products are similar. This is especially true of polypropylene and polyester mesh products, which are poorly visualizable unless there is a fat content between the mesh and the muscle. The lightweight mesh products are nearly invisible. However, polytetrafluorethylene-based mesh has a distinctive bright hue and is easily visible on CT scan. In the right clinical setting, a negative CT scan should be re-evaluated by the surgeon and MRI should be considered as the next step in the workup.

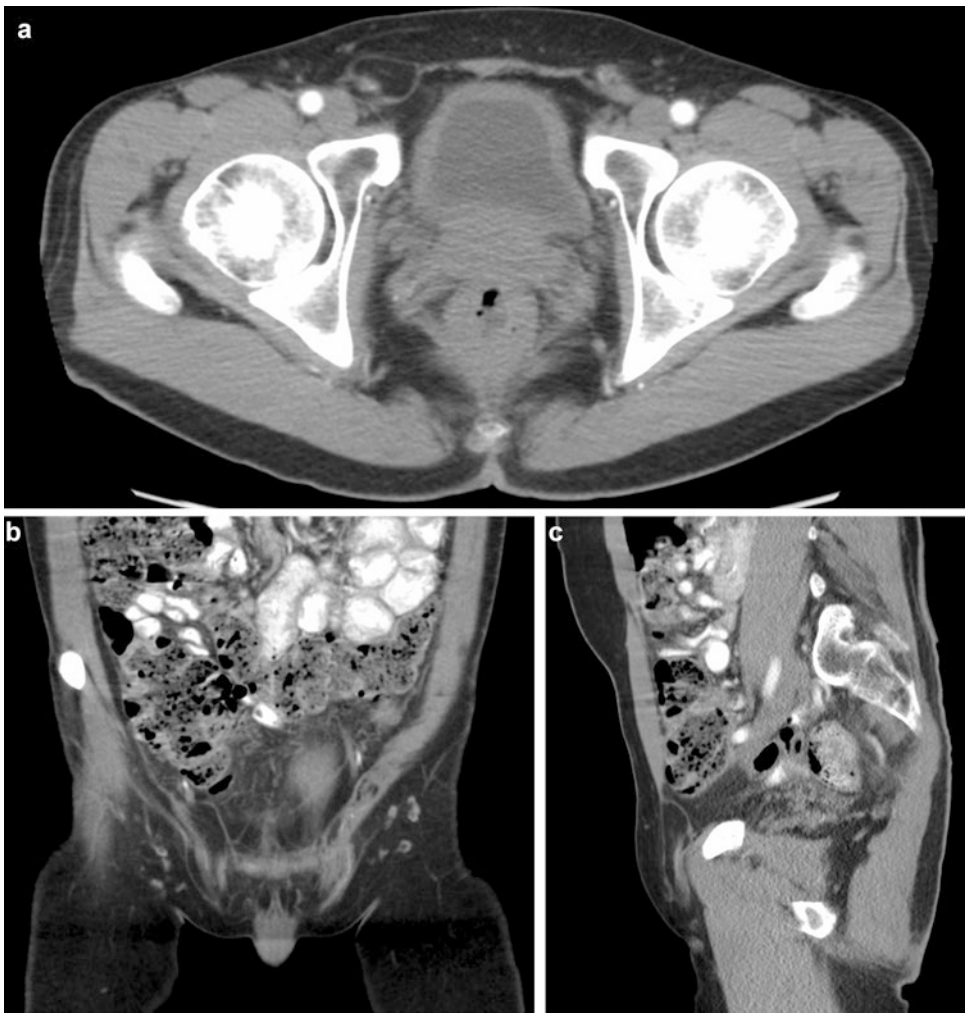

Fig. 6.2 CT scan of fat-containing right inguinal hernia in axial (**a**), sagittal (**b**), and coronal (**c**) views. Note the smaller left inguinal hernia as well

6.5 Magnetic Resonance Imaging

Magnetic resonance (MR) imaging of the pelvis provides the highest sensitivity for evaluation of musculoskeletal and soft tissue disorders, including inguinal hernias. The MR pelvis does not involve radiation, yet access is limited, it is time-intensive, and it is more costly than other modalities. Also, most surgeons and many radiologists are uncomfortable reliably interpreting MR images.

The MRI pelvis is a non-contrast study with no oral or IV contrast necessary. Though most centers do not yet have a protocol for dynamic imaging with the MRI, it is possible. In our center, we follow the inguinal hernia protocol for MRI pelvis listed in Table 6.3, which we have found to be highly sensitive for inguinal hernia. The protocol can be performed with any 1.5 or 3 Tesla MRI. It is not feasible with the "open" MRIs, as they are lower in power.

Unlike CT scan, which depends on density as a single parameter to differentiate between different tissue types, MRI provides a variety of sequences that can help differentiate among different tissue types. These include T1-weighted images for fat, T2-weighted images for water, and Short Tau Inversion Recovery (STIR) sequences for edema. Inguinal hernias are best visualized on T2 imaging (Fig. 6.3).

Table 6.3 Protocol for non-contrast dynamic MRI pelvis for imaging of occult inguinal hernia

• Axial, sagittal, and coronal T2 HASTE with breath hold
• Axial, sagittal, and coronal T2 HASTE with valsalva
• Single-slice sagittal plane dynamic valsalva acquisitions (typically about five individual acquisitions, both through and on either side of the fiducial marker)
• Axial T1 gradient echo
• Axial T2 fat sat (either fast-spin echo or STIR depending on the machine)

Area of maximal pain is marked by fiducial marker

In the case of inguinal hernia, the increased resolution of the MRI and the ability to differentiate details between the soft tissue and muscle tissue makes it the most sensitive and specific study for all inguinal hernias, especially occult hernias (Tables 6.1 and 6.2). In the operated groin, this quality of the MRI is most useful to help differentiate mesh, scar, and infection from the surrounding fat and muscle. As a result, it is the preferred study when evaluating the operated groin.

MR neurography involves the unique formatting of the typical MRI that tunes into the unique water properties inside a nerve. Some of us have dabbled with the use of the MR neurogram for evaluation of the peripheral ilioinguinal, iliohypogastric, and genitofemoral nerves in the anterior pelvis. Theoretically, MR neurography can assess any nerve entrapment, perineural fibrosis, and neuroma, caused by direct injury, scar, mesh, or fixation. The abnormalities appear as T2 hyperintensities within the affected nerve. However, most centers do not have the expertise to adequately interpret these images. Also, we have abandoned using MR neurography except in the most complex of clinical situations, as we have found that it does not add significant value to our clinical assessment, nor does it significantly change our plan of care.

6.6 Summary

According to guidelines published in 2009 by the European Hernia Society and a more recent study in 2014 evaluating the role of imaging for inguinal hernias, patients with obscure pain and/or swelling in the groin should undergo US if expertise is available. If US is negative, then MRI should be obtained. That said, CT scan seems to be the most widely used modality in the USA for evaluation of the pelvis, groin,

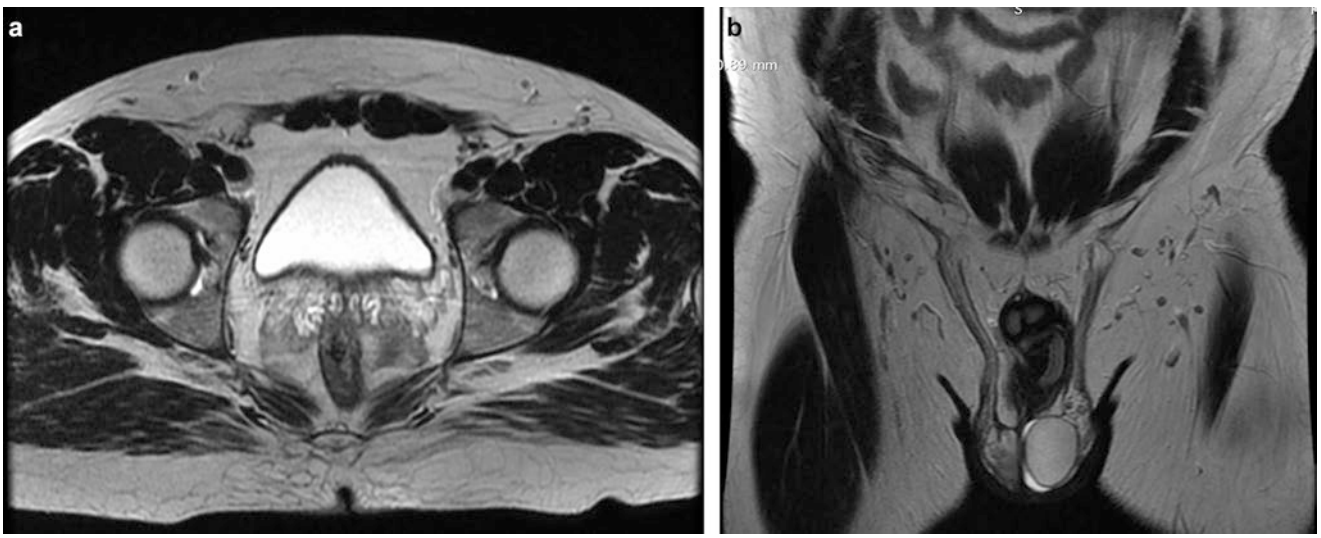

Fig. 6.3 MR image of fat-containing right inguinal hernia in T2 axial (**a**) and coronal (**b**) views. Note the smaller fat-containing left inguinal hernia as well

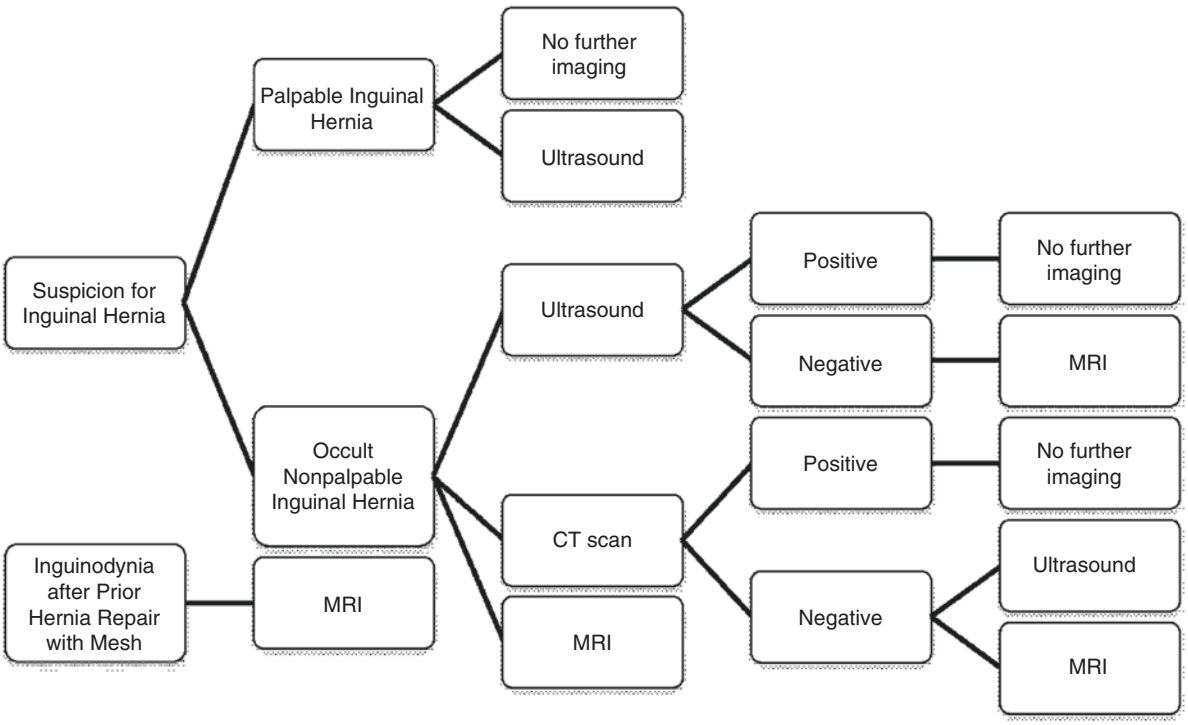

Fig. 6.4 Algorithm for choice of imaging in evaluating for inguinal hernia. US = Hernia US with dynamic images. CT = CT pelvis with oral contrast with valsalva. MRI = MRI pelvis with valsalva, no contrast

and abdominal pain in general. It is important to the provider to understand the shortcomings of CT scan for evaluation of the pelvis, especially for occult inguinal hernias. Understanding the limitations of each study and interpreting it relative to the patient's history and physical examination is key to successful diagnosis. The algorithm in Fig. 6.4 summarizes recommendations for imaging.

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Overview of Modern Surgical Techniques in Inguinal Hernia Repair

7

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The ancient history of inguinal hernia is remarkable with many creative but mostly futile approaches to its treatment. One illustrated and informative resource for the work and workers of that era are the early chapters in Hernia Healers by Stoppa et al. [1].

The modern era of inguinal hernia repair began with the works of Bassini [2]. He recognized that the transversalis fascia was the Achilles tendon of the groin, the layer through which hernias develop. He proffered that to correctly repair an inguinal hernia the groin must be dissected layer by layer knowledgably and carefully from the skin into the preperitoneal space. Only then could the muscles, fascial elements, vessels, nerves and vassal structures be identified and preserved. His reconstruction began with the posterior wall opened. After checking for a femoral hernia he dissected the peritoneal sac to its true neck and ligated it there. He then used a three-layered interrupted suture repair to reconstruct the canal's posterior wall. His deepest suture line included the lateral edge of the rectus muscle, the internal oblique muscle, the tranversus abdominus muscle, and the medial edge of the transversalis fascia. He approximated that four-layer composite to the lateral edge of the transversalis fascia and the inguinal ligament. He replaced the spermatic cord in its normal position and sutured the external oblique aponeurosis to comfortably re-create the obliquity of the canal and the external inguinal ring. In his earlier operations, starting in 1844, Bassini insisted his patients be awakened enough from anesthesia to perform straining motions to prove that his repair was sound. Bassini's results for inguinal hernia repair was astounding compared to the poor results of other surgeons of his time. With 90 % personal follow-up of 262 cases over 4 years, his failure rate was less than 3 %. He eventually reported this in a paper entitled, *Nuovo metodo operativo per la cura dell'ernia inguinale*. While some have noted that Bassini never specifically wrote about the importance of opening the posterior wall, illustrations by his devoted pupil, Catterina, clearly showed that he did open it and that he had described doing so in his own paper, *Bassini's operation for the radical cure of inguinal hernia* [3].

Bassini's true repair was altered and became known as the Modified Bassini Repair/North American Bassini Repair as was its impressive results. Many North American surgeons, influenced by Andrews, did not appreciate the importance of completely reconstructing the canal's posterior wall. Most simply ligated the peritoneal sac and pulled the transversus arch to the inguinal ligament, frequently under enough tension that a relaxing incision was needed. The short- and long-term result of the Modified Bassini repair was not good. Most failures could be traced to the inability of tissues pulled together under tension to withstand normal intraabdominal forces associated with ordinary bodily functions.

In the early part of the twentieth century a number of other suturing techniques were used to approximate the internal oblique and transversus abdominus muscle, with or without the medial flap of the external oblique, to the shelving edge of the inguinal ligament. The "Darn" technique was popular in the UK, Europe and the Far East [4]. Continuous single or double strands of nylon or silk suture that bridged the canal created a mesh-like structure. This technique never gained much interest with American surgeons.

E.E. Shouldice, a Canadian surgeon, revitalized Bassini's original principals of inguinal hernia repair [5]. Using a local anesthetic Shouldice dissected the structures of the groin including opening the posterior wall into the preperitoneal space. Differing from Bassini's interrupted suture technique, Shouldice used continuous 34-gauge stainless steel wire to reconstruct the posterior wall and repair the hernia. The results of many-thousand repairs at the Shouldice hospital

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_7

are impressive. Shouldice championed using local anesthesia and insisted on patients ambulating early. His detailed dissection through the double layers of transversalis fascia, along with the contributions of Rives and Stoppa of France and Nyhus and Condon in the USA and the earlier work of Henry and Cheatle helped set the stage for the eventuality of posterior repairs.

In 1958, Usher of Texas introduced Marlex mesh in the form of a polyethylene patch to fill tissue defects. He wrote, "by suturing it to the edge of the defect in the preperitoneal space it did a 'tension-eliminating' repair" [6]. When polyethylene was found unstable to sterilizing temperatures the polymer product was altered to polypropylene. Usher's work was revolutionary as it introduced a reproducible synthetic barrier to block the hernia defect. Polypropylene in various forms and weights has remained the mainstay of many forms of mesh products. Mesh penetration into the hernia market was not immediate. Initially it was used infrequently and only in cases of complex and unusually challenging hernias that had recurred multiple times. From the author's personal observation of polls taken in different years at the five hernia conferences, *Advances and Improvements in Hernia Surgery, mesh gradually became part of most surgeons's* armamentarium. In 1984 mesh was used in less than 5% of operations, by 1987 it rose to about 10% and by 1989 it reached about 15%. Brewing at the 1991 meeting, and clearly evident by the 1993 meeting was that mesh was accepted and essential for all laparoscopic repairs and it had gained acceptance for most open hernia repairs as well. In countries where laparoscopic techniques lagged in acceptance the use of mesh for open repairs also was slow.

In France, Rives used nylon mesh, and Stoppa used polyester mesh to do preperitoneal inguinal hernia repairs [7]. Their operation was known as *Giant Reinforcement of the Visceral Sac* (*GPRVS*). Colleagues saw the technique applicable for very challenging hernias but the technique was considered difficult and reserved it as a tool mostly for surgeons experienced using it. It was Wantz who brought that operation to America and helped it to gain interest to be used in operations to repair multiple time bilateral recurrent inguinal hernias and giant scrotal hernias.

It was Lichtenstein of California who was the strongest and most vocal advocate for the use of Marlex in hernia repairs. He used a local anesthetic and initially did a tissue repair approximating the conjoined tendon to the shelving portion of the inguinal ligament. He then reinforced that repair with a patch of Marlex mesh that he sutured above the tissue suture-line. Initially he based his repairs on the part played by Marlex as an adjunct to reinforce his tissue repair [8]. In 1984, Newman of New Jersey, after meeting Lichtenstein in Miami Beach at the 1984 conference, encouraged him to use his Marlex tension-sparing repair. Additionally, Newman gave Lichtenstein permission to call the operation the "Lichtenstein Tension-free Inguinal Hernia Repair". Lichtenstein clearly deserves credit and kudos for popularizing the "tension-free" concept that now pertains in every technique of inguinal hernia repair, regardless of the approach to the hernia defect or the type of barrier used. Shouldice and Lichtenstein both showed that most open hernia operations could be done under local anesthesia, that patients could ambulate immediately and return to usual activities much sooner that was typical for those times.

Ralph Ger in New York in 1982, viewing the deep inguinal ring in 15 dogs through a peritoneoscope, used Kocher clamps to apply Michele staple clips to the neck of the peritoneal sac [9]. Ger's work was interesting but it did not create much clinical interest. In June of 1988, McKernin and Saye in Marietta, GA, and Reddick and Olson in Nashville, TN, successfully removed gall bladders laparoscopically in humans [10]. Though surgeons in Europe, including Muhe (1987) in Germany, and Mouret (1988) and Dubois (1988) in France, had done laparoscopic cholecystectomy, none stimulated the amount of interest in this new approach, as did these American surgeons. It was their work that proved revolutionary and opened the world's surgical community and its supportive industries to further explore and to teach the numerous possibilities of laparoscopic surgery.

Three basic approaches to laparoscopic groin hernia have evolved: the intraperitoneal onlay mesh (IPOM), the transabdominal preperitoneal inguinal hernia repair (TAPP), and the transabdominal extraperitoneal inguinal hernia repair (TEP). Robotic techniques are being explored for hernia repair.

Those techniques will be discussed in other chapters of this book.

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Anesthetic Considerations in Inguinal Hernia Repair

8

Ciara R. Huntington and Vedra A. Augenstein

8.1 Introduction

The clinical comparison of anesthetic effect on inguinal hernia repair dates back to the 1900s when Harvey Cushing extolled the advantages of local anesthesia over general anesthesia, "There is avoidance of the unpleasant or dangerous post-etherization sequelae. There is no vomiting or retching to put strain on recent sutures. Urinary disturbances are less apt to occur, and catheterization is rarely necessary. The diet continues as before the operation. […] Above all is the advantage gained in being able to operate with comparative safety in patients who would incur immediate risk submitting to general anesthesia" [1].

Today, more than a century later, the risk of general anesthesia has significantly decreased from Cushing's era, but both general and local anesthesia are still used for open and laparoscopic inguinal hernia repair. Yet, with over half a million inguinal hernias repaired each year in the USA and up to 20 million repairs globally [2], the optimal anesthetic approach remains an area of debate.

In this chapter, we will review the options for anesthesia for inguinal hernia repair based on operative approach, clinical setting, patient characteristics, cost, and long-term quality of life.

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8.2 Options for Anesthesia in Inguinal Hernia Repair

8.2.1 Local Anesthesia

8.2.1.1 Patient Selection

Most open inguinal hernia repairs are eligible for repair under local anesthesia. Though better studied in the elective setting, local anesthesia appears safe and effective in the emergent setting. In a study of 90 emergent open inguinal hernia in Shanghai, China, the patients who had local anesthesia had fewer cardiac and respiratory complications, shorter ICU and hospital stays, and lower costs compared to those who had general anesthesia; the authors concluded acutely incarcerated hernias be safely performed under local anesthesia, especially when surgeons predicted a low probability of bowel resection [3].

Cardiopulmonary and significant medical comorbidities are common indications to avoid general anesthesia in elective hernia repair. Infants, patients with high anxiety, morbid obesity, or strangulated hernias benefit from general anesthesia [4]. Furthermore, when a bowel resection is anticipated, the need for abdominal wall paralysis and adequate sedation becomes more important if the operation requires intra-abdominal exploration via either laparoscope or midline incision. Patients under local anesthesia can be asked to "bear down" to check the patency of a repair and also forces the surgeon to use delicacy when handling tissue, which may resort in less tissue trauma than under other anesthetic modalities.

Anesthesia choice is affected by operative approach, as laparoscopic repairs are most often performed under general anesthesia. In some patients, a laparoscopic approach may be preferred, especially those patients who have high risk of wound infection such as poorly controlled diabetics, active tobacco users, and morbidly obese patients. In addition, patients who have had a failed open inguinal hernia repair are good candidates for a laparoscopic approach. A Cochrane review found a significantly lower risk of wound infection in

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_8

laparoscopic versus open repairs (Odds ratio 0.45, 95 % confidence interval 0.32–0.65) [5]. A laparoscopic approach for primary hernias is also preferred by European Hernia Society (EHS) due to faster patient recovery, improved recurrence rates, and the ability to identify and fix bilateral hernias via same incisions, when the surgeon has appropriate laparoscopic expertise [4].

8.2.1.2 Technique for Local Anesthesia: Open Approach

In a Turkish study of 300 outpatient open inguinal hernia repairs, a typical dose of local anesthesia was 102 mg for lidocaine (median 100) and 48 mg for bupivacaine (median 50) [6]. The Lichtenstein method of local anesthesia administration, performed in over 10,000 patients and adopted by the EHS guidelines, recommends infiltration with 40–60 mg of a 50:50 mixture of 0.5 % bupivacaine and 1 % lidocaine, with a maximum recommended dosage of 300 mg 1 % lidocaine and 175 mg of 0.5 % bupivacaine (though this will vary by the patient's weight and if epinephrine is added) [4, 7]. The subcutaneous and intradermal space are infiltrated with approximately 3 and 10 mL, respectively, of local anesthetic [7] (Fig. 8.1). After the incision is made and carried down to the aponeurosis of the external oblique, local anesthesia is carefully injected into the subfascial space with at least 6–8 mL of local anesthetic into the inguinal canal to bathe in anesthetic and numb the three nerves to the inguinal region [7]. Slow injection, talking to the patient, and addition of sodium of bicarbonate solution as a buffering agent can improve patient tolerance of the procedure [7]. Additional injections near the pubic tubercle and around the neck or interior of the hernia sac are sometimes required for reduction of hernias [7] (Fig. 8.2).

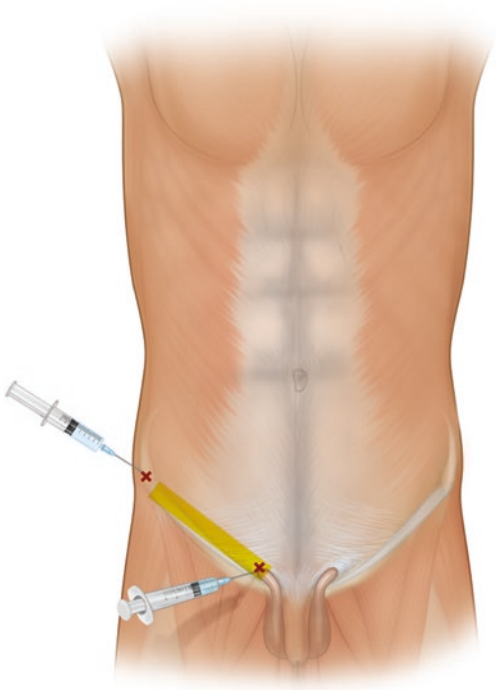

Fig. 8.1 Injection of local anesthesia in open inguinal hernia repair. *Yellow region* indicates location of subcutaneous and subdermal administration of local anesthesia. *Red* "X"s mark anterior iliac spine and superficial ring—administration of local anesthesia near these locations can anesthetize the three nerves to the inguinal region for an effective block

Local anesthesia can be combined with low dose propofol and/or benzodiazepine systemic administration; with selective use, this may improve patient tolerance of the procedure without compromising postoperative recovery time or creating need for a protected airway. Low dose propofol inhibits autonomic nervous system, has mild anticholinergic properties that prevent nausea, sweating, tachycardia, and much of the "hangover" effect of general anesthesia [8]; however, many Hernia Surgeons do not require this adjunct when utilizing local anesthesia in the standard patient [7].

8.2.1.3 Technique for Local Anesthesia: Laparoscopic Approach

A preliminary case series from Staten Island University Hospital of 10 patients with 14 hernias demonstrated that an extraperitoneal laparoscopic hernia repair could be safely performed under local anesthesia [9, 10]. Extraperitoneal may be better tolerated than intraperitoneal laparoscopic repair, as intraperitoneal insufflation is not required, but there is a published report of a patient tolerating bilateral intraperitoneal hernia repair under local anesthesia [11].

For laparoscopic repair under local anesthesia, the incision sites are anesthetized prior to incision [9]. The dissection of the peritoneal and development of the space of Retzius can be completed without pain and additional injections [9]. Discomfort can be associated with reduction of direct hernia contents, but can be mitigated by injecting lidocaine along the fold separating the transversalis fascia and peritoneal sac [9]. The cord structures should also be anesthetized at the internal ring. In a study comparing local ($n=14$) to general ($n=93$) anesthesia in extraperitoneal laparoscopic repair, there was no differences in postoperative complications or recurrence rates; the surgery was on average 29 minutes longer in the local anesthesia group, but patients tolerated the procedure well without any conversion to general anesthesia or open repair in the series [9].

8.2.2 General Anesthesia

8.2.2.1 Benefits and Risks

The discovery of general anesthesia revolutionized the field of surgery and allowed for the creation of modern surgical practice [12]. Today, general anesthesia routinely accompanies

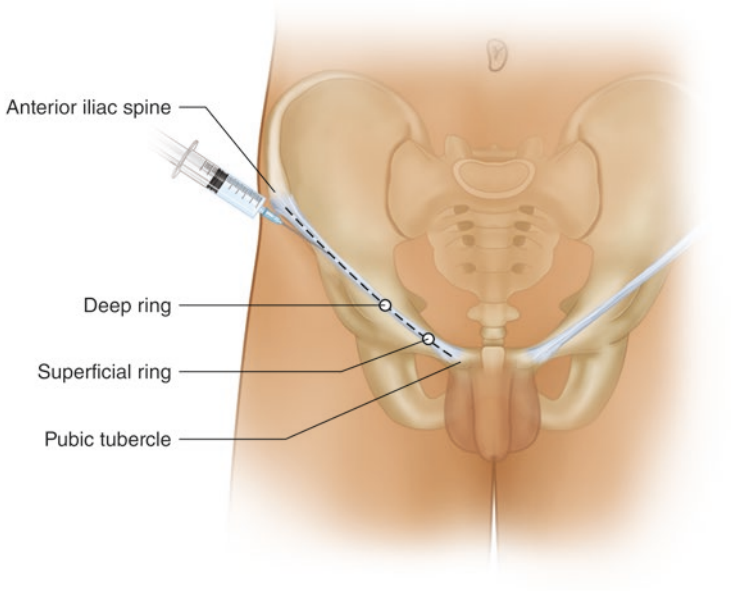

Fig. 8.2 Injection of local anesthesia. The skin and subdermal tissues are numbed along the inguinal ligament. Deeper subfascial injection anesthetic is utilized by the entry and exit to the inguinal canal, with careful aspiration to avoid intravascular administration

outpatient surgical procedures; 83 % of inguinal hernia repairs are performed as outpatient procedures in the USA [13]. Though local anesthesia has demonstrated benefits, general anesthesia has also been shown to be safe and effective in inguinal hernia repair. In a randomized controlled trial, patients who had general anesthesia had no detrimental short- or long-term effects on cognitive or motor function compared to regional anesthetic [14]. Even elderly patients can also be treated as outpatients; however one study found that age over 85 years, cardiovascular and cerebrovascular disease, and general anesthesia were independent predictors of hospitalization and death after outpatient surgery [15, 16].

General anesthesia facilitates laparoscopy by relaxing the abdominal muscles and allowing for insufflating for an intraperitoneal approach. Laparoscopic hernia repairs are commonly recommended for young women (due to the risk of femoral hernias), bilateral or recurrent hernias, and for patients who desire a quick return to work or activities [4, 6, 17, 18]. The European Hernia Society recommends laparoscopic approach, with preference for extraperitoneal approach, over open repairs for primary inguinal hernias, where the surgeon has laparoscopic expertise. As noted above, laparoscopy over open repair may also have benefits for patients at high risk for wound infection—such as patients with obesity, poorly controlled diabetes, tobacco use, and chronic steroid use. This is especially important in the setting of the increasing obesity epidemic of the Western world, with the majority of Americans now categorized as overweight and 34.9 % as medically obese. Laparoscopic surgery may also be safe and feasible in elderly cohorts [19], with improved short-term outcomes in one prospective series ($n=345$) compared to an open approach, as measured by the Carolinas Comfort Scale, a validated hernia quality of life survey [20].

8.2.2.2 Optimizing Postoperative Recovery from General Anesthesia

The incidence of postoperative urinary retention ranges between 5.9 and 38 % after inguinal hernia repair and is one of the most common complications after general anesthesia for inguinal hernia repair [21]. Urinary retention appears to be more common after laparoscopic versus open approach (7.9 vs. 1.1 %, $p<0.01$) [22]. However, the increase in urinary retention rates must be weighed against the risk of other postoperative outcomes such as hematoma, infection, and chronic pain, where an open approach has demonstrated significantly higher rates compared to a laparoscopic repair [23]. Drugs provided during general anesthesia can increase urinary retention. Common anticholinergics like atropine and glycopyrrolate block detrusor muscle contractions, and if more than 750 cm^3 of intravenous fluids are given, the risk of urinary retention increases by 2.3 times [21]. Preoperative discussion with the anesthesia team is necessary to reduce the risk of this common but bothersome postoperative complication by having the patient empty their bladder preoperatively, limit intraoperative fluids, and avoid reversal of the patient after surgery.

8.2.3 Regional/Spinal Anesthetic

Extensive research has demonstrated that spinal anesthetic has no benefit over local anesthesia in open inguinal hernia repair and increases the risk of postoperative urinary retention [4]. However, this technique is still commonly utilized across the globe. It is sometimes selected in patients who have bilateral hernias but in whom general anesthesia is not preferred or recommended. Epidural and spinal anesthetics

have been explored for extraperitoneal laparoscopic repairs. In one analysis of 1289 laparoscopic total extraperitoneal (TEP) hernia repairs in India, patients who had spinal anesthesia compared to general anesthesia had similar rates of recurrence, conversion to open, and postoperative complication [24]. Additional research from the USA, India, and China reveals that TEP under spinal anesthesia appears to be safe and feasible [25–27]. Though post epidural headaches occurred in up to 5 % of patients, in general, these studies found decreased rates of postoperative pain and improved quality of life when spinal anesthesia was compared to general anesthesia, as measured by use of oral analgesics, visual analogue scale, and Kernofsky's performance survey [24, 25, 27, 28]. Though more research is needed for definitive recommendations, spinal anesthetic may be a useful anesthetic choice in the patient who is otherwise an excellent candidate for TEP, but not fit for general anesthesia.

8.3 Epidemiology and Current Trends

8.3.1 Anesthesia and Operative Approach

When considering inguinal hernia repair, main choices for anesthesia are local, general, and regional/spinal (Table 8.1). Operative approach and anesthetic of choice varies greatly between regions of the world. Open inguinal hernia repair is the most common approach worldwide: 86 % of hernias are repaired via an open approach in the USA, 96 % in UK, and 99 % in Japan [17].

General anesthesia appears to be the dominant anesthesia choice in most Western medical centers [29]. In Denmark, 64 % of 57,505 elective open groin hernia repairs were performed under general anesthetic, 18 % regional anesthetic, and 18 % local anesthetic [30]. In a study of private and public sector patients in the UK, general anesthesia was utilized more often local anesthesia in both the private sector (52 % of cases) and public sector (66 %) [18]. However, local anesthesia is the preferred anesthetic approach for open repairs conducted at some specialist hernia centers, including those in the UK [31], Sweden [32], and the USA, such as the Lichtenstein Hernia Institute at ULCA [7]. However, the popularity of the laparoscopic approach has been increasing as surgeons gain expertise. In a Massachusetts General Hospital study of physicians who underwent inguinal hernia repair, the percentage of physicians choosing laparoscopic repair for their own inguinal hernias increased from 16 % in 1994 to 75 % by 1997, which increased faster than the non-physician group, where the proportion of laparoscopic repairs still increased from 22 to 42 % in the same study period.

Laparoscopic repairs make up minority of inguinal hernia repairs, though the incidence of this operative approach is growing in North America [6]. While France and UK acceptance of laparoscopy for primary inguinal repair has been <5 %, in a survey of Canadian surgeons, 15 % of surgeons preferred a laparoscopic approach in a primary inguinal hernia, but this increased to 30 % of surgeons for recurrent or bilateral hernias [6, 33]. Per European Hernia Society guidelines, laparoscopic inguinal hernia techniques result in a

Table 8.1 Options for anesthesia in inguinal hernia repair

	Pros	Cons	Contraindications	Ideal use
General anesthesia	• Relaxed abdominal wall for laparoscopy • Secure airway • Allows for extension of procedure to include laparotomy and/or bowel resection	• Patient unable to participate • Higher rates of urinary retention • Risk of intubation and cardio-pulmonary complications • Higher cost	Severe cardiopulmonary disease	Laparoscopic inguinal hernia repair
Local anesthesia	• Least expensive method • High rates of patient acceptance • Long-term quality of life benefits compared to general anesthesia[a] • Patient may participate with Valsalva	• Very challenging to perform laparoscopy • May need to convert to general anesthesia if procedure becomes more complex	Severe obesity Anxiety Infants	Open inguinal hernia repair without concern for major bowel resection
Spinal anesthesia	• Good cardiopulmonary risk profile compared to general anesthesia	• Higher urinary retention rates • Post-spinal headache • Difficulty walking/moving postoperatively • Lower patient satisfaction	Bleeding disorders Systemic anticoagulation Anatomical variation in spine	Resource limited settings with inability to perform general anesthesia safely

[a]In open inguinal hernia repairs

lower incidence of wound infection, hematoma formation, and an earlier return to normal activities or work than the Lichtenstein technique however requires laparoscopic expertise. Like most laparoscopic procedures, the majority of laparoscopic inguinal hernia repairs are performed under general anesthesia. Several small recent studies have demonstrated that a laparoscopic repair is safe and feasible under local anesthesia [9, 10] and spinal anesthesia [24, 27, 28].

8.3.2 Current Guidelines and Recommendations

For open inguinal hernia repair, numerous randomized controlled trials have found benefit of local anesthesia over regional and general anesthesia [4]. In a Swedish multicenter trial, local anesthesia was associated with shorter hospital stay, less postoperative pain, and less urinary retention [34]. In prospective data collected on more than 29,000 hernia repairs in Denmark, regional anesthetic was associated with more postoperative complications including urinary retention and general medical complications compared to local anesthesia [35]. The current literature supports the use of local anesthesia over spinal anesthesia, as the results of ten randomized controlled trials demonstrate that repairs under local anesthesia have superior postoperative pain scores, reduced incidence of urinary retention, decreased rate of anesthetic failure, and increased patient satisfaction compared to spinal anesthesia [4, 32, 35–37].

Currently, the European Hernia Society (EHS) recommends that local anesthesia be considered for all adult patients with a primary, reducible, unilateral inguinal hernia undergoing an open repair. Additionally, the EHS warns that regional anesthesia has no demonstrated benefit over local anesthesia for patients and increases the risk of postoperative urinary retention. In 13 of 14 randomized controlled trials, local anesthesia has been shown to be superior to regional and/or general anesthesia for open repairs in metrics such as patient satisfaction, time to discharge, recovery time, and postoperative complications [4]. Furthermore, for patients with an American Society of Anesthesiology (ASA) classification III or IV, local anesthesia is also recommended as a preferred anesthetic method over general anesthesia.

8.3.3 Cost Considerations

When considering cost, many factors need to be assessed by patients, researchers, and care providers. Operative approach and type of anesthesia are the main determinants and can be quantified. Patient preference, costs associated with postoperative recovery, and return to work are important and also need to be considered.

A British multicenter randomized controlled trial noted lower overall costs for open inguinal hernia repair under local anesthesia in part due to earlier discharge and shorter operative times [34]. Regional and general anesthetic had higher total hospital and overall costs and were not significantly different compared to each other [34]. Other studies have demonstrated similar results comparing general anesthesia and local anesthesia, where cost benefit is again demonstrated by local anesthesia, secondary to increased anesthesia and recovery room fees [38].

Per Cochrane review, patients undergoing a laparoscopic inguinal hernia repair often return to work more quickly which may lead to an overall cost savings when compared to an open approach [5]. Furthermore, the use of more expensive general anesthesia is often cited when comparing the pros and cons laparoscopic versus open approach, as laparoscopy is rarely performed without general anesthesia [9]; however, the increased cost burden of general anesthesia is often balanced by the cost effectiveness for laparoscopy in addressing bilateral groin hernias, commonly discovered in up to 10 % of cases and repaired in one operative setting [39]. Similar to other systematic reviews, European Hernia Society Guidelines note that hospital costs alone many be lower in open approach, but when including socioeconomic factors, including quicker return to work, laparoscopy has cost benefits over an open approach, even when performed under local anesthesia [4].

8.3.4 Anesthetic Choice in Resource Limited Settings

Inguinal hernia is a global problem with significant burden in the developing world, and repair of a groin hernia can be a cost-effective global health intervention, given its positive effect on patients' disability adjust life years [40–42]. However, because of shortage of medical supplies, trained personnel, monitoring and specialized equipment, anesthetic choice is often limited in developing countries. Globally, 19 % of operating rooms lack even a pulse oximeter and many more have inconsistent supply of anesthetic drugs and supplies [43]. General anesthesia is less likely to be utilized in these settings, and local anesthesia and spinal anesthesia are the preferred techniques for local providers and international NGOs alike [40, 41, 44]. In a study of 452 patients who underwent inguinal hernia repair in northwest Tanzania, 69 % had their hernia repaired under spinal anesthetic and only 1 % had repair under local anesthesia [44]. The increased hernia size, chronicity, high rates of bowel resection, and often emergent presentation of hernias repaired in resource limited settings adds to the challenge of repair and associated anesthesia. Spinal anesthetic, where a modest amount of local anesthesia is injected into the subarachnoid space

without need for many supplies or monitoring, remains the preferred anesthetic choice for inguinal hernia repair in resource limited settings [43].

8.4 Patient Satisfaction and Long-Term Quality of Life

An international, prospectively collected study of over 1100 open inguinal hernia repairs found significantly improved quality of life (QOL) outcomes in patients undergoing repair under local versus general anesthesia [45]. Patients undergoing repair under general anesthesia reported more than three times higher odds of pain, movement limitation, and mesh sensation in the first postoperative month compared with those who underwent local anesthesia; these differences persisted for up to 6 months for all QOL indicators [45]. The local anesthesia infused prior to incision and surgery may hypothetically stop the buildup of nociceptive molecules and prevent their inappropriate upgrade [7]. A recent multicenter trial demonstrated that local anesthesia compared with regional or general anesthesia was associated with short length of stay, reduced immediate postoperative pain, and, similar to Cushing's observations, the trial demonstrated that patients repaired under local anesthesia had less nausea, vomiting, and anorexia after surgery [46].

With rates of infection and recurrence after inguinal hernia repair decreasing and becoming reproducible in both laparoscopic and open approaches [47], postoperative quality of life has become a benchmark for an effective hernia repair. Despite the fact that as few as 14 % of patients are warned of the risk chronic pain during the preoperative consent process [48], chronic pain remains the most common complication after inguinal hernia repair with reported rates of 8–40 % in the literature [49–60]. From a survey of 2456 patients from the Swedish Hernia registry, bothersome pain was conveyed by 31 % patients following an inguinal hernia repair with long-term follow-up; furthermore, 6 % of patients described symptoms interfering with work or leisure activities, and 2 % frequent severe pain [52]. Numerous studies have examined the effects of operative approach with a slight advantage towards laparoscopic over open [47, 50, 61–63], nerve identification [54, 64–67], mesh type and weight [68–71], anesthesia type [45, 72], and mesh fixation methods [73–77] to understand and reduce the risk of chronic pain after inguinal hernia pain. After introducing a hernia-specific index to quantify quality of life (QOL) in patients undergoing hernia repair, Heniford et al. at the Carolinas Medical Center's Hernia Center developed an algorithm to predict postoperative pain following an inguinal hernia repair based on preoperative risk factors. This has been adapted into a free mobile app for daily clinical use [20, 78] (Carolinas Equation for Quality of Life, CeQOL™, Charlotte, NC, available online) and has been downloaded in over 135 countries. Despite ongoing research, chronic pain continues to complicate postoperative outcomes, which may prompt a more thorough informed consent that includes detailed discussion of operative approach and intended anesthesia.

Despite some surgeons' perceptions, patient acceptance of local anesthesia is high. In one large case series of consecutive open inguinal hernias repaired under local anesthesia, 99 of 100 patients stated they would choose local anesthesia again over other anesthetic choices if they had to undergo repeat repair [79]. Even when performed by surgical residents, patients who chose local anesthesia had acceptable outcomes with 93–95 % of patients in another study stating they were "very satisfied" with the operation, with no statistical difference between attending and supervised resident surgeons with results from a 10-year audit [80].

8.5 Conclusions

Inguinal hernia repair under local anesthesia is associated with less postoperative nausea and pain, better postoperative quality of life scores, lower overall cost, and is well tolerated by patients. When performing an elective open inguinal hernia repair in an adult, local anesthesia should be considered as it is associated with better postoperative outcomes including long-term pain and quality of life and reduced costs compared to repair via general and regional anesthesia. Laparoscopic inguinal hernia repair is recommended for primary hernias, hernias in women, and bilateral hernias, as well as patients with a desire to return to work or activity more quickly or those at risk of wound infections. In those patients who undergo laparoscopic repair, general anesthesia is still the standard. However, laparoscopic hernia repair under local anesthesia, especially via extraperitoneal approach, may be a promising alternative in the future. As the trend is toward increase in laparoscopic inguinal hernia repairs, further larger studies should be performed to investigate this approach and compare quality of life outcomes as well as cost.

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The Shouldice Repair 2016

9

Robert Bendavid, Andreas Koch, and Vladimir V. Iakovlev

Facts do not cease to exist because they are ignored.

–A. Huxley (1894–1963)

9.1 Preamble

The inclusion of a section on pure tissue repairs in a modern textbook of hernia surgery confirms the wisdom and foresight of William Faulkner that "the past is not dead; it is not even past." In an ironic twist of fate, this past is now pointing to a renewed faith in pure tissue repairs.

In a parallel manner to nature, there has been an evolution in the last 30 years in the management of hernias. As the word implies, evolution will select and retain what is beneficial, adaptive, and useful and will discard what is extraneous, purposeless, or harmful. As a result, there is a new respect, induced by fear, towards artificial tissue replacements. God's tissues are best, Ralph Ger once stated, regretting his original move as the first surgeon to do a laparoscopic hernia repair in 1982 during which he did not use mesh [1]!

In a world which has been awash with synthetics such as polypropylene, ePTFE, and polyesters, we are finally discovering that these artificial tissue replacements have not been without a significant downside. There has been a trumpeting of synthetics with a promise to simplify, expedite surgery, and eliminate forever the curse of recurrence. Those predictions are falling short of their promise. Evidence points to the fact that meshes, polypropylene in particular, because of their ubiquitous use, are a frequent source of pain and that in 10–12 %, they are the cause of the new, chronic postherniorrhaphy pain syndrome. A pain severe enough to instigate a new approach in treatment, mesh removal, which is happening and being reported more frequently [2].

Recently there has been some elucidation into the mechanism for the causation of pain at the tissue–mesh interface. Nerves have been identified growing within the weave and pores of meshes which undergo micro-compartment and micro-entrapment types of syndromes [3]. What is important and very much understated is the fact that there are far more nerves, thousands more, which cannot be seen with the naked eye than can be. The nerve ingrowth may take place in as many as thousands of pores which, following mesh shrinkage, will provide mini-incarceration, edema, hypoxia, acidosis resulting in pain. The mesh-related pathology also includes inflammation, scarring with subsequent shrinkage, distortion, displacement of mesh, and erosion into adjacent nerve trunks and other tissues and viscera, namely the vas deferens. While not all patients manifest clinical symptoms, we are still unable to detect those who will and thus avoid using mesh!

Figure 9.1 shows pathology slides revealing invasion of the vas deferens and peri-vasal nerves by polypropylene mesh, presence of a neuroma, scar tissue, and inflammatory reaction.

A new philosophical wave of "tailored approach" is emerging whereby mesh should be used if and when necessary rather than universally for all hernias [4–7]. The Aachen Group shows excellent results with nearly zero recurrences in Types I and II indirect hernias and Type I direct hernias at a 10-year follow-up. They have shown too that the individual risk factors (smoking, family history, recurrence, age >50) play a significant role. Mesh, especially the many gadgets made of polypropylene flooding the market, should no longer be considered de rigueur. I know of no hernia which cannot be eminently handled, least invasively, by a simple, flat sheet of mesh.

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_9

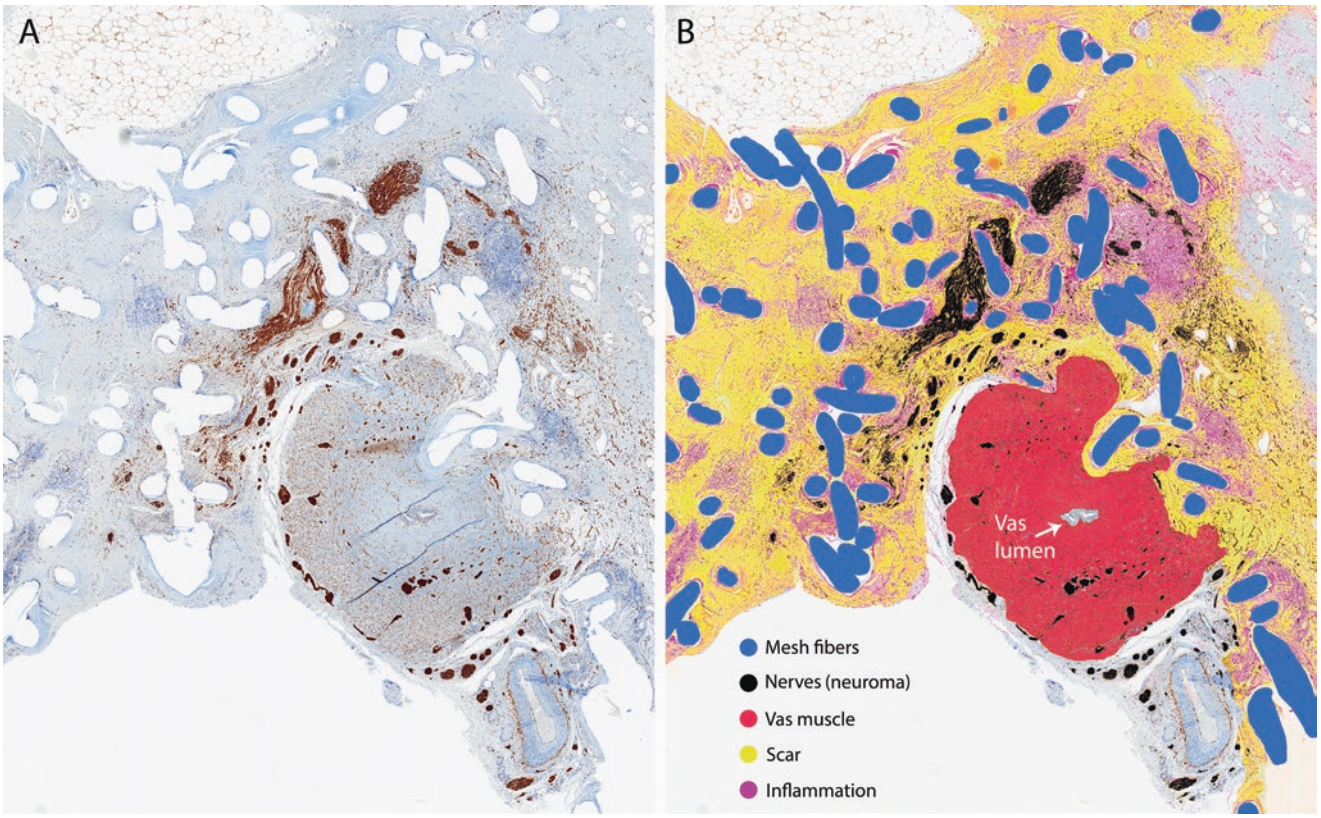

Fig. 9.1 Pathology slides revealing invasion of the vas deferens and peri-vasal nerves by polypropylene mesh, presence of a neuroma, scar tissue, and inflammatory reaction

Reverting more frequently to pure tissue repairs, which have given as good a result as mesh repairs when properly indicated and performed, may reduce the incidence of the much feared chronic post-herniorrhaphy pain syndrome.

An upcoming academic problem is that pure tissue repairs have become nearly extinct. Patients in the USA are hard put to find a surgeon within their borders who can do a Shouldice repair or any hernia repair without mesh! University programs are woefully omitting to teach them. There is however a renewal of interest which cannot count on the industry to teach them. We are doing our share in welcoming surgeons to the Shouldice Hospital. The Canadian Hernia Society has held a wet lab during their annual conferences 2 years in a row and will surely hold them again, so popular have they been.

9.2 History

The Shouldice Hospital was created in 1945 in Toronto, Canada. It is unique in having dedicated its existence to performing strictly external abdominal wall hernias. Dr. Edward Earle Shouldice (1890–1965) realized quite early the poor results of inguinal hernia surgery, despite the good results reported by Bassini some 60 years earlier. During the 1930s, a patriotic bent led him to discover that young men were refused in the armed services prior to and during WW II when they had hernias. His efforts led to improved results and therefore the seed and plan to create a facility to manage the vexing problem of hernias.

The present hospital in Thornhill, a Toronto suburb, handles an annual average of 7000 patients. Very much a man aware and ahead of his time, Dr. Shouldice realized that specialization and repetition improved performance. This was true for individuals and for organizations as advanced by Frederick Taylor, an engineer and efficiency consultant who developed the principles in 1911. Principles were reconfirmed in 1974 by Wickham Skinner of Harvard who spelled that "Simplicity and repetition breed competence."

The four pillars which would stabilize the institution were anatomy, weight control, local anesthesia, and early ambulation.

9.2.1 Anatomy

This most common of surgical condition has not been blessed with the simplest anatomy and this fact may be a tenuous argument in favor of intelligent design! Such names as Marcy, Lucas-Championnière, Narath, Lotheissen, McVay, Bassini,

Fruchaud, and Bogros are being rediscovered. Fruchaud, Bogros, and Bassini have recently been translated into English and are becoming a must in a surgeon's library. A common mistake is to refer to the posterior wall as the floor of the inguinal canal! The floor of the inguinal canal is the pubic ramus as pointed out so clearly by Fruchaud. Anatomical nomenclature is described with the patient in the standing position.

Clarifications must be set forth with reference to the Transversalis Fascia. This fascia is an extension of the endoabdominal, endopelvic fascia. It contributes no strength to the posterior wall of the inguinal canal. Anterior to it is a thin layer of adipose tissue, both are posterior to the posterior wall of the inguinal canal. This posterior wall of the inguinal canal, as it should properly be named, is an extension inferiorly of the muscular and aponeurotic layers of the internal oblique and transversus muscles [8] in some degree of combination.

Another common confusion touches upon the anatomy of the genitofemoral nerve. The latter is far more constant than the ilioinguinal nerve. I have never failed to identify the genital branch which emerges at the deep inguinal ring while the femoral branch remains in the preperitoneal space. A delicate site for bifurcation since a plug at the internal ring will invariably irritate and invade both branches. I have many such explants, usually plugs.

As to the tensile strength and pain following the Shouldice repair, the Schumpelick team from Aachen, Germany, has concluded that they "failed to see any evidence for the hypothesis that higher inguinal tensile strength induced by the Shouldice repair leads to an elevated level of postoperative pain" [9].

For the surgeon who is still concerned about tension, relaxing incisions (Wölffler, Tanner, Berger, Koontz, and nine others) have been described [10]. Koontz has proven as well, that the denuded musculature revealed by a relaxing incision is recovered by a new layer of anterior rectus sheath within a week! [11].

9.2.2 Weight Control

Obesity is the bane of a surgeon's existence. The evidence has been generously documented, particularly with reference to incisional, ventral hernias but also after laparotomies [12]. However, overweight does not appear to be a factor in primary or recurrent groin hernias [13–15]. Nevertheless, ideal weight for inguinal hernia makes for easier and expedient surgery, lesser amount of local anesthetics, earlier ambulation, and elimination of such complications as atelectasis, pneumonitis, deep vein thrombophlebitis, surgical site occurrence, and infections. A patient's cooperation can be counted on more often than one expects and extreme weight losses have been recorded.

Table 9.1 Patients 50 years and older: 52.1 % have comorbidities

Cardiac arrhythmia	50 %
Hypertension	20 %
Congestive heart failure therapy	17 %
History of myocardial infarction	15 %
History of angina	15 %
Anticoagulation (ASA, warfarin, sulfinpyrazone)	12 %

9.2.3 Local Anesthesia

Although Halsted and Cushing get credit for reporting on the properties of cocaine as a local anesthetic agent, Shouldice made local anesthesia the method of choice for nearly all groin operations thus popularizing its use worldwide [16]. The safety of this mode of anesthetic can easily be appreciated. A history of cardiac disorders has been recorded in 52.1 % of patients over the age of 50 (Table 9.1). Local anesthesia also implies a minor procedure to most patients and therefore does not present a major objection on their part.

Procaine hydrochloride is still used as it is quite safe, inexpensive, and not known to cause malignant hyperthermia. Its concentration is 1 % (200 cc) or 2 % (100 cc). It may cause the occasional tremulousness but that can easily be controlled by the usual preoperative sedation with a benzodiazepine or barbiturate.

9.2.4 Early Ambulation

At the end of the operation, the patient sits on the operating table, is then helped to stand, then walks to a waiting wheel chair to be returned to his room. In a few hours, after the effect of preoperative sedation wears off, the patient is allowed to stand and walk about. Only the first meal is served in his room, after that he joins a communal dining room with other patients.

As a result, deep vein thrombophlebitis, atelectasis, and pulmonary emboli are a rarity. The following day, light group exercises are performed to music, led by a nurse.

9.3 General Principles

9.3.1 Division of the Posterior Inguinal Wall

This is an important step. The incision begins at the medial aspect of the internal ring, cuts through the anterior and posterior lamellae of the posterior inguinal wall (the so-called transversalis fascia of common usage, though not exactly accurate), and is extended to the pubic crest. The space of Bogros is thus entered and is easily recognized by the moist, glistening layer of preperitoneal fat. This preperitoneal space is developed in

order to carefully search for additional hernias (femoral, paravesical, prevesical, low Spigelian) as they occur in 13 % of patients according to our statistical records. These hernias when missed are the future so-called "missed hernias" which laparoscopists delight in discovering. Entering the space of Bogros also allows to assess the thickness and quality of the posterior wall of the inguinal canal before incorporating it in the Shouldice repair. This step also prevents the blind "imbrication" of the posterior wall, a move which fostered modified and corrupt repairs thus leading to high levels of recurrence.

9.3.2 The Hernia Sac

It took a long time to discard the resection of the hernia sac which had been introduced by Banks in 1887 [17]. E. Ryan and D. Welsh proved and confirmed that the practice of freeing the sac and simply reducing it was as effective, had no bearing on recurrence, and lessened postoperative pain [18, 19]. A wise step and valuable contribution which eliminates the rare danger of inadvertent injury to a sliding hernia containing colon or in female infants, the fallopian tubes and ovaries. The seminal articles by Ryan and Welsh provided the clearest handling and solution to the age old fear of a sliding hernia. Simply freeing and reducing the sac without any of the older and archaic techniques of peritoneoplasties, abdominal counter-incisions, or even opening a hernia sac.

If a hernia sac is not detected, it must become routine to look for a peritoneal protrusion on the medial aspect of the spermatic cord. The protrusion can then be injected with procaine hydrochloride, freed, and also reduced in the preperitoneal space. This step confirms the absence of an indirect sac, avoids missing a hernia or a minor sac which could act as a lead to a possible future recurrence or may be a cause of pain for occult hernias.

9.3.3 The Cribriformis Fascia

Beneath the lowermost fibers of the external oblique aponeurosis, one sees the cribriformis fascia which is a thin, diaphanous layer. It is a medial extension of the fascia lata of the thigh. It is incised gingerly from the level of the femoral artery to the pubic crest. One can easily note the suggestion or presence of a femoral, pre-femoral hernia or femoral fat tabs. Femoral fat tabs may be resected below the femoral opening and the stump left in place, anchored with a suture to maintain the plug effect.

In the preperitoneal space, the fat pad sitting on the femoral ring and its frequently accompanying lymph node of Rosenmüller (or Cloquet) must not be disturbed as such a move will provide a lead-in for a femoral hernia in the form of a recurrence.

9.3.4 Resection of the Cremaster

The resection of the cremasteric muscle was introduced by Bassini. His only reason was to identify the internal ring and dissect it widely and thus never miss an indirect inguinal hernia. This move has become routine in the Shouldice repair with the standardized division of the cremaster into two segments: a proximal segment which will wrap around the cord at the internal ring like a scarf to help create a new, snugly sealed internal ring about the cord. The distal segment is anchored near the pubis to provide suspension for the testicle which would otherwise droop in the scrotum and over time, the scrotum itself becomes pendulous, unsightly and uncomfortable. When the cremaster is divided, each stump is doubly ligated as each will be incorporated in the repair subsequently when the needle will penetrate between the ties, thus avoiding bleeding.

Missed indirect inguinal hernias have been of the order of 37 % in recurrences which come to Shouldice Hospital [20].

9.3.5 Relaxing Incision

First described by Wölfler in 1892 [21], it was rightly popularized by Tanner and Halsted. I have used it in over 1500 instances without ever seeing a recurrence through the incision on the anterior rectus sheath.

The principle is of course widely seen to a much larger extent in ventral hernias in the component separation technique Ramirez, Albanese, TAR procedure, pie-crusting of Clotteau-Premont and the Gibson techniques.

9.3.6 Sutures and Stainless Steel

Stainless steel as a suture material was introduced in 1941 by Jones [22]. Shouldice introduced stainless steel wire quite early in the practice of the hospital. This use was promoted at a time when silk sutures were being extruded regularly, creating chronic infected sinuses. The other advantage of stainless steel is that in cases of infections, a repair never needs to be taken down. Two disadvantages: wire can kink and lose tensile strength and fracture, the other disadvantage is that the ends of the wires (gauges 32–34) are quite sharp and can penetrate the skin. Double gloving is no protection. Some surgeons prefer polypropylene sutures and results are just as good. In terms of sutures and bites, evidence-based reports are beginning to appear proposing smaller bites of tissues, less than 1 cm away from the edge and 1 cm apart as recommended by the EHS Guidelines on the closure of the abdominal wall ([23] and Jeekel and his group [24]). Steel remains the ideal, inert suture.

9.3.7 Cost

Health care costs have been difficult to contain under all systems of medical care. The addition of mesh varieties as plain sheets or gadgets have been out of proportion when one considers that there is less than 2–3 cents worth of polypropylene per plug or patch. The cost we are told is in "quality control"! Laparoscopic equipment too has not come cheap and now, robotics has been somewhat prohibitive for most centers. The Shouldice repair, when considering the necessary accessories, e.g., mask, cap, gloves, needles, syringes, drugs, scalpel blades, and sutures etc., amounts to a paltry US$ 30 per patient!

9.4 Surgery: Technical Aspects

9.4.1 Sedation

Preoperative sedation is not graven in stone and can vary. It has consisted traditionally of Diazepam (10–20 mg) orally 90 min before surgery and Pethidine Hydrochloride (25–100 mg) 45 min before. Dimenhydranate (Gravol®) is often included to offset nausea. Variations have introduced Morphine, OxyContin IR (Instant Release). Short acting IV conscious light anesthesia is presently being entertained to avoid the lengthy postoperative sedation which has often led to patient's unsteady gait and occasional falls.

9.4.2 Local Anesthesia

Procaine Hydrochloride (Novocain®) 1–2 % is used. Its onset is rapid within 2–5 min. Maximum volume is 100 cm^3 (2 %) or 200 cm^3 (1 %). A bleb is raised with 1–2 cm^3 of procaine, then infiltered with 30–50 cm^3 along the proposed incision. While most textbooks of hernia surgery propose an incision 2–3 cm superior to a line joining the anterior superior iliac spine and the pubic crest, I prefer making that incision along that very line as it will avoid undue painful traction on wound edges while affording easier access to the pubic and infra-inguinal areas as well as the area of the internal ring.

After ligating subcutaneous bleeders, dissection will reveal the external oblique aponeurosis, deep to which an additional 20–30 cm^3 of local anesthetic will be allowed to spread (Figs. 9.2 and 9.3).

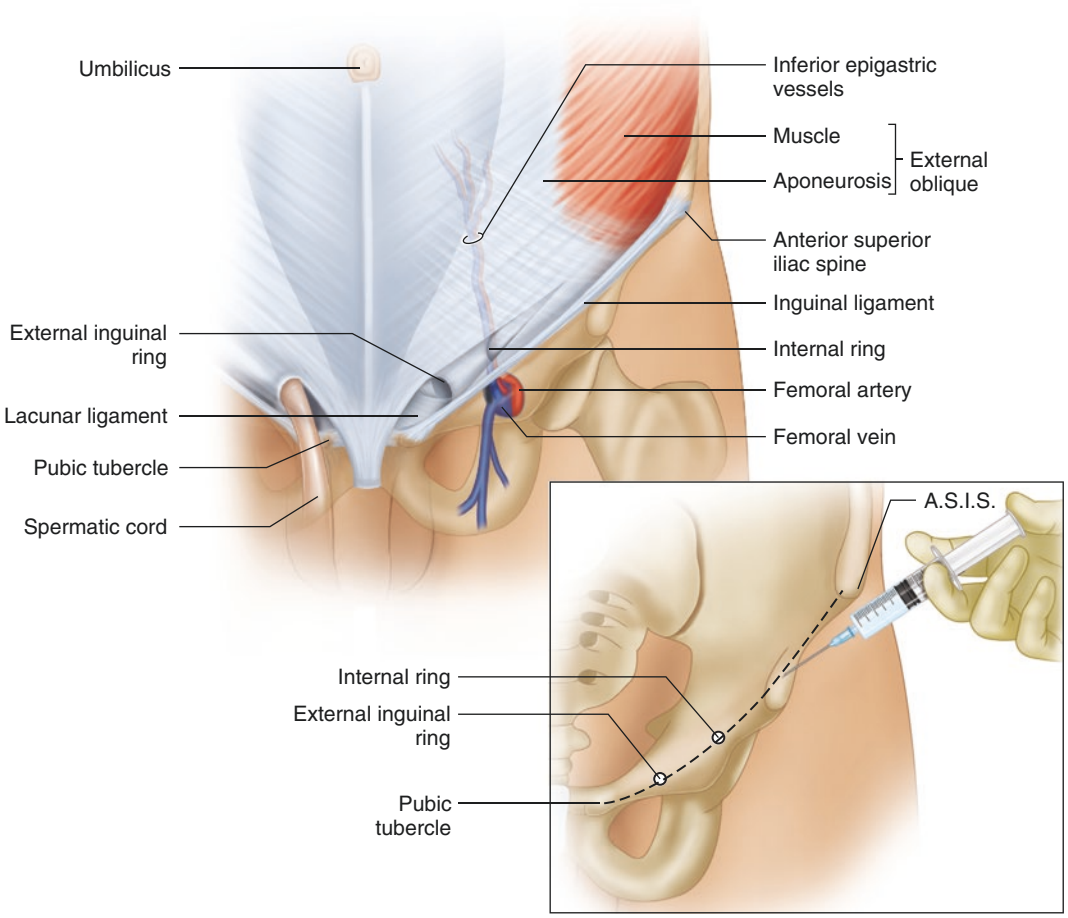

Fig. 9.2 Incision will extend for 9–10 cm from the pubic crest laterally on the very line joining the pubic crest to the ASIS

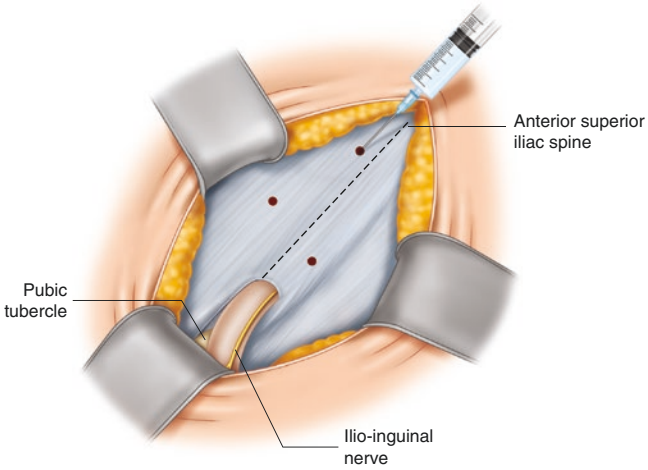

Fig. 9.3 A volume of 20–30 cm^3 of local anesthetic is injected deep to the external oblique aponeurosis allowing wide extravasation of the drug

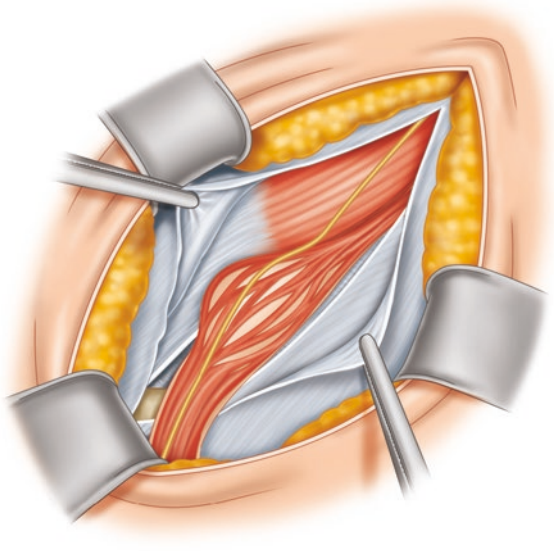

Fig. 9.4 Once the external oblique aponeurosis is divided, every visible nerve can be individually infiltrated

9.4.3 Dissection

The external oblique aponeurosis is now incised and the incision extended from the level of the superficial inguinal ring laterally to 2–3 cm lateral to the deep inguinal ring, resulting in two flaps which are gently freed as far medially and laterally to reveal an expanded inguinal canal (Fig. 9.4).

At this stage, the lateral flap of the external oblique aponeurosis is lightly tensed forward with the help of a hemostat. The thin cribriformis fascia is incised from the level of the femoral artery to the pubic crest (Fig. 9.5). This step will reveal the presence of a prevascular or femoral hernia as well as a femoral fat tab if one is present.

Next, at the mid-portion of the spermatic cord, anteriorly, the cremasteric fibers are incised longitudinally and the incision extended from the level of the pubic crest to the internal ring. As a result, the cremaster forms two flaps: (a) medial flap which is flimsy and can be entirely resected and (b) the lateral flap, more substantial in size and containing the external spermatic vessels and the genital branch of the genitofemoral nerve. This latter flap is doubly clamped, divided between the clamps and each stump doubly ligated with a resorbable suture. The double ligature will allow future needle insertion between the ligatures without causing any bleeding (Fig. 9.6).

Now, with the anatomy clearly displayed, a search is carried out for an indirect or direct inguinal hernia(s). An indirect sac would now become evident on the medial aspect of the cord and freed. The sac can be reduced into the preperitoneal space especially if it has a wide base. Resection may result in postoperative pain of some degree.

With the posterior inguinal wall fully displayed, any direct inguinal hernia becomes plainly evident.

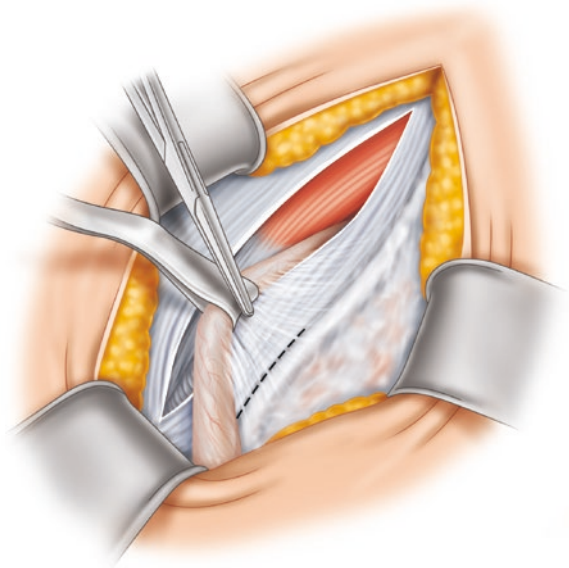

Fig. 9.5 With the lateral portion of the external oblique aponeurosis under tension, the cribriformis fascia is incised from femoral artery to pubic crest

The next step is likely the most important as it will fully display the anatomy as it ought to be seen. It is the view that the laparoscopic surgeons also seek.

Starting on the medial side of the deep inguinal ring, a light nick of the posterior wall will allow the insertion of scissor tips to extend the incision to the pubic crest, taking care not to nick the inferior epigastric vessels. This posterior wall is made up of two lamellae, the anterior one being the thicker. The posterior lamella is thin, diaphanous, and must be incised to reveal the glistening preperitoneal fat which

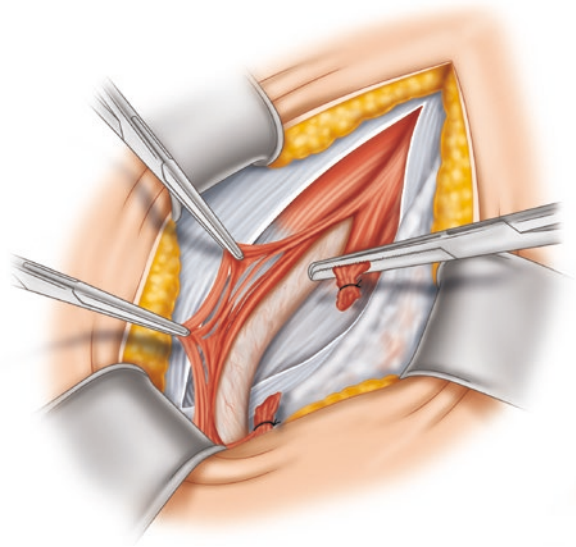

Fig. 9.6 Division of the cremaster and genital branch of the genitofemoral nerve. Both stumps are doubly ligated. The medial one suspends the testicle near the pubis. The lateral one will be incorporated by the last suture of line 1 as it reverses its course and becomes line 2. The cremaster stump will fit snuggly as a scarf around the cord. The muscle, not the suture, must become part of the new internal ring

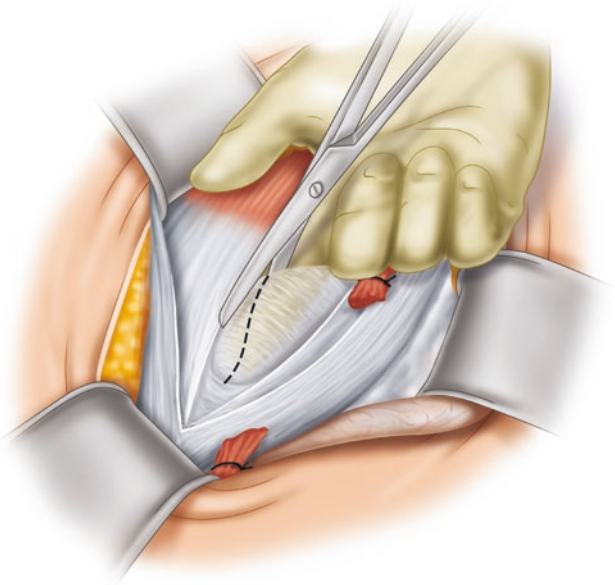

Fig. 9.7 Division of the posterior wall of the inguinal canal

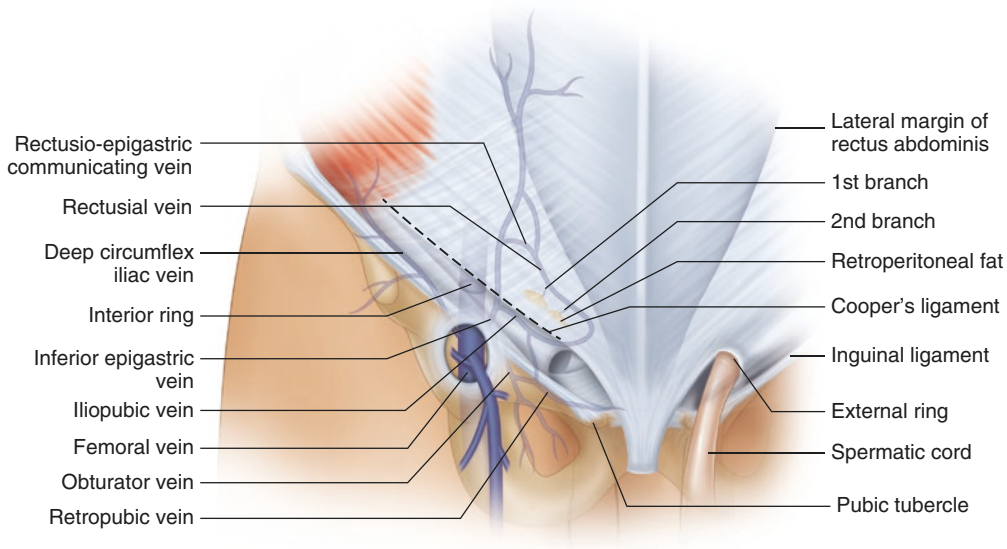

Fig. 9.8 Preperitoneal venous circle within the space of Bogros. An anatomy worth remembering when dividing the posterior inguinal wall. Reprinted with permission from the Journal of the American College of Surgeons, formerly Surgery Gynecology & Obstetrics.1992;174:355–358

confirms the presence in the preperitoneal space of Bogros. This posterior lamella makes up the layer which Read refers to as the second deep inguinal ring and which is, he felt, the site where constriction and incarceration take place with either direct or indirect inguinal hernias [25]. The medial portion of the divided posterior inguinal wall will reveal the full thickness of the internal oblique and transversus muscles. The lateral border of the rectus also becomes clearly visible (Fig. 9.7).

From this vantage point, all possible hernias can be identified. Femoral hernias cannot be missed nor prevesical ones, Laugier and low Spigelian hernias. So is the venous vasculature clearly seen to avoid injuring it (Fig. 9.8). Tissues can be assessed as well as to their quality. With this dissection, any

corrective operation with or without mesh becomes possible for any and all types of groin hernias. The lateral half of the posterior inguinal wall is often rather thin, especially near the internal ring and is referred to as the iliopubic tract. A clear description of this complex anatomy has been detailed and well worth consulting [8].

In women, the posterior wall is usually quite resilient. Some surgeons choose not to enter the preperitoneal space. In this case, a bi-finger examination of the femoral ring above and the femoral opening below the inguinal ligament will ascertain the absence of a femoral hernia. From above, the index finger is inserted through the internal ring which may already be wide or made so through a 1 cm incision of the posterior inguinal wall medially from the internal ring.

9.5 Reconstruction

9.5.1 Reconstruction of the Posterior Inguinal Wall

The aim of reconstruction is to obtain a firm posterior inguinal wall. To that end, two stainless steel wires are used (gauge 32 or 34). Each wire will contribute two lines of suture to the repair. The first line is begun medially near the pubic crest. Here, the suture coming from the lateral side penetrates the iliopubic tract, then crosses over to incorporate the true thin transversalis fascia, the transversus abdominis, the internal oblique muscles (the triple layer), and the lateral edge of the rectus, Fig. 9.9. The suture is tied with a long end left dangling to be incorporated to the returning suture when line two returns. As the first line of the suture proceeds laterally, incorporating the triple layer medially to the iliopubic tract laterally, an edge about 1 cm wide of the medial flap is fashioned to hang free. About half way up towards the internal ring, the edge of the rectus is no longer available and is omitted from the continuous suture. The latter continues then to the internal ring (Fig. 9.10).

At the internal ring, the suture reverses its course, becomes line number two and in so doing, incorporates the lateral stump of the cremaster which will now be carried beneath the triple layer (Fig. 9.11). This line proceeds towards the pubic crest by incorporating the hanging edge of the triple layer to the inguinal ligament. Near the pubic crest, the wire suture will meet and tie with the wire which had been left dangling (Fig. 9.12).

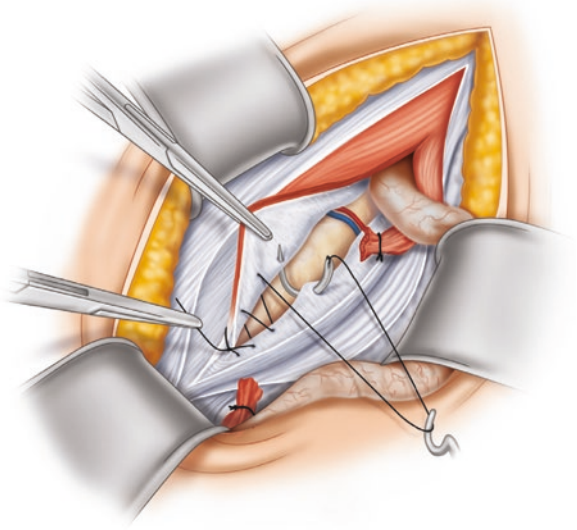

Fig. 9.10 The first line of suture which begins medially

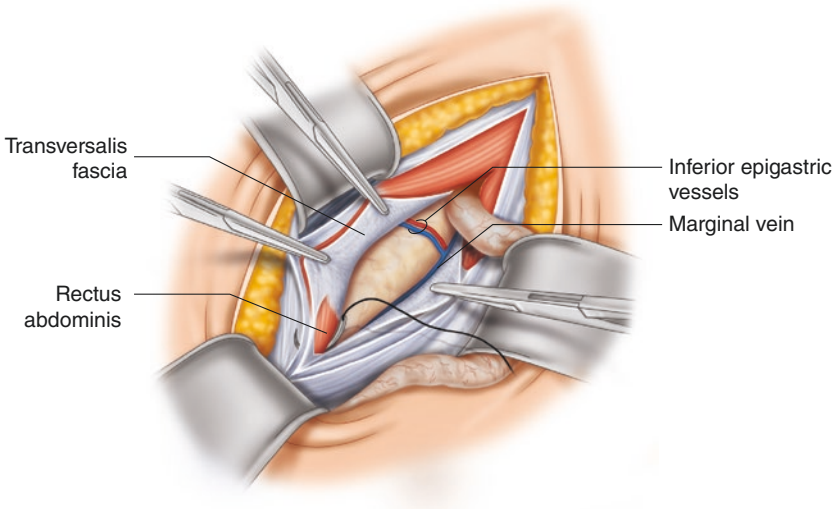

Fig. 9.9 Final appearance of a complete dissection. No hernia can be missed. Any choice of repair can be carried out, with or without mesh

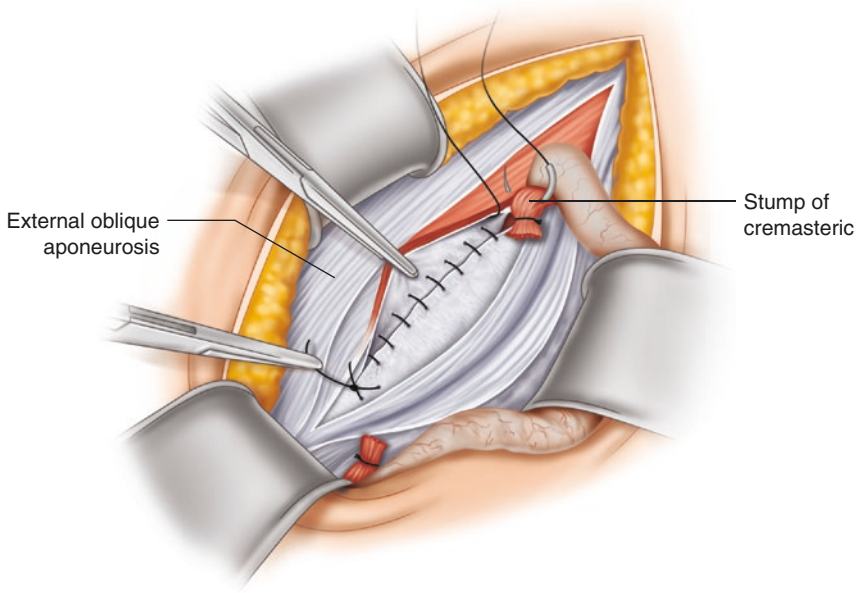

Fig. 9.11 Last step of the first line of suture. The lateral cremasteric stump is picked up between the two ligatures and carried beneath the medial triple layer

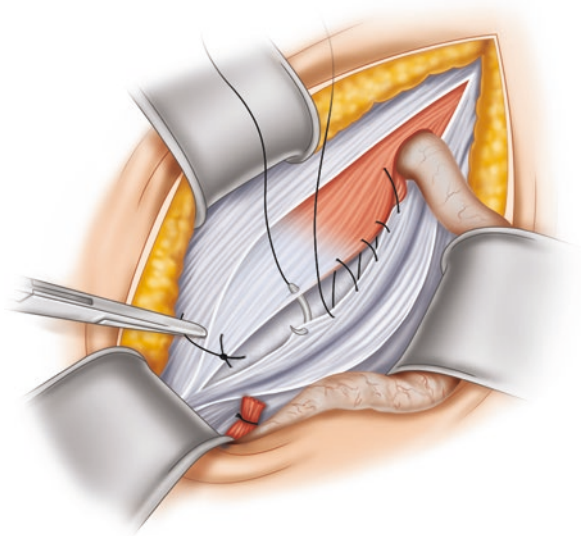

Fig. 9.12 Continuation of the second line of suture to be tied near the pubis

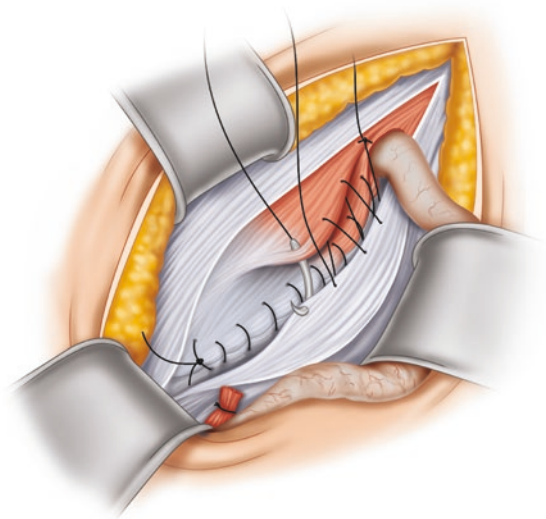

Fig. 9.13 The third line of suture which begins at the internal ring and proceeds towards the pubis

The second wire suture will now be used and will contribute lines 3 and 4. Line 3 begins at the internal ring by penetrating on the medial side the triple layer (the thickness of it blindly), then crosses over to incorporate the inner surface of the external oblique aponeurosis, parallel to line 2 but more superficially, thus creating an artificial second inguinal ligament (Figs. 9.13 and 9.14).

At the pubic crest, the suture will reverse its course and become line 4 to return to the internal ring (Fig. 9.15).

While beginning line 4, the wire suture will pick up the very edge of the lowest portion (2–3 cm) of the external oblique aponeurosis and splay it flat over the very medial portion of the new posterior wall. This is the site where recurrences are prone to occur! Line number 4 then pro-

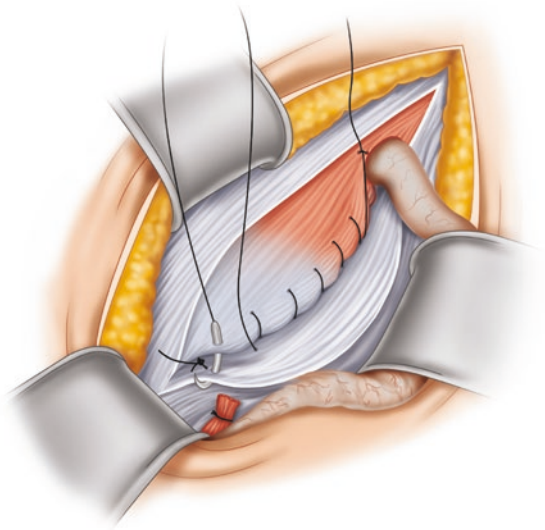

Fig. 9.14 End of line 3 of suture before reversing back its course towards the internal ring

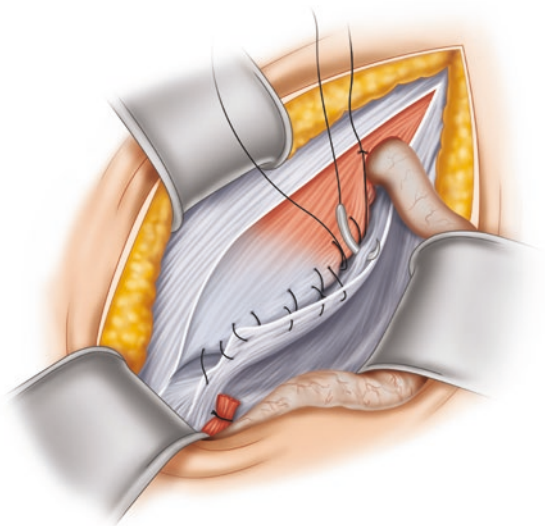

Fig. 9.15 End of line 4 at the internal ring

ceeds towards the internal ring, by incorporating anew the triple layer to the internal aspect of the external oblique aponeurosis as if creating, yet again, another inguinal ligament. At the level of the internal ring, the two ends of the suture are now tied.

The spermatic cord is now replaced in its normal anatomical bed and the external oblique aponeurosis approximated over it with a resorbable suture (Fig. 9.16). The subcutaneous tissues are closed with a resorbable suture and the skin is closed with Michel clips, half of which are removed in 24 h, the remaining half at 48 h. The patients are discharged on the third day.

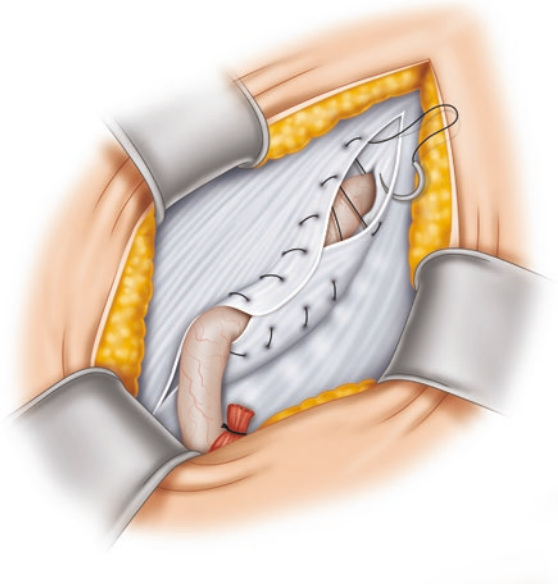

Fig. 9.16 Approximation of the external oblique over the spermatic cord

Table 9.2 All groin hernias

	Indirect	Direct	Femoral	Ing.fem	Total	%
Men	3361	1984	38	1	5384	89.45
Women	571	16	48	0	635	10.55

Table 9.3 Primaries and recurrences in men

	Indirect	Direct	Femoral	Ing.fem	Total	%
Primary	3232	1808	20	0	5060	94
Rec.	129	176	18	1	324	6

Table 9.4 Primaries and recurrences in women

	Indirect	Direct	Femoral	Ing.fem	Total	%
Primary	206	14	39	0	259	95
Rec.	3	2	9	0	14	5

9.6 Statistics and Results

Total number of hernias done in 2013 (all hernias): 6665.

There were 143 incisional hernias of which 43 were iatrogenic trocar site hernias (30.3 %) (Tables 9.2, 9.3, and 9.4).

9.7 Results

Less than 20 years ago, the Shouldice repair was the gold standard in hernia repair. Prominent surgeons of the time reported results which mesh and laparoscopy have not

Table 9.5 Recurrence rate following the Shouldice operation of primary inguinal hernias

Author	No. of cases	% Follow-up	Years follow-up	Recurrence (%)
Shearburn and Myers [26]	550	100	13	0.2
Volpe and Galli [27]	415	50	3	0.2
Wantz [28]	2087	–	5	0.3
Myers and Shearburn [29]	953	100	18	0.7
Devlin et al. [30]	350	–	6	0.8
Flament [31]	134	–	6	0.9
Wantz [32]	3454	–	1–20	1.0
Shouldice (Welsh) [33]	2748	–	35	1.46
Moran et al. [34]	121	–	6	2.0
Berliner et al. [35]	591	–	2–5	2.7

Table 9.6 10-year follow-up and results from the Aachen group [40]

	I (%)	II (%)	III (%)
L (indirect)	0	0	6.6
M (direct)	0	4.6	7.4

improved on in terms of recurrence, to date. Professor Schumpelick's statement to the American Hernia Society 10 years ago, that mesh and laparoscopic surgery have not lessened the recurrence rate, is becoming dated but the facts remain the same (Table 9.5).

More recent publications of the last 5–10 years are upholding the fact that in terms of recurrence, the Shouldice repair still performs as well as mesh repairs and laparoscopic surgery when the repair is done by surgeons who understand anatomy [6, 36–39] (Table 9.6 [40] and Figs. 9.17 and 9.18).

The most outstanding review of the last 30 years on the Shouldice repair, and an excellent example of evidence-based medicine, was released this year and covers a series of 235,192 repairs done in Ontario, Canada. The study relied on a registry held by the Ontario Government of all surgeries performed in the province. It has become the equivalent of the Swedish and Danish hernia registries but bigger than both of them combined. The study looked at 14 years. In terms of statistical power, this study may be considered overkill! [38].

The study covered the period of January 1, 1993–December 31, 2007. Of the 235,192 patients who underwent hernia surgery, 65,127 (27.7 %) had their surgery performed at the Shouldice hospital. The non-Shouldice patients numbered 170,065 patients and were divided into four classes (quartiles) depending on the volume of surgery performed on average by each hospital. Numbers of patients in each quartile were:

Quartile	Average	Range	Total	Patients
1	61	1–106	42	427
2	142	107–185	42	644
3	219	186–267	42	346
4	341	268–803	42	648

9.7.1 Findings

From the general hospitals in Ontario, comparing those who did the least number of surgeries (quartile 1) with those who did the most (quartile 4), the risk of recurrence rate ranged from 5.21 % (95 % CI 4.94–5.49 %) to 4.79 % (95 % CI 4.54–5.04 %), respectively. In marked contrast, the Shouldice Hospital revealed a recurrence risk of 1.15 % (95 % CI 1.05–1.25 %). All the calculations for a cumulative probability of recurrence were lower, significantly, among patients who had surgery at Shouldice Hospital: ($p < 0.001$).

The age-standardized proportion of patients who had a recurrence ranged from 5.21 % (95 % confidence interval [CI] 4.94–5.49 %) among those who had surgery in the lowest volume general hospitals to 4.79 % (95 % CI 4.54–5.04 %) of those who had surgery at highest volume general hospitals. In contrast, those who had surgery at the Shouldice Hospital had an age-standardized recurrence risk of 1.15 % (95 % CI 1.05–1.25 %). The cumulative probability of recurrence was significantly lower ($p < 0.001$) among patients who had surgery at the Shouldice Hospital than at general hospitals, regardless of volume [39].

To examine whether Shouldice surgeons were "cherry picking" easier patients to account for their good results, the study looked at 633 (9.6 %) patients who were originally seen at the Shouldice Hospital but subsequently elected to have their surgery elsewhere in the period 2004–2006. A recurrence developed in 20 of them or 3.1 % recurrence rate.

Over the years the Shouldice Hospital has in fact reported recurrence rates of 0.5–1.5 %, the lesser incidence associated with primary inguinal hernias.

The authors had no way of knowing that, at the Shouldice hospital for the year 2013, the latest year with a complete set of statistics, mesh was used on 30 of 291 operations on women (10.3 %) and on 41 of 5384 men (0.76 %).

The trend in all Hospitals in Ontario (outside of the Shouldice) has been to use mesh in all hernia repairs, an approach which we feel is statistically unnecessary in view of the many problems which are rearing their heads such as

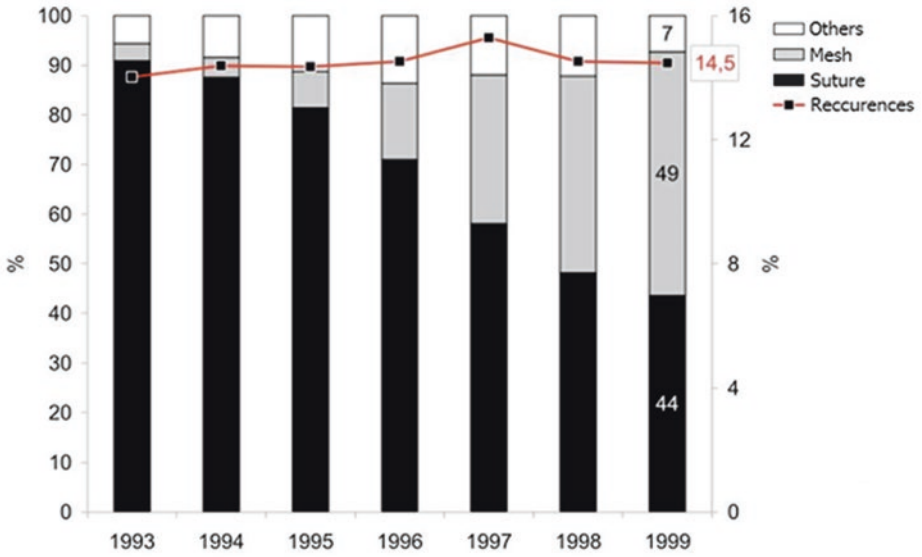

Fig. 9.17 The increase in the use of mesh has reached much higher levels in 2016, but the incidence of recurrence has remained the same at 14.5 % average. Courtesy: Professor V. Schumpelick

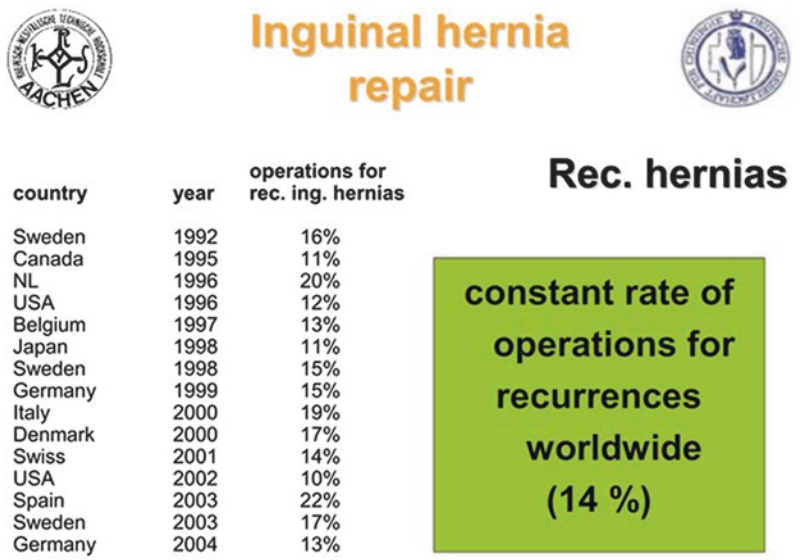

Fig. 9.18 Despite the increase in the use of mesh and introduction of laparoscopic repair, the worldwide incidence has remained the same. Courtesy: Professor Volker Schumpelick

chronic inguinodynia, orchialgia, and most distressing dysejaculation [41]. Not to be discarded is the fact that 30.3 % of all incisional hernia repairs carried out at Shouldice Hospital are for iatrogenic trocar site hernias resulting from previous laparoscopic surgery.

A supreme irony in overuse of mesh emanated from the Edoardo Bassini Hospital of Milan, in August 2004; 148 surgical departments reported on the use of mesh on 16,935 patients or 97.4 % of the patients in Lombardy! This was tantamount to removing venerable Bassini from his plinth in that hospital [42].

9.8 Complications

It should come as no surprise that complications are minimal when surgery is carried out under local anesthesia, with early ambulation in a hospital where nosocomial infections are minimal. The hospital is considered “clean” because no surgery is carried out where contamination could be a possibility. The presence of an infection in a prospective patient, whether pulmonary, genitourinary, upper respiratory, cutaneous, etc., would automatically cause surgery to be can-

celled and his admission delayed until the clinical infection clears up.

Testicular atrophies were calculated in a retrospective study which identified a 7 year cumulative total 52 testicular atrophies and which were analyzed by a statistician. Successive, multiple recurrences did elevate the recurrence rates and can be gathered in much more detail from the original study [43]. The results given below were averages for recurrences which ranged from 0.36 to 0.74 % depending on the hernia type and the number of previous repairs.

Complications for the year 2013 were calculated from total operations: 6669 groin hernias, comprising males and females.

Infections		
Cellulitis	32	0.48 %
Seromas	8	0.12 %
Hematomas	16	0.24 %
Dysejaculation		0.04 %
Testicular atrophy		
In primary	19/51761	0.04 %
In recurrence	33/6673	0.49 %

9.9 Pain

Any surgery will be followed by pain for a few days and will clear within days, weeks. Chronic post-herniorrhaphy pain beyond 3 months is an industrial complication which seems to have come along as a result of the unrestrained promotion and use of mesh, particularly polypropylene. Bassini does not mention it in his opus magnum of 1889 (New operative method for the cure of inguinal hernia. Prosperini, Padova, Italy). Nor does Alfred Iason in his encyclopedic HERNIA of 1941 (Blakiston publishers) mention pain except in association with strangulation. Lloyd Nyhus in HERNIA (1964-first edition) does not mention pain until Starling rediscovered genitofemoral neuralgia (in the third edition of 1989). Starling's review states that only 12 cases had been previously reported and due to neuromas [44]. Nor have Fruchaud (1956) Ravitch (1969) discussed post-op neuralgia. Ponka in his seminal book (*Hernias of the Abdominal Wall*, WB Saunders 1980, pp. 601–2) mentions ilioinguinal and genitofemoral nerve as involved in scar tissue but describes them as "uncommon" in half a column.

The Shouldice Hospital throughout its 75 years of existence had not observed chronic pain to the extent of investigating its etiology, mechanism, or incidence. I have personally known three cases of nerve entrapment which were easily recognized and, upon division of the affected nerve, was followed by complete relief. A clean and clear dissection in pure tissue repair identifies all nerves, and their frequent variations, quite accurately.

Current literature on pain has proliferated much faster than its classification, standardization, etiologies, and treatments (medical and surgical). The issue of pain, assessed at 24 h, 48 h a week, etc. has been used as a biased tool to promote one's preferred agenda of surgical approaches or particular brand of prostheses. Accordingly every technique, with and without mesh, has been implicated to the same extent but one has to be careful in assessing publications which often emanate from authors with vested interests.

9.9.1 Dysejaculation

This syndrome was first reported in 1992 [45]. Its incidence was 1/2500 (0.04 %) in pure tissue repairs, at a time when meshes were beginning to be introduced in hernia surgery. That incidence today is 3.1 %, along with 10.9 % who report groin and testicular pain during sexual activity [46]. This 77.5-fold increase stated another way is a 7750 % increase in incidence of dysejaculation at a time when mesh repair is becoming the norm. How many patients would be willing to take this risk when the possibility of true dysejaculation is properly explained to them? Ostensibly, not many.

9.9.1.1 Mesh Removal, Explantations

The removal of prosthetic materials is becoming a frequent type of surgical intervention. Those whose vested interests are being threatened are clamoring that there is no evidence that such "drastic" measures are of any benefit. Of course there will be none. The world is just realizing that when unbearable pain becomes an issue, mesh removal would appear to be a logical answer [2, 45–51]. Removals have thus begun. Several studies have now been reported and confirming with impressive results in two-thirds of the cases or more. The problem does exist. The literature covering the many forms of nonsurgical management have become legend but with little benefit as most pain clinics are reporting to the embarrassment of many surgeons [2, 52–60]. The largest series of explants was reported by Klosterhalfen and Klinge and covered recurrences, pain, and infection [47]. Another series covering pain only and mesh removal was presented by Kevin Petersen (USA) [61] at the first World Conference on Abdominal Wall hernia surgery, on April 26, 2015, in Milan, Italy. Petersen reported on 114 consecutive mesh removals for severe pain, 67 males and 21 females. Follow-up of 76 % up to 6 years (average 23.5 months). Operations were for groin, incisional, umbilical hernias. In summary: 18 % were cured; 47 % were much better; 23 % a little better; 8 % had no change; 3 % a little worse; 1 % much worse. What is becoming apparent is that the later surgery is instituted for pain relief, the more difficult the task becomes. For those who show no improvement, the mechanism of phantom pain types of mechanism must be evoked and those can be challenging.

9.9.2 Literature

More than ever, surgeons must become more discriminating with what they read, see, and hear! Barbour warns that journals "may be becoming works of fiction dictated by lobbyists" [62]. The Cochrane review states that the quality of the studies which compare the Shouldice repair to the mesh is low. But no one ever quotes this important opinion [63]. Not insignificant either is the fact that only 50 % of clinical studies which are registered under clinicaltrial.gov are published thus leading to an overestimation of the advantages and an underestimation of disadvantages of the method [64]! Ioannidis, a noted epidemiologist, emphasizes that "false findings are the majority or even the vast majority of findings" [65]. Steen on the other hand discusses the extent of retracted journals and their scientists in 2010! Evidence-based medicine, just like statistics, may be a double edged sword when improperly applied. Logic and experience should never be too readily discarded either, when being bombarded by an unrelenting industry [66]. Finally, the imponderable paradox of the evidence-based century is that we have far more knowledge than ever before but, regrettably, less wisdom in its application.

9.10 Conclusion

The Shouldice repair has proven to be a good operation in competent hands. Some cases will require mesh but these should be far fewer than have been performed. Beware of "fashions" warned George Bernard Shaw, "they are nothing more than an induced epidemic"! Simplicity is always a classic in any endeavor and it would be a good amendment to add to Hippocrates's tenet of… "First do no harm."

I have no doubt that if a safety pin were to be designed today, it would have four moving parts and would need servicing three times a year!

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Lichtenstein Tension-Free Hernioplasty

10

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10.1 Introduction

Inguinal hernia has been a source of significant morbidity and mortality throughout human history. As early as the 1800s, it was recognized that weakening of the tissues of the abdominal wall was responsible for formation of inguinal hernias. Successful, replicable inguinal hernia repair was first introduced by Eduardo Bassini in 1887, when he demonstrated to the Italian Surgical Society that native tissue could be used to durably restore the integrity of the inguinal floor. The Bassini repair and other tissue-based techniques were considered the gold standard until the 1980s. Under these techniques, weakened tissue is approximated under tension to repair the inguinal floor and, as such, reducing the frequency of hernia recurrence was an ongoing challenge.

During this time, attempts to increase the tensile strength of operative repair using prosthetic material resulted in high rates of infection and rejection. These difficulties continued until the advent of polypropylene mesh in 1959. Compared to prior materials, polypropylene mesh was lighter in weight and offered superior strength and flexibility. Crucially, polypropylene is a biologically inert material, allowing for infiltration of fibroblasts, collagen fibers, blood vessels, and macrophages without inciting an inflammatory response or harboring infection. The availability of a suitable prosthetic mesh spurred renewed interest in development of a tension-free technique to repair inguinal hernias.

The Lichtenstein tension-free hernioplasty was described in 1986 by Drs. Irving Lichtenstein, Alex Schulman, and Parviz Amid at the Lichtenstein Hernia Institute in Los Angeles [1]. While others had described similar tension-free techniques, the Lichtenstein group's protocol-based approach to using synthetic for all forms of inguinal hernia including systematic evaluation and tracking of outcomes led to widespread adoption. The Lichtenstein technique avoids the hazard of suture line tension by placing mesh between the transversalis fascia and the external oblique aponeurosis, where it reinforces the entire inguinal floor (Fig. 10.1). While increased intra-abdominal pressure (such as that associated with straining) results in increased tension on the suture line of a tissue-based repair, this is not the case with the Lichtenstein hernioplasty. As pressure increases and the external oblique muscle contracts, the external oblique aponeurosis applies counterpressure on the mesh, allowing for excellent durability even under high intra-abdominal pressures [2]. Accordingly, the Lichtenstein tension-free hernioplasty both addresses the present herniation and protects the inguinal floor against future mechanical stresses.

10.2 Preoperative Management

Patients seen in the Lichtenstein-Amid Hernia Clinic are screened for hernia type and comorbidity. Risk stratification and medical optimization are undertaken prior to elective hernia repair for patients of advanced age or those with medical comorbidities. Smoking cessation is encouraged and glycemic control in diabetics is optimized. They are instructed that shaving of the groin or abdomen should be avoided in the preoperative period, as resulting microtraumas may increase the infectious risk of the operation.

10.3 Materials

Several prosthetic mesh options are available for tension-free hernia repair. Monofilament, macroporous polypropylene and polyester meshes provide optimal functionality and resistance to infection. It is our preference to use lightweight

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_10

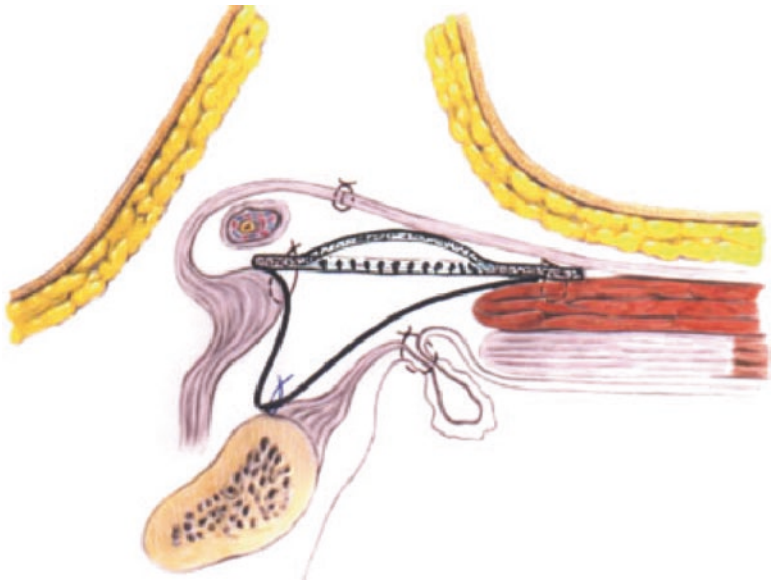

Fig. 10.1 Sagittal view of mesh placement with inverted direct hernia sac. The *black dotted line* shows incorrect placement, resulting in tension. The *solid black line* shows position of mesh for femoral hernia repair

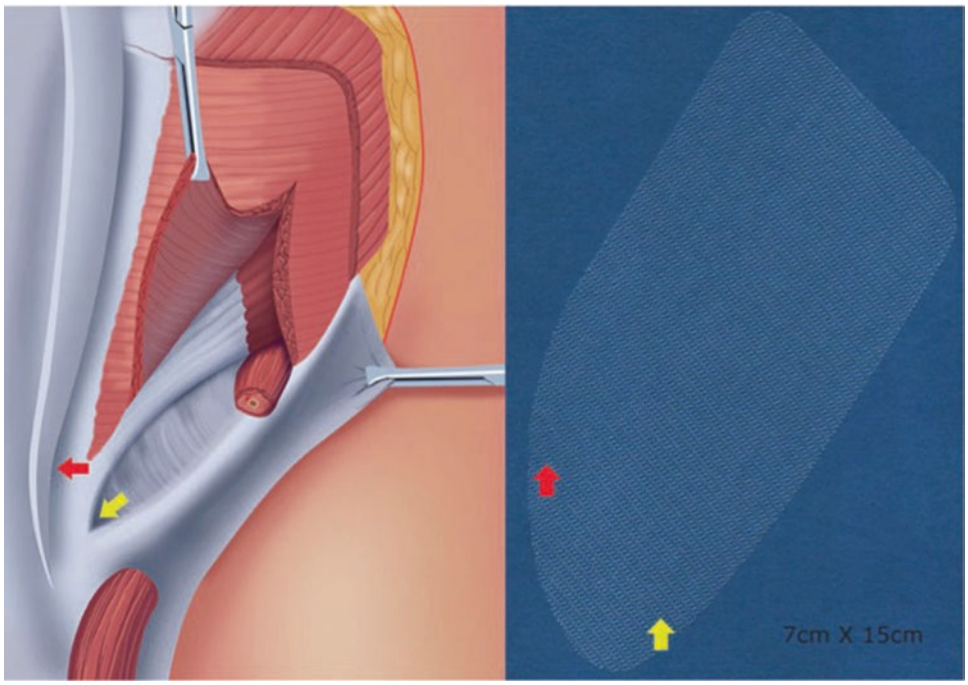

Fig. 10.2 Appropriate shape and orientation of the mesh to cover the inguinal floor. *Arrows* indicate where the borders of the mesh should lie

mesh, as this formulation provides adequate strength and has recurrence rates equivalent to heavier mesh, but causes less postoperative discomfort and pain [3]. The standard size of the prosthetic mesh sheet should be 7.5 × 15 cm, allowing for coverage of the entire inguinal floor, from the internal ring to beyond Hesselbach's triangle. The medial corner is trimmed in a rounded shape with the apex tailored to fit the angle between the inguinal ligament and the rectus sheath (Fig. 10.2). In the case of a femoral hernia, the mesh size and shape may be modified with a lateral triangular extension that is affixed to Cooper's ligament to exclude the femoral canal.

10.4 Operative Technique

10.4.1 Positioning and Preparation

The operation is performed with the patient in the supine position. Skin preparation with an antiseptic solution is performed, extending from superior to the umbilicus to the scrotum inferiorly. The scrotum should be included in the operative field if a large inguinoscrotal hernia is present. Perioperative antibiotics are not required for clean, elective cases.

10.4.2 Anesthesia and Sedation

Lichtenstein hernia repair can be safely and comfortably performed under local anesthesia. This is our preferred technique of anesthesia for adults with reducible inguinal hernias as it is safe, effective, and low cost without the side effects of general anesthesia, such as nausea, vomiting, urinary retention, and hemodynamic disturbances. If the hernias are not reducible, we prefer general anesthesia or epidural anesthesia in addition to local infiltration of anesthetics. As an adjunct to local or epidural anesthesia, light sedation using short-acting anxiolytic and amnestic medications (e.g., midazolam, propofol) along with analgesic medications may serve the reduce anxiety and decrease the required volume of local anesthetic mixture.

At the Lichtenstein-Amid Hernia Clinic, our preferred local anesthetic mixture is a 50:50 mixture of 1 % lidocaine and 0.5 % bupivacaine with 1/200,000 epinephrine. A unilateral hernia repair can typically be performed comfortably using 30–40 mL of this mixture. The technique for use of this mixture is described in the steps of the operation below.

Finally, immersing the canal in 10 mL of the anesthetic mixture prior to closure of the external oblique aponeurosis may improve the duration of local anesthesia and minimize immediate postoperative discomfort.

10.5 Operative Steps

After skin preparation, the planned line of incision is marked. The skin incision starts from the pubic tubercle and extends 5–6 cm laterally, following the Langer line. This position and orientation provides exposure from the pubic tubercle to the internal ring.

Local anesthesia is then administered. The subdermal tissue along the line of incision is first infiltrated with approximately 5 mL of the anesthetic mixture using a fine gauge needle. This serves to anesthetize subdermal nerve endings and minimizes the pain of intradermal infiltration. Injecting as the needle is advanced parallel to the surface of the skin reduced the chance of intravascular administration. The needle is then withdrawn until the tip is intradermal and the dermis along the line of the incision is infiltrated with 2–3 mL of the mixture (Fig. 10.3). The last step before initial incision is to inject the anesthetic mixture into the deep subcutaneous tissues in the operative field (Fig. 10.4). The needle should be inserted vertically at points separated by approximately 2 cm, and should be kept in motion while injecting. Approximately 10 mL of the mixture is used for subcutaneous infiltration.

The skin is then incised and the subcutaneous tissues are divided. At this point, another 10 mL of the mixture is injected directly into the inguinal canal. This is achieved

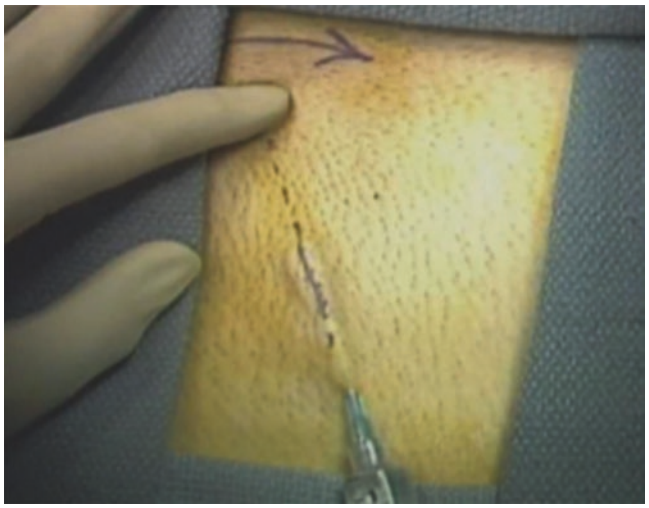

Fig. 10.3 Intradermal injection of the planned incision site

before the canal is opened by inserting the needle through the external oblique aponeurosis close to the lateral aspect of the incision (Fig. 10.5). Half of the injection may be directed superiorly up the canal and the other half inferiorly towards the external ring. At this point, the ilioinguinal nerve, iliohypogastric nerve, and genital branch of the genitofemoral nerve are all immersed in local anesthetic within the canal, allowing for excellent anesthesia of these nerves. Additionally, the injected fluid hydrodissects the inguinal canal and lifts the external oblique aponeurosis away from the ilioinguinal nerve, thereby protecting it from injury when the aponeurosis is divided.

The external oblique aponeurosis is divided over the course of the entire inguinal floor, starting from the external ring to and proceeding superiorly. The upper leaf of the aponeurosis is separated from the internal oblique muscle, and the lower leaf is separated from the spermatic cord structures. These steps provide exposure of the entire inguinal floor and the field into which the mesh prosthesis will be placed (Fig. 10.6). The internal oblique aponeurosis should be exposed at least 3 cm superior to the upper margin of the inguinal floor to ensure adequate overlap with the mesh. At this time the ilioinguinal and iliohypogastric nerves are exposed and should be identified so that subsequent injury or entrapment can be avoided. The ilioinguinal nerve will originate medial to the anterior superior iliac spine and then typically courses over the cord structures to exit the external ring. The iliohypogastric pierces the internal oblique medially and will then proceed caudally and medially to exit the canal at the conjoined tendon. There is considerable neuroanatomic variation of these nerves and identification is key to determine preservation versus pragmatic division.

The spermatic cord is next separated from the inguinal floor and pubic tubercle, continuing approximately 2 cm inferiorly past the tubercle. This is performed atraumatically

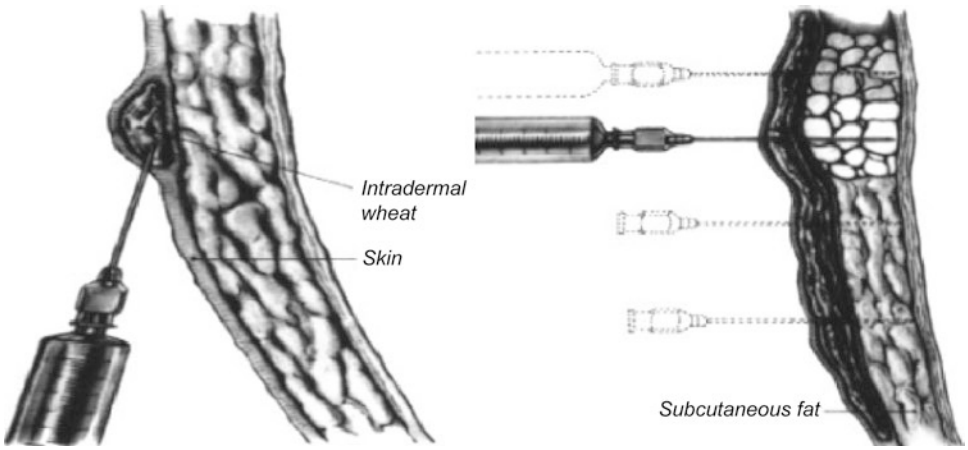

Fig. 10.4 Intra-dermal and deep subcutaneous injection of local anesthetic

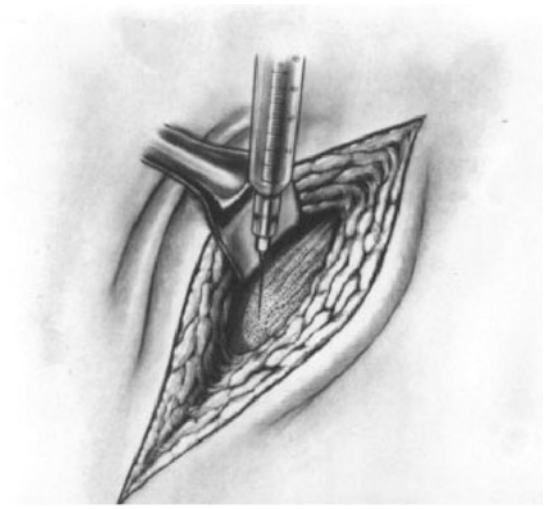

Fig. 10.5 Sub-aponeurotic injection of local anesthetic directly into the inguinal canal

with a gauze peanut dissector, lifting the structures off of the floor and tubercle from the inguinal ligament, preventing trauma to the cremasteric bundle and its contents. Infiltration of local anesthetic into the tissues surrounding the pubic tubercle may be necessary. A Penrose drain may be passed around the cord and used to retract it away from the inguinal floor if necessary at any time during dissection and mesh placement (Figs. 10.6–10.10). At this time, the genital branch of the genitofemoral nerve is identified coursing alongside the more easily visible external spermatic vein, which appears as a blue streak lateral and posterior within the cord. All three major nerves should be preserved during dissection. If a nerve is noted to be injured or transected during the operation, it is our practice to ligate the nerve ending and to bury it in the muscle belly to avoid neuroma formation and minimize development of neuropathic pain (known as a "pragmatic neurectomy").

The cremaster muscles which for the outer covering of the spermatic cord are divided longitudinally near the deep inguinal ring, and the cord is explored to determine whether an indirect hernia sac is present. Complete removal or transection of the cremasteric fibers is not recommended as it results in increased risk of exposure of cord structures to mesh, increasing risk of nerve injury and chronic pain. If present, the indirect hernia sac is dissected away from cord structures until the neck of the sac is freed. (If anesthesia is noted to be incomplete, injection around the neck of the hernia sac or inside an indirect hernia sac may be beneficial.) The sac is then inverted into the pre-peritoneal space. Ligation of the sac is not necessary, does not affect recurrence rate, and increases risk of postoperative pain. In the case of a large non-sliding hernia extending into the scrotum, the sac is transected at a midpoint in the canal and the distal section is left in place. The anterior wall of the distal sac should be incised to prevent hydrocele formation, but does not need to be dissected free and removed, as this increases the risk of injury to testicular vessels and testicular atrophy or loss.

If a direct hernia is observed and a large sac is present, it may be inverted to allow for adequate positioning and contact of the mesh. This closure should not be performed under tension and approximates only the transversalis fascia. A narrow-necked direct hernia may be imbricated and closed with an absorbable purse string suture. A broad-based direct hernia can be imbricated with a running suture along the floor approximating the transversalis fascia along the length of the defect.

A small opening in the inguinal floor through the transversalis fascia or an opening in the hernia sac is used to interrogate the femoral canal. (The presence of a coexisting femoral hernia may be addressed by extending the subsequent mesh fixation to Cooper's ligament.)

A 7.5 × 15 cm mesh sheet is tailored to the shape of the myopectineal orifice as described above. The mesh is first affixed at its apex to the pubic tubercle using a nonabsorbable, monofilament suture. Suturing through the periosteum of the bone increases postoperative pain and should be

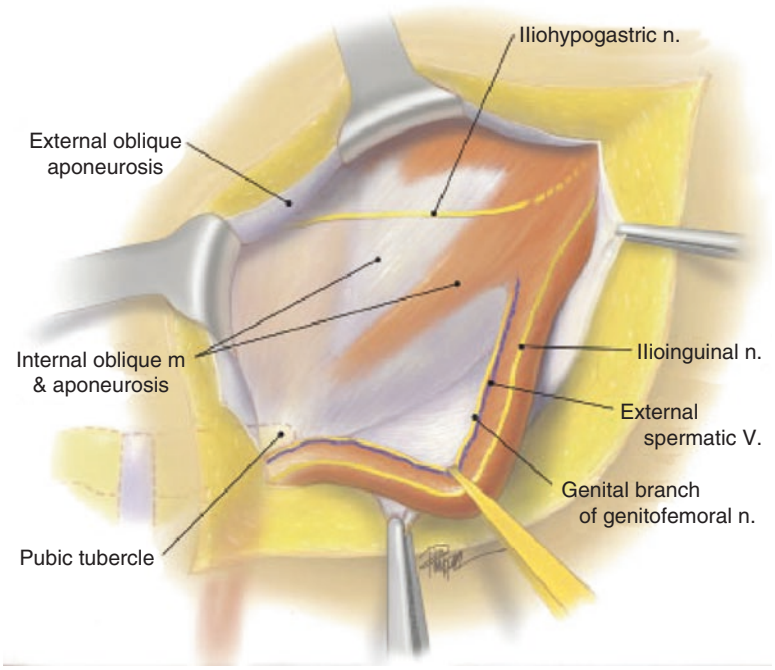

Fig. 10.6 Anatomy of the inguinal region with identification of relevant nerves

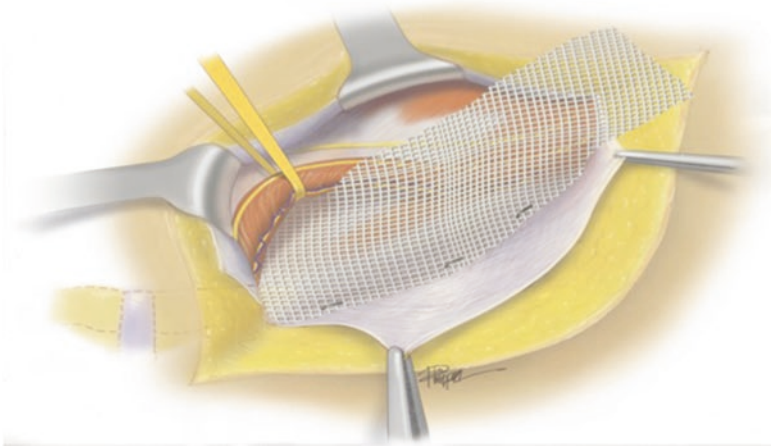

Fig. 10.7 Running, nonabsorbent suture is used to affix the lateral mesh border to the inguinal ligament

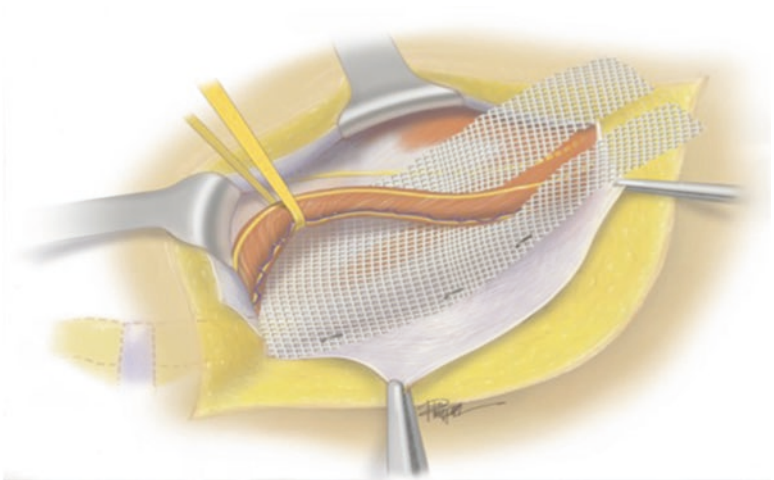

Fig. 10.8 A longitudinal slit is made in the mesh from the lateral edge, with the superior tail twice the width of the inferior tail

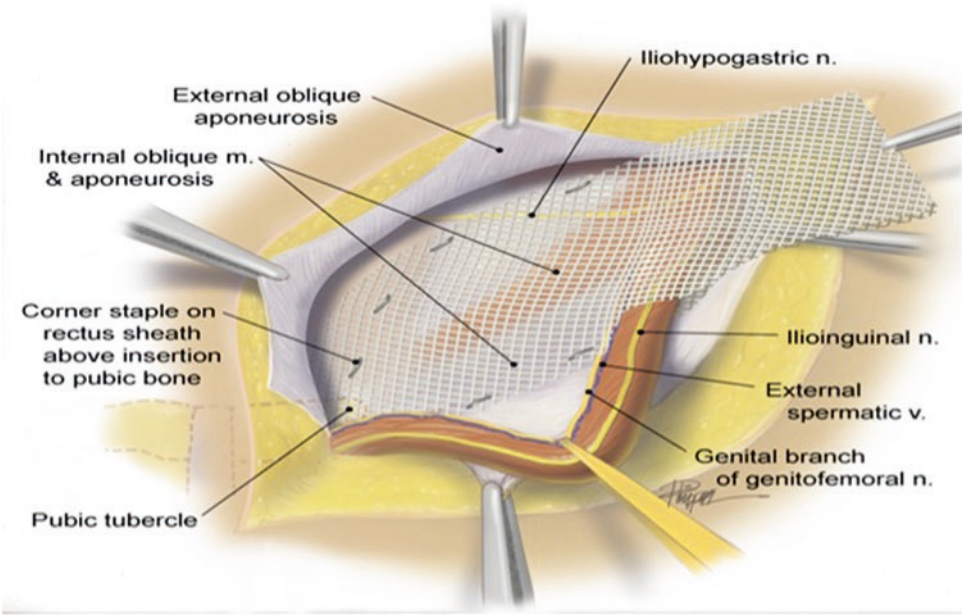

Fig. 10.9 Interrupted, absorbable suture is used to affix the upper mesh border to the internal oblique aponeurosis

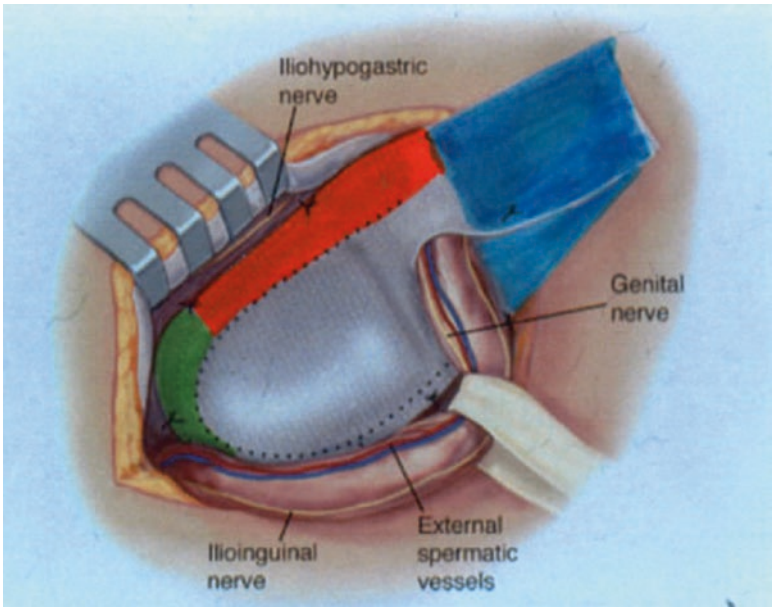

Fig. 10.10 Mesh tails are sutured together to the inguinal ligament with nonabsorbable suture to recreate the internal inguinal ring

avoided. The mesh should overlap the tubercle inferiorly by 1–2 cm. Failure to adequately cover and overlap the pubic bone with the mesh may result in recurrence of the hernia as the mesh contracts. Once the initial stitch has been placed at the pubic tubercle, the same suture is used to attach the mesh to the inguinal ligament using a running stitch (Fig. 10.7). The suture is continued up to a point lateral to the deep inguinal ring, as going any further risks injury to the lateral femoral cutaneous nerve.

A slit is cut along the long dimension of the mesh starting from the lateral end. This creates two tails; the superior tail should be approximately twice as wide as the inferior tail. The wider tail is passed medially and superiorly under the spermatic cord using forceps. The spermatic cord is now positioned between the two tails of the mesh (Fig. 10.8). The two mesh tails are then crossed with the wider, superior tail on top, and are held in place with a clamp.

The spermatic cord is then retracted downward while the upper leaf of the external oblique aponeurosis is retracted upward, exposing the lateral edge of the rectus sheath and the internal oblique aponeurosis. When possible, the course of the iliohypogastric nerve should be identified as medial

fixation places it at risk. The superior border of the mesh is sutured to the aponeurotic portion the internal oblique adjacent to the conjoined tendon using absorbable suture in an interrupted fashion to minimize injury to the iliohypogastric nerve. These sutures should proceed superiorly to a point just medial to the internal inguinal ring (Fig. 10.9). Care should again be taken in identification and avoidance of the iliohypogastric nerve which may run a sub-aponeurotic course at this level, and the mesh should not be sutured directly to the internal oblique muscle, as this may result in entrapment of the intramuscular portion of the iliohypogastric nerve. Avoidance of overtightening stitches may also reduce the likelihood of nerve injury.

Finally, a single stitch of nonabsorbable monofilament suture is used to affix both the inferior edges of both mesh tails to the inguinal ligament just lateral to where the lower running suture ends. The tails should be pulled sufficiently tight to recreate the mesh internal ring while allowing for passage of the spermatic cord (Fig. 10.10). A general rule is that the recreated ring should allow for passage of the tip of a hemostat, but should not be so loose as to allow passage of a finger.

The lateral mesh tails should extend at least 5 cm beyond the recreated internal ring, but any excess mesh beyond this distance may be trimmed and the corners of the tails rounded. The tails are then tucked underneath the external oblique aponeurosis, and the external oblique is closed over the cord and mesh with an absorbable suture. Care should be taken not to constrict the cord vessels at the new external inguinal ring created by this closure.

Scarpa's fascia and subcutaneous tissues are closed using absorbable suture in an interrupted fashion. Skin closure is achieved with an absorbable subcuticular suture or staples.

10.6 Postoperative Management

Lichtenstein tension-free hernioplasty is typically performed as an outpatient procedure. Postoperatively, patients may resume all normal cardiovascular activities and are encouraged to start this immediately. Normal daily activities and lifting are unrestricted. Strenuous or vigorous activity that elevates the intraabdominal pressure is limited in the early postoperative period for reasons of comfort. Patients are provided with oral analgesic medications at discharge.

10.7 Associated Risks and Complications

Lichtenstein inguinal hernia repair can result in several complications, including bleeding, infection, hernia recurrence, nerve injury or entrapment, chronic pain, visceral injury, vascular injury, spermatic cord injury, testicular ischemia, atrophy, or loss, hematoma, seroma, urinary retention, bladder injury, osteitis pubis, or intestinal adhesions. Overall, the operation is low risk and each of these complications is rare. Recurrence rates are consistently low, with most studies citing rates less than 1 % [4–7]. Chronic pain is a more common complication, usually resulting from nerve injury, entrapment, or exposure to the mesh. Depending on how it is defined and measured, rates of chronic pain are generally reported from 5 to 30 % [7], but have even been reported above 50 % [8]. With proper and meticulous technique including three nerve identification, these rates can be decreased to less than 1 %. Infection, bleeding, and ischemic orchitis are low frequency events [7, 9]. Seroma and hematoma typically cause minimal morbidity and are amenable to expectant management. Visceral injury is rare but can occur, especially with sliding or Richter's hernias, or in the case of incarceration or strangulation.

Death is a rare complication of inguinal hernia repair, and occurs mostly in elderly patients, those with severe comorbidities, or those requiring emergency operation. Mortality rate for elective Lichtenstein hernia repair is less than 0.001 %, while emergency repair increases mortality risk to 0.02 % [10]. The setting of emergency repair requiring bowel resection further increases mortality risk [7, 10].

10.8 Modifications and Evolution of the Operation

The Lichtenstein tension-free hernioplasty has undergone several crucial modifications since its inception, all aimed at decreasing recurrence, chronic pain, and other complications. These changes were reported by Dr. Parviz Amid in the 1990s, and were based on key principles identified as being crucial to outcomes [2].

The operation was modified from its original description to account for position and activity-dependent changes in intra-abdominal pressure. With a patient supine, as occurs during the operation, mean intra-abdominal pressure is approximately 8 cm H_2O. When standing upright, this increased to 12 cm H_2O, and may reach as high as 80 cm H_2O during straining or vomiting. Increases in intra-abdominal pressure result in increased tension of the lower abdominal wall, causing an anterior protrusion of the wall structures, especially the transversalis fascia. For a repair to be truly tension-free, the mesh must remain under minimal tension even during this protrusion. For that reason, the operation has been modified from its original form to include a slightly relaxed, tented, or domed shape of the mesh (Fig. 10.1) in order to minimize tension on the suture lines when the abdominal wall experiences increased tension from high intra-abdominal pressure.

The operation has similarly been modified to account for the contraction or shrinkage of mesh over the months and years following the operation. Postoperative mesh shrinkage

of up to 20 % in each dimension was identified and described in the late 1990s, and was determined to be a contributing factor to many cases of recurrence [3, 11]. Accordingly, the mesh preparation was modified to use a larger sheet, now the standard 7.5 × 15 cm, and to allow sufficient overlap of the pubic tubercle and borders of the inguinal floor, allowing it to remain attached and tension free despite shrinkage. An incorrectly or undersized mesh may result in recurrence, nerve entrapment, mesh migration, meshoma, or chronic postoperative pain.

Finally an increased emphasis was placed on identification and protection of the ilioinguinal nerve, iliohypogastric nerve, and genital branch of the genitofemoral nerve during the operation. Initially, both the superior and inferior borders of the mesh were secured using continuous sutures. The Lichtenstein group later determined that risk of injury to the iliohypogastric nerve could be minimized by the use of interrupted sutures along the superior border of the mesh [9]. Furthermore, if the iliohypogastric nerve is noted to be abutting the upper border of the mesh, a slit can be made in the mesh to allow passage of the nerve and minimize contact with edge of the mesh. The previous practice of dissecting the genital nerve and lateral spermatic vessels away from the other cord structures was determined to increase nerve injury as well, and has been abandoned [9].

10.9 Discussion

Success in hernia surgery is contingent upon detailed knowledge of groin anatomy and the ability to choose and execute various hernia repair techniques based on clinical circumstances. An understanding of the advantages, disadvantages, and indications for each technique is crucial. In 2014, the European Hernia Society (EHS) published updated consensus guidelines on the treatment of inguinal hernia in adults [12]. Based on data from the latest randomized controlled trials (RCTs), the use of the Lichtenstein tension-free hernioplasty for repair of primary, unilateral, symptomatic inguinal hernias is supported by the highest level of evidence (1A) and the highest grade of recommendation (A). This technique is considered superior to the Bassini and Shouldice methods of tissue repair [4–7].

The 2014 EHS guideline updates included new data on the efficacy and safety of Lichtenstein repair compared to other mesh-based repairs such as the Prolene Hernia System (PHS) and the Plug and Patch (PP) techniques. Several RCTs) and meta-analyses now exist comparing PHS to Lichtenstein and PP to Lichtenstein with follow-up intervals in the range of 1–4 years. The PP technique was found to have a shorter operative time by 5–10 min, but no significant difference in other outcomes. In comparing PHS and Lichtenstein techniques, there were no differences in regard to recurrence or chronic pain, and no trend emerged for difference in rates of complications between the two methods [12]. PHS involves entry into the pre-peritoneal space, exposing the nerves to additional risk and obliterating planes that can be utilized for repair of recurrent hernia or for prostate cancer resection. The problem of inadequate deployment of these devices, meshoma formation, or mesh migration has led to our preference to avoid these three-dimensional hernia meshes in favor of both anterior and posterior flat mesh-based repairs.

A second assertion of the updated EHS guidelines is that unilateral and bilateral primary inguinal hernia repairs have equivalent recurrence rates and rates of chronic pain whether done via the Lichtenstein technique or by a laparoscopic approach [12]. An important note is that this equivalence is achieved by experienced laparoscopic surgeons, and that the learning curve is substantially longer for the laparoscopic technique. Nonexperts and supervised residents can achieve outcomes comparable to those of experts when performing the Lichtenstein technique for repair of primary inguinal hernias [12], while experts achieve significantly better than nonexperts when performing laparoscopic repair [13]. Though the safety of both Lichtenstein and laparoscopic techniques has been established, there is slightly increased risk of blood vessel or abdominal organ injury with laparoscopy [14]. The ability to perform Lichtenstein repair without the physiologic stresses of general anesthesia or abdominal insufflation is an added benefit. Still, laparoscopic technique is preferred for bilateral hernias and recurrent inguinal hernias after prior anterior repair, as it results in improved postoperative pain, recovery time, and incidence of chronic pain in this cohort [12].

Finally, recent evidence has questioned the need for suture fixation of the mesh to the inguinal floor. The argument against use of suture fixation is that it causes trauma and may lead to hematoma, nerve damage or entrapment, or chronic pain. Alternative methods of mesh fixation include fibrin glue, cyanoacrylate glue, and self-gripping mesh. The highest quality study of fibrin glue has been the Tissucol/Tisseel for Mesh fixation in Lichtenstein hernia repair (TIMELI) trial, a prospective RCT comparing fibrin glue to traditional suture fixation [15]. This study found that fibrin glue was associated with significantly less postoperative pain at 1 and 6 months, and provided a 45 % reduction in chronic symptoms such as numbness, pain, and groin discomfort at 1 year. Cyanoacrylate glue and self-gripping mesh were evaluated in a multicenter RCT published in 2015. This study found that cyanoacrylate glue had no appreciable benefit over suture fixation in terms of postoperative and chronic pain, and that self-gripping mesh demonstrated less pain only on the first postoperative day [16]. Though recurrence rates are equivalent to those of traditional suture fixation [12, 15, 16], evidence is mixed for the benefits of atraumatic fixation methods as a whole.

10.10 Conclusion

The Lichtenstein tension-free hernioplasty has evolved over the past 20 years to produce optimal patient outcomes. The technique has the benefits of being low cost and rapidly learned, and can be performed under local anesthesia. It compares equivalently or favorably to other repair technique methods in terms of recurrence, postoperative pain, chronic pain, and other complications. The Lichtenstein repair remains the operation of choice for repair of initial, unilateral inguinal hernias and in patients wishing to avoid the risks of general anesthesia.

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The Gilbert Bilayer Connected Device (PHS) and Other Mesh Repairs

11

Jerrold Young, Rafael Azuaje, and Arthur I. Gilbert

11.1 Principles of Hernia Repair: The Ideal Technique

The underlying principle for successful inguinal hernia repair is the reduction of the hernia contents behind the musculo-aponeurotic plane of the abdominal wall and prevention of recurrent herniation. This requires complete coverage of the myo-pectineal orifice (MPO) as outlined in a classic treatise by Henri Fruchaud in 1956 and described figuratively as the "triple triangles of the groin" by Gilbert in 2000 [1] (Figs. 11.1 and 11.2). Robert Condon wrote: "The anatomy of the inguinal region is misunderstood by surgeons of all levels of seniority." A complete understanding of the anatomy of the region is critical to the success of the procedure. Because of the complexity of the anatomy and the variable skill of surgeons, there have been many different hernia repair techniques described, seeking the ideal procedure.

There are several components that comprise the ideal hernia repair. Most important are the results of the procedure and patient satisfaction. There should be minimal post-op and long-term pain, minimal disability, a low risk for other side effects and complications, and very few recurrences. The procedure would be performed as an outpatient under local anesthesia, with a short operative time, at low cost. The technique should have a short learning curve, with excellent reproducible results when performed by all general surgeons as well as experts. There is no single repair which has all of these desired features. The suture techniques of Bassini, McVay, and Shouldice had excellent outcomes in their hands, but were difficult to duplicate without the detailed meticulous technique they used and their understanding of the anatomy. Mesh techniques, open and laparoscopic, were developed to improve outcomes. The position of the mesh can be in front of the muscles, or behind them in the preperitoneal position, or, as in the case of a bilayer repair, both in front and behind. While surgeons become familiar with and prefer their own procedures, some techniques provide better results than others, and there has been continued investigation and analysis of new concepts, and new products and techniques as surgeons try to improve outcomes.

11.2 Quality of Life Issues: Improving Outcomes and Patient Satisfaction

In recent years there has been an increased focus on patient satisfaction with health care services in general. Physicians and hospitals are paying more attention to patients, especially since reimbursements are now likely to be influenced by outcomes and satisfaction surveys. With improved surgical technique and the introduction of mesh for hernia repair, recurrence rates have been reduced, but there is increased attention directed to quality of life issues—the ability of the patient to return to activities of daily living, and particularly the problem of significant chronic pain, a consequence reported in up to 6% of patients after hernia surgery. Complaints of somatic, visceral, and neuropathic pain, as well as testicular pain, dysejaculation, and claims of sterility are concerns for patients and surgeons alike. Although mesh has been implicated as a causative factor, similar problems existed because of scarring after suture repairs, as noted by Cunningham in 1996 [2]. Placement of mesh results in immediate strength of the repair. It induces an inflammatory reaction and increased scarring, making the repair stronger as the scar creates a plate of tissue. Depending on where the mesh is placed, nerves, muscle, the

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_11

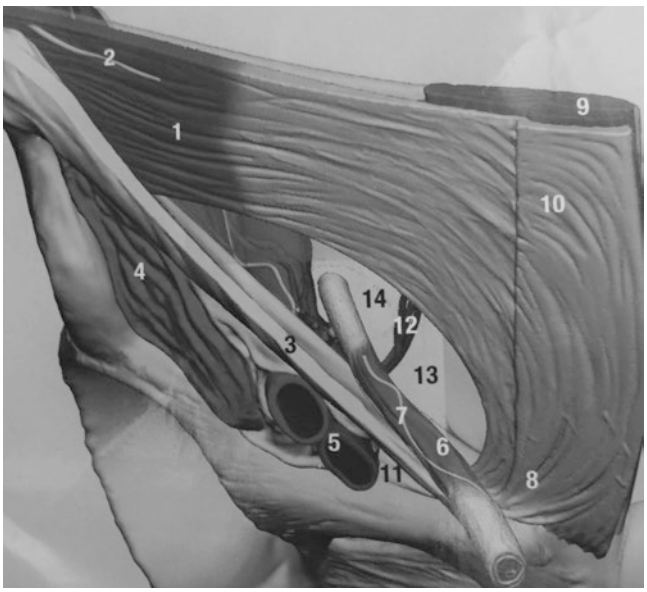

Fig. 11.1 Anterior view. *1*. transversus abdominis, *2*. iliohypogastric n *3*. inguinal ligament, *4*. iliopsoas, *5*. femoral a & v, *6*. spermatic cord, *7*. ilioinguinal n on spermatic cord, *8*. pubic tubercle, *9*. rectus abdominis, *10*. anterior rectus sheath, *11*. femoral canal, *12*. inferior epigastric a & v, *13*. Hesselbach's triangle, *14*. deep inguinal ring

spermatic cord, and all structures in the pre-peritoneal space and the inguinal canal may come in contact with mesh. This is true in open anterior repairs as well as open pre-peritoneal repairs and laparoscopic (LAP) repairs. When an onlay mesh patch is placed on top of the internal oblique, in the area lateral to the internal ring, it unavoidably comes into contact with the ilioinguinal (II) and iliohypogastric (IH) nerves. The nerves are protected by a layer of investing fascia, but wrinkling of the mesh may result in inflammation and scarring involving these structures. The same may be true for structures in the inguinal canal, or in the pre-peritoneal space (PPS) after open or LAP procedures.

Regardless of procedure used, there are technical causes of chronic pain related to the skill and attention to detail of the operating surgeon. There is information in guidelines papers on factors which come into play for all types of hernia repair techniques—hernia surgeons should be familiar with and follow these guidelines in order to reduce the risk of chronic groin pain [3]. Some of these technical recommendations are clear. Nerve trauma should be avoided by identifying and preserving the II, IH, and the genital branch of the genito-femoral (GN) nerves. To reduce the risk of injury, one should not do any blunt dissection or retraction of the nerves to "keep them out of the way" or use direct electro-cautery. If a nerve is thickened or involved with scar from the hernia, or may be in the way of the repair, resection of the nerve and proximal ligation and implantation into the muscle should be considered rather than leaving it exposed to the scarring. Other technical considerations are: limiting dissection along the spermatic cord to reduce scarring that may result in cord dysfunction, obstruction, and possible injury to the nerves and vessels that are present in the adventitia of the vas; avoiding placement of mesh in direct opposition to the vas when possible; using absorbable sutures with air knots and placing sutures in the internal oblique away from visible nerves; dividing a long indirect sac near the internal ring and avoid dissecting along the spermatic cord distally; and avoiding placement of sutures around nerves or into the periosteum of the pubic tubercle (PT). The risk for chronic pain may be inherent in the procedure per se—many valid studies compare different techniques with chronic pain as a measure of outcome.

11.3 "Tailored" Surgery: Selection of Technique

There has been an increased focus by hernia surgeons on choosing the method of groin hernia repair by tailoring the technique according to the needs of the patient, as well as the surgeon's personal skill and experience. Although a single technique can be used to repair all different types and sizes of inguinal hernias, the choice of procedure for an individual patient should be based on the anatomical findings, the type of defect, the needs of the patient, and the expertise of the surgeon with the technique being used. Patients have different anatomy, and their hernia problems differ by size, location, and history of prior repair. Some patients may be more susceptible to recurrence because of age, occupation, activities, body habitus, collagen disorders, and smoking. A small congenital type 1 indirect hernia with an intact floor in a young male individual does not require the same repair as a large type 4 recurrent direct hernia with a complete blow-out of the floor of Hesselbach's triangle. Some techniques which are easier to perform may offer excellent results, while some techniques that are more difficult may actually yield poorer outcomes. Surgeons should have experience with different techniques as part of their armamentarium to be able to perform the best technique for the patient depending on the circumstances.

The surgeon's expertise includes an understanding of anatomy and pathophysiology, training and experience, knowledge of current accepted principles and techniques, surgical ability, and attention to detail. Most hernia repairs are done by surgeons who may do less than 50 hernia repairs per year. A procedure with a longer learning curve requires more experience to become proficient—this may lead less than satisfactory outcomes for patients during the surgeon's learning phase. The success of the procedure will ultimately depend on the skill of the surgeon—both in choosing the correct procedure and in performing it. It should be performed according to the technique described by the originator. While modifications can be made, one should be aware that with major changes from the expert's technique the results may not be as good as the original procedure, and deviation from the standard of care may lead to difficulties if complications ensue.

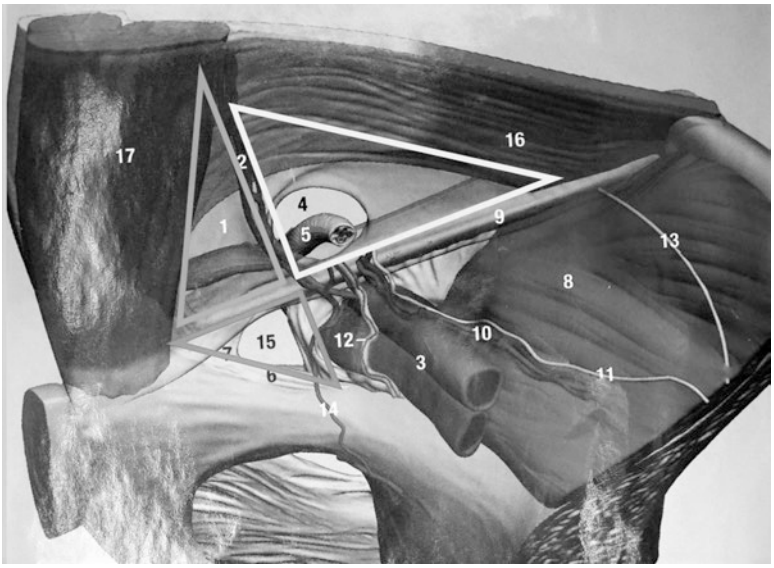

Fig. 11.2 Posterior view. *1*. Hesselbach's triangle,, *2*. inferior epigastric a & v, *3*. external iliac a & v, *4*. deep inguinal ring, *5*. spermatic cord, *6*. Cooper's ligament, *7*. lacunar ligament, *8*. Iliopsoas, *9*. inguinal ligament, *10*. testicular a & v, *11*. genital branch of genitofemoral n, *12*. vas deferens, *13*. lateral femoral cutaneous n, *14*. corona mortis, *15*. femoral canal, *16*. transversus abdominis, *17*. rectus abdominis

11.4 Suture Techniques

Early in his career, Dr. Arthur Gilbert, the developer of the Prolene Hernia System (PHS), became interested in and devoted his energy to the field of "herniology." He wanted to understand the work of earlier surgeons whose original suture techniques required opening the floor of the inguinal canal and suturing the correct layers to close the hernia defect. He visited Padua, the home of Bassini and studied his procedure in detail, realizing the importance of an appreciation of the anatomy in order to suture the correct layers and perform successful repairs. For femoral hernias and large direct inguinal hernias most surgeons used the McVay technique, an anatomic repair which also required opening the floor and approximated the transversus arch to Cooper's ligament. In 1976, Gilbert traveled to Toronto to visit the Shouldice Clinic, where surgeons observed and assisted in hundreds of cases before they were deemed qualified to perform repairs on their own. He was impressed with their meticulous surgical technique, which also required opening the floor of the inguinal canal and the use of multiple layers of wire suture, but more so with the use of local anesthesia and early mobilization of the patient. Gilbert learned that opening the transversalis fascia (TF) was an integral part of these early suture techniques, but equally important, gave the surgeon an excellent view of the PPS. However, because of the lack of experience and the concern about opening the floor, most surgeons were reluctant to delve into the PPS, and were not able to perform the experts' techniques as described. They simplified the procedures by modifying them, and as a consequence, they were not able to duplicate the excellent results of the original techniques. In addition, patients and surgeons alike became frustrated with the pain associated with the tension created by approximating the transversus arch and the internal oblique down to the inguinal ligament, as well as the length of disability, and the high recurrence rates. Surgeons as well as patients were dissatisfied with the results of suture repairs—they began using mesh to reinforce their repairs by placing mesh on the outside of the inguinal canal as an onlay patch, on top of the suture repair, but this still created tension and significant pain, leading to tension-free techniques that are popular today.

11.5 Mesh Repairs

11.5.1 Onlay

In the 1980s, using the concept of bridging the defect recommended by Usher from 20 years earlier, Irving Lichtenstein popularized a tension-free onlay mesh repair, which was easier for the average surgeon to perform than suture repairs [4]. Although Lichtenstein's results were superior to other surgeons using his technique, their outcomes were still better than when they used suture repairs. Dr. Amid has pointed out that surgeons should follow the specific details of the operation as described and not modify it if they expect to duplicate Lichtenstein's results in terms of recurrence and patient satisfaction. Because of its ease of use and the success in all surgeons' hands, the Lichtenstein technique is the most popular hernia technique to which all other procedures are compared.

11.5.2 Mesh Plug Repairs

Early in his career Gilbert used a rolled-up mesh plug as a stopper placed into the pre-peritoneal space through the hernia defect. Rutkow popularized the technique, and added an onlay patch to create the plug and patch repair

[5]. Permanent sutures were used to secure the plug to the transversalis fascia. Unfortunately, the plug was annoyingly palpable and resulted in significant pain, particularly in thin patients, and a significant number of patients had to have the plug removed. There were cases where an improperly fixed plug "migrated" inward and resulted in fixation or erosion of bowel and bladder and fistulas. To alleviate this concern, here have been modifications to make the plug "lighter" or absorbable, but these have not been adopted by many surgeons. There are still surgeons who have expertise and success with this procedure in their hands, but overall, the use of plugs has been decreasing over the past 20 years.

11.5.3 Pre-peritoneal Mesh Repairs

The concept of placing mesh behind the abdominal wall where intra-abdominal force would help hold the mesh in place is based on Pascal's principle. Repairs using the pre-peritoneal or retro-muscular space for mesh placement in abdominal wall hernias were popularized by Rives and Stoppa in France, and Wantz in the USA. The work of Nyhus and Condon using open posterior repairs for inguinal hernias also attracted surgeons' interest. After visiting and operating with Rene Stoppa in Amiens, Gilbert was further convinced that the ideal place to position mesh is in the PPS, between the force of the hernia contents and the defect in the abdominal wall. For inguinal hernias, the point of entry for access to the space can be either through the defect, or via a separate incision above the inguinal canal. In 1992, Gilbert described a suture-less "umbrella plug" repair whereby he folded a 3″×5″ piece of polypropylene mesh, and placed it through the hernia defect into the PPS, between the peritoneum and the TF, and allowed it to unfold and cover the defect from behind. However, the mesh did not always unfold as predicted and did not cover the complete MPO, resulting in some recurrences in different location from the original hernia.

Robert Kugel designed a layered mesh with a plastic ring to maintain its shape, which he inserted it through a separate incision in the muscles above the inguinal canal, using his fingertip to do a blind dissection of the PPS. His personal results were excellent, but for most surgeons the learning curve was too long and the results not reproducible. The layered mesh became encased by scar and "shrunk" in many cases, leaving the MPO vulnerable for recurrence.

11.5.4 Laparoscopic Mesh Repairs

The first LAP operation for an inguinal hernia was performed in 1982—this was a simple ligation of the sac with clips. LAP mesh repairs were performed and then refined in the 1990s. Today the two most common LAP techniques are trans-abdominal pre-peritoneal (TAPP) repair and totally extra-peritoneal (TEP) repair. The biggest hurdle facing surgeons at the beginning of the learning curve is failing to understand the anatomy of the pre-peritoneal space seen through the laparoscope (Fig. 11.2). Although the mesh is placed in the same space as the previously described open pre-peritoneal procedures, the surgeon must have a precise knowledge of the region as viewed from inside to avoid complications. LAP inguinal hernia repair offers advantages in the management of recurrent hernias that were initially repaired via an open approach and in cases of true bilateral hernias. LAP techniques appear to have less acute pain and faster early recovery than open. The disadvantages include a risk for serious complications from undetected bowel injuries and vascular injuries and the longer learning curve results in initial higher recurrence rates compared to open techniques. Also, there is a need for general anesthesia, increased cost, and a longer operation. There has not been adoption of LAP hernia repair as there was for LAP gallbladder surgery and other abdominal procedures. Currently, approximately 15–20 % of inguinal hernia repairs are performed laparoscopically.

11.5.5 Combined Anterior and Posterior Repair: The Prolene Hernia System (PHS)

In 1997, with a personal experience of over 20,000 hernia repairs, Gilbert was asked to design an ideal mesh product for inguinal hernia repair. His goal was to develop a technique that was easy to master, with a short learning curve, and with reproducible results for all surgeons compared to experts. The product had to be suitable for all groin hernias using minimal sutures, and give immediate strength and excellent long-term outcomes with few complications and minimal chronic pain. He felt that the anterior approach was desirable since it could be done under local anesthesia with sedation. With these criteria in mind, he designed the Prolene Hernia System (PHS) (Fig. 11.3)—a bilayer connected polypropylene mesh device with three components: a flat round underlay, an elongated overlay (oval shaped with flat edges), and a 1.5 cm round connector that joins these in the center [6]. The underlay blocks the triple triangles from the rear, while the overlay reinforces the medial and lateral triangles. The connector blocks the hernia defect and secures the two layers so that very few absorbable sutures are required to hold it in place. Three sizes are available—medium, large, and extended. The PHS is symmetrical in the longitudinal axis, and can be used on either the right or left side—it is designed to allow the surgeon to cut and shape the device as needed for the individual patient.

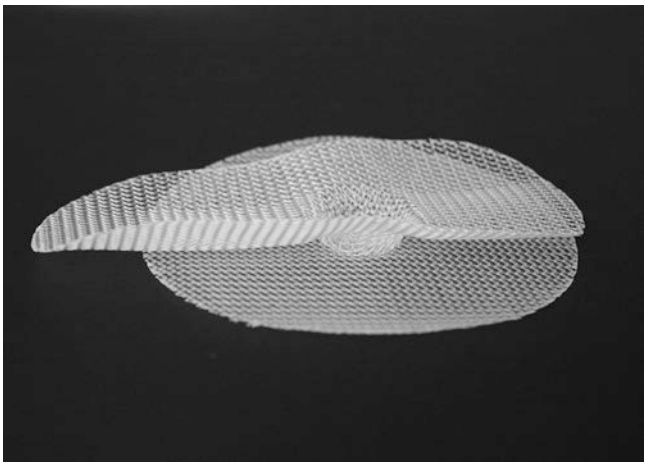

Fig. 11.3 Prolene hernia system

11.6 Technique of Local Anesthesia

The preferred method of anesthesia at the Hernia Institute in the 1970s and 1980s was spinal or epidural—which required a prolonged stay in the recovery room, and an increased incidence of post-op urinary retention. After visiting the Shouldice Clinic, Dr. Gilbert became more familiar with intravenous sedation and local anesthesia. As outpatient procedures became the norm, this method was used to allow earlier post-op recovery and discharge. Currently, 98 % of our inguinal, umbilical, and ventral hernia patients are managed in an ambulatory surgery setting with intravenous sedation using Versed and Propofol administered by anesthesia, and local anesthesia with ¼ % bupivacaine (Marcaine®). A good working relationship with the anesthesiology team is key to this approach. When available, injectable liposomal bupivacaine (Exparel®), a long-acting local anesthetic is injected in all layers just prior to closure, with care not to inject into blood vessels or the femoral nerve, which may cause prolonged numbness in the thigh or even quadriceps weakness that lasts for 2 days. In our experience, patients will be awake in the OR as the procedure finishes, and have very little requirement for oral analgesics in the recovery room. The use of the liposomal bupivacaine has reduced patients' pain scores in the first 2–3 days and also the need for narcotic pain medication.

11.6.1 PHS Insertion Technique

There are four parts to a hernia repair with the PHS:

1. Preparation of the anterior space
2. Posterior space dissection
3. Underlay deployment
4. Application of the overlay

11.7 Preparation of the Anterior Space

Preparation of the anterior space and application of the overlay patch are essentially the same as the technique that is used for a Lichtenstein procedure. Versed® is administered by the anesthesiologist before patients are brought to the operating room. After additional sedation with Propofol®, 20–30 mL of bupivacaine with epinephrine is injected into the dermis and subcutaneous Scarpa's fascia directly in the area of the surgery. Depending on the patient's size, a 4–7 cm skin incision is made 1 cm above and parallel to the inguinal ligament, beginning just lateral to the pubic tubercle towards the anterior superior iliac spine. The superficial epigastric vessels are retracted, or ligated and divided, and Scarpa's fascia opened. The subcutaneous tissues are cleared from the external oblique aponeurosis (EOA), exposing the II nerve and cord structures as they exit the external ring—care is taken not to stretch the nerve. An additional 20 mL of local is injected behind the EOA to "flood" the area, avoiding multiple punctures and direct injection into the nerves which may cause an injury and result in neuropathy.

The EOA is opened in the direction of its fibers through the external ring and the upper medial flap is elevated and separated from the internal oblique muscle and aponeurosis going medially to expose the anterior rectus fascia. The II and IH nerves are identified and left undisturbed within the investing fascia on top of the muscle. They are not dissected or retracted outside the EOA to "protect" them. If a nerve is thickened or involved in scar, or will interfere with the repair, it is resected and ligated proximally with a 3-0 Vicryl® tie, and buried in the muscle. Lateral to the internal ring, the anterior space dissection is carried out for 3–5 cm towards the iliac crest. The infero-lateral flap of the external oblique is then elevated with careful dissection medially towards the lacunar ligament and the PT. In patients with large hernias, reduction of the hernia contents at this juncture may facilitate mobilizing the cord structures. At this time, additional local is be injected along the area of the inguinal ligament and around the anterior rectus fascia above the PT. Usually, after this injection, less sedation is needed for the remainder of the procedure. For recurrent hernias with a lot of scarring, a Doppler is used to help identify the vessels within the cord and also the deep epigastrics. In some cases, to help identify the hernia defects, anesthesia can "lighten" the patient and ask him to cough.

There are two ways to create an arch to accommodate the overlay of the mesh. Our original method was to open the cremasteric muscle lengthwise as is done with the Shouldice technique, allowing direct visualization of the transparent, relatively avascular internal spermatic fascia that surrounds the vas deferens. The spermatic cord and the testicular vessels are elevated with a Penrose and the arch is opened between these structures and the lesser cord, leaving the lateral cremasteric muscle with the vessels and the genital

nerve attached to the floor. These lesser cord structures are not divided as they are in the Shouldice technique, but lay attached to the shelving edge of the inguinal ligament and exit behind the medial part of the overlay. This method requires more dissection along the vas which may cause more scarring or leave the cord in closer contact with the mesh. Our current preferred technique to create the arch is to elevate the entire cord structures off the floor beginning near the pubic tubercle, and encircle them with a ¼ "Penrose drain." The medial cremasteric muscle can be divided as needed. Careful dissection is necessary to limit trauma to the genital branch of the genito-femoral nerve and the vessels which lay within the lateral cremasteric muscle. This preferred method of elevating the entire cord structures favors limiting dissection of the vas deferens and testicular vessels within the internal spermatic fascia.

The presence of a femoral hernia is ruled out by incising the cribriform fascia just below the inguinal ligament at the junction of the thigh. The posterior wall over Hesselbach's triangle is inspected for a direct hernia or weakness. If there is a direct hernia, a femoral hernia can be identified and reduced internally after opening the floor. To check for an indirect hernia, the cremasteric muscle is opened 1–2 cm from internal ring, avoiding the ilio-inguinal nerve, facilitating inspection for a patent processus vaginalis, or a true indirect hernia. If an indirect sac is identified and its distal part is relatively short within the inguinal canal and not firmly adherent to the cord, the intact sac is dissected from the cord up to its true neck at the level of the transversalis fascia, where it is either ligated and divided or inverted. If the distal portion extends beyond the external ring or into the scrotum, the sac is divided 1–2 cm from its neck, dissected to the shoulder of the sac at the level of the transversalis fascia, and the proximal end is ligated. The distal part of the sac is left in place, thereby limiting dissection along the vas and vessels. Sliding hernias must be identified—opening the sac away from the bowel may help to appreciate the anatomy and the dissection, but the sac must be closed as the hernia is inverted. Herniating lipomas can be ligated and transected, or inverted. Interstitial fat that may have internal spermatic vessels associated with it should be left intact—dissection can lead to post-op inflammation of the cord and pain—it can also result in increased resistance to venous outflow from the testicle.

11.8 Direct Hernias: Posterior Space Dissection

The posterior space must be dissected prior to insertion of the mesh in order to properly deploy the underlay. In no case is it possible to successfully create the space by simply forcing the device in as a ramrod without a careful dissection. This would leave the mesh as a wad or plug, rather than a fully expanded patch as it is intended to be which may lead to internal adhesions. The dissection is done through the hernia defect—an appreciation of the anatomy is important. There are two layers of TF—the anterior layer passes in front of the epigastric vessels, and the posterior layer behind them. The floor of the medial triangle is opened by a circular incision through both layers of the TF and the edges are grasped with hemostats. As the deep layer of the TF is opened the true yellow pre-peritoneal fat pushes its way out. To allow the mesh to be deployed, the pre-peritoneal fat and the sac is pushed inward and the space actuated using a ray-tec sponge—the sponge's traction helps to separate the pre-peritoneal fat from the undersurface of the transversalis fascia. The space behind the MPO is conical, not flat. In the superior direction behind the transversus abdominus muscle and medially, behind the pubic tubercle, the space is relatively flat. On the inferior side, the part of the MPO deep to the inguinal ligament curves posterior to pass behind the iliopubic tract and cooper's ligament medially, the femoral lymphatics, and iliac vein and artery in the center portion, and the spermatic cord and testicular vessels laterally. This dissection goes laterally behind the deep epigastric vessels. If there is an indirect defect or pantaloon hernia, the direct space is communicated with the lateral space. If there is no indirect defect, we limit this lateral pre-peritoneal dissection to just behind the epigastrics, and use the overlay portion to protect the floor lateral to the internal ring, thereby avoiding dissection of the pre-peritoneal vessels and cord.

11.9 Preparation and Insertion of the PHS Underlay

The PHS overlay tails are "triple-folded" inward along its length, then both ends pulled up and grasped with a sponge forceps near the connector, creating an appearance of a "taco" in the underlay (Fig. 11.4). This allows easy deployment and visualization of the underlay after insertion. Since the PPS is conical, if the full underlay is inserted, it will have some radial folds to accommodate the conical shape of the space. The underlay is therefore trimmed into oval shape by cutting some of the edge away allowing it to fit into the space created by the dissection and minimize folding (Fig. 11.5). The entire device is inserted by aligning the overlay parallel to the inguinal ligament until the perimeter of the underlay is under the floor. For direct hernias, the device is inserted posteriorly, straight down at a right angle through the opening. As the overlay component is gently extracted, the underlay is deployed by separating the perimeter from the connector. The edges of the underlay are placed medially behind the pubic tubercle, superiorly behind the transversalis fascia, laterally behind the epigastrics, and inferiorly covering Cooper's ligament, where it will protect the femoral canal (Fig. 11.6). For inguinal hernias, sutures are not necessary in the underlay—the intra-abdominal pressure pushes the mesh

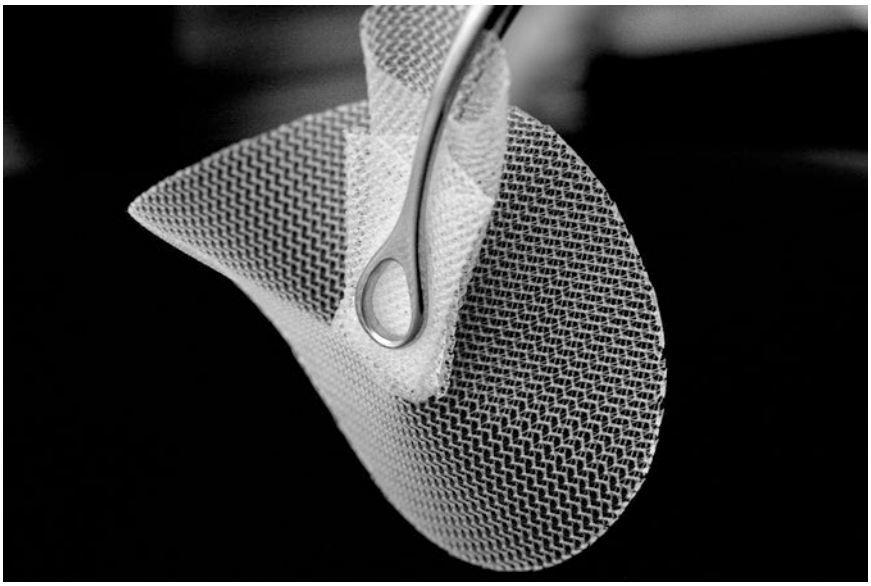

Fig. 11.4 Triple fold

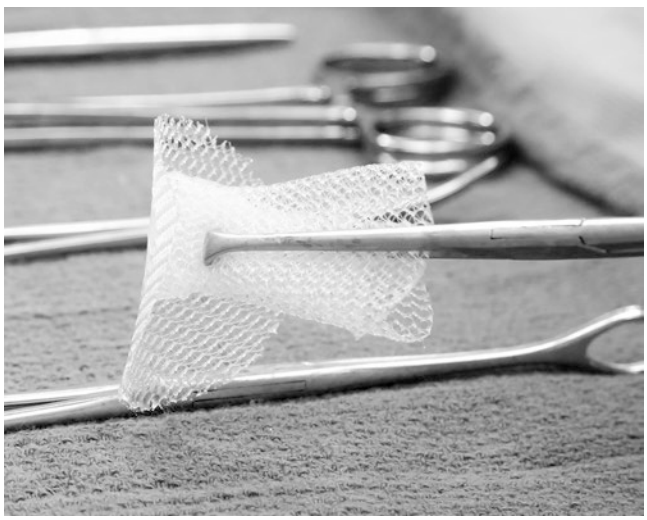

Fig. 11.5 Trimmed mesh

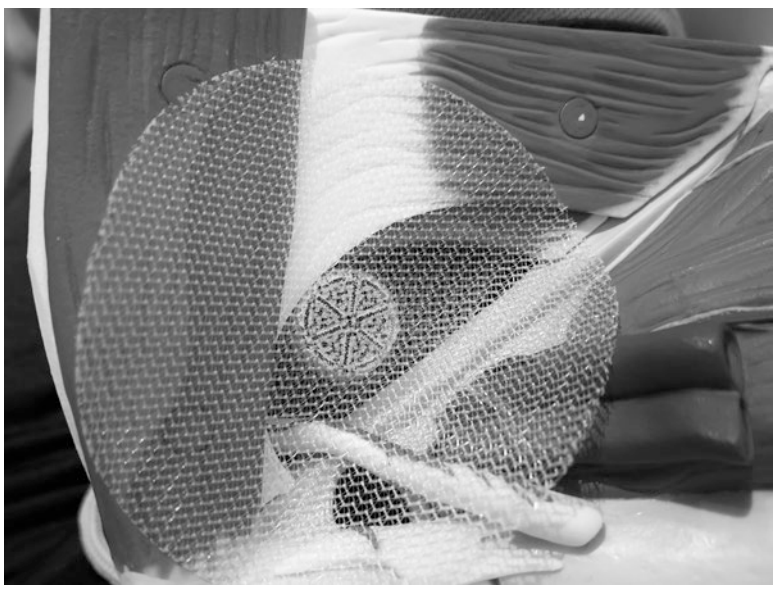

Fig. 11.6 Posterior view—mesh covering MPO

against the floor and holds it in place. If there is a femoral hernia, a single 2-0 Prolene suture can be placed to secure the underlay to Cooper's ligament. This may be easier if done prior to inserting the device. The opening in the floor of the medial triangle is closed snugly around the connector with one or two figure-of-eight absorbable sutures. If the opening for the connector is too tight and "constricts" the connector, it may be difficult to deploy the overlay.

11.10 Small Indirect Hernias

For small indirect hernias with a 1 fingerbreadth opening (Gilbert type 1) the preparation of the sac is completed during the anterior space dissection. Originally, the internal ring was opened and the device inserted through the internal ring—this required dissection along the cord and vessels. Our current approach is to deploy the device through a small opening in the floor just medial to the epigastric vessels, and the indirect space can be covered by the overlay. The device can then be secured by one or two absorbable sutures rather than permanent sutures along the shelving edge of the inguinal ligament.

11.11 Large Indirect Hernias

For medium or larger indirect hernias (Gilbert type 2 or 3), regardless of how the distal portion of the sac is treated, the peritoneal sac that resides within the deep inguinal ring must be carefully dissected from the cord and from the investing fibers of the transversalis fascia at the musculofascial threshold of the deep ring and dissected away from the undersurface of the transversus abdominus at the edges of the hernia defect. There may be some scarring in this area—care is taken not to open the sac as it is separated from the cord structures. The "shoulders" of the sac must be separated from the transversalis fascia to create the space for the underlay. The sac is then invaginated through the internal ring with a forceps, and the surgeon's forefinger is inserted through the internal ring and placed laterally behind the transversus abdominus, adjacent to the forceps. The forceps are removed, and the forefinger left in place, pulling up gently on the muscle as an open dry 4×4 sponge is passed under the forefinger to develop the pre-peritoneal space. This helps to separate the hernia contents from the elements of the cord. The dissection through the internal ring is done superiorly and laterally behind the transversus abdominus muscle, inferiorly between the hernia contents and the cord contents, and medially behind the deep epigastric vessels. An army-navy retractor placed behind the epigastric vessels or an Allis clamp around them facilitates the medial dissection which extends under the floor of Hesselbach's triangle to behind pubic tubercle and inferiorly behind Cooper's ligament. This space is created easily with the open 4×4 sponge, but it is also possible to do it with the index finger, or forceps and cautery. The sponge is temporarily left in place to maintain the passageway and removed just prior to inserting the mesh. For a combined direct and indirect (pantaloon) hernias, after the space is dissected both medially and laterally, a Penrose drain is placed around the epigastric vessels, or the vessels can be ligated and divided and the two spaces are joined.

11.12 Deployment of the Underlay: Indirect Hernias

With the surgeon's forefinger placed behind the transversus abdominis laterally, the muscle is gently elevated as the device is slid down the medial side of the finger into the pre-peritoneal space—the direction of insertion is medial and superior, aiming just beneath the umbilicus. The underlay perimeter is placed behind the transversus abdominis muscle superiorly and laterally, where it lies in the horizontal plane, while medially it is deployed behind the epigastric vessels and the pubic tubercle. Inferiorly the perimeter is directed more posterior, covering the femoral canal and the tissues behind Cooper's ligament, and it separates the hernia contents from the cord contents. Typically, when repairing an indirect hernia, unless it is a large type III defect, the internal ring is not tightened around the connector—the obliqueness of the internal ring offers additional protection to the underlay patch. Effectiveness of the underlay patch alone can be demonstrated by having the patient cough and perform a Valsalva maneuver before the overlay is deployed. After the operation, when the patient stands, intra-abdominal pressure flattens the underlay is against the abdominal wall between the peritoneum and the transversus abdominis.

11.13 Application of the PHS Overlay

The overlay component is extracted to the level of the internal oblique using the sponge stick and the tips of the overlay are simultaneously pulled apart to a flat shape. The lateral flap is temporarily "parked" behind the external oblique while the upper edge of the overlay is flattened up to the medial end which is positioned 1–2 cm over the pubic tubercle. A 2-0 Vicryl® suture secures the medial edge of the overlay to the aponeurosis of the rectus muscle (not into the periosteum) superior and medial to the pubic tubercle. An inferior or lat-

Fig. 11.7 Mesh over MPO—slit for cord

eral slit is made in the overlay large enough to comfortably accommodate the spermatic cord and its contents without compression. One option is a slit with a "T" in the inferior edge of the overlay, close to the connector—the center of the slit is aligned with mid-portion of the cord contents. The cord structures are passed through the slit, and the edges of the slit are then sutured to the shelving edge of the inguinal ligament (Fig. 11.7). A second option especially for direct hernias is a lateral slit with a keyhole cut to accommodate the cord. The tails are sutured together with a 2-0 Vicryl and laid down flat 2 cm over the internal oblique laterally—it is not necessary to suture the lateral flap that lies flat in the anterior space and is well covered by the EOA. Additional 2-0 Vicryl® sutures can be placed—one at the superior edge of the mesh to the internal oblique using an air knot and avoiding the iliohypogastric nerve, and one at the inferior edge of the mesh to the mid-portion of shelving edge of the inguinal ligament. Permanent sutures are not used unless the hernia is very large, or in some cases of recurrent hernias. The underlay component is there to prevent herniation in this area. The overlay should be trimmed if any excess is noted where the mesh folds on itself, usually on the inferior edge of the lateral and medial flaps. The spermatic cord and ilioinguinal nerve are replaced over the medial part of the onlay patch. All layers are irrigated with Bacitracin®–Polymyxin® solution. The external oblique is closed with 3-0 continuous Vicryl® suture, re-creating the external ring, being careful not to make it too tight, anticipating that some swelling of the cord structures will occur. The subcutaneous layer is closed with 3-0 Vicryl® sutures, and the skin with a subcuticular 3-0 Vicryl Rapide® suture. The skin is covered with Dermabond® or Steristrips®.

11.14 Femoral Hernias

Femoral hernias which are diagnosed pre-op in the office are managed by performing an ultrasound with Valsalva. If an inguinal hernia is present also, the repair with PHS is done by deploying the mesh medially—the femoral component is reduced into the direct position converting it into a direct hernia. The underlay is sutured to Cooper's ligament near the femoral canal. If there is no inguinal hernia, the repair is done below the inguinal ligament. The femoral hernia is reduced, a sponge placed into the femoral canal from below, and a medium PHS is placed through the opening after trimming the underlay. Prolene sutures (2-0) are used to secure the connector to the rim of the defect anteriorly, medially, and posteriorly near Coopers' ligament. Sutures are not placed laterally since the femoral vein is there. The overlay is then cut off. This approach avoids any dissection in the inguinal canal where cord structures and nerves are present.

11.15 Post-op Care: Instructions

Patients go directly to the outpatient discharge area, or to the recovery room if they are too sleepy or need monitoring. Most patients leave the ambulatory center 45 min–1 h after the operation, after they have voided. An ice bag is applied

immediately, and is used for 2 days. Patients are told to expect mild to moderate pain, sometimes going down to the testicle, for 1–2 days, after which the pain diminishes. They may experience some burning or shooting pain for a few weeks after the surgery. They are encouraged to ambulate often (if not light-headed on the day of surgery) and to resume all activities that are not uncomfortable. All patients are given a prescription for an anti-inflammatory to be taken regularly for 5–7 days after surgery, and a narcotic analgesic such as oxycodone and acetaminophen to use as needed. Patients are told to expect testicular swelling and some ecchymosis around the incision and into the scrotum which will last for several days. They are told that swelling under the incision forms a firm wound healing ridge that lasts 6–8 weeks. As the healing ridge becomes more prominent, it narrows and rises before it flattens. Milk of magnesia is recommended if the patient has not had a bowel movement by the next day. Out-of-town patients are seen 1 day post-op and may drive or fly home. Local patients are seen 7–14 days for a wound check. The surgeon speaks with patients who call with complaints of pain beyond 1–2 weeks to re-assure them or have the patient come in for an examination or other recommendations.

11.16 Results

Recurrence: From April 1998 through December 2015, five surgeons performed more than 12,000 PHS groin hernia repairs at the Hernia Institute of Florida. Male patients accounted for 93 %. Simultaneous bilateral repairs were done in 10 % of the patients. Fifteen percent of the repairs were for recurrences of one to six times and femoral hernias were found accounted for 2 %. All sizes of PHS were used, although our preference is large or extended—the medium size is used for femoral hernias and in some females. All patients not covered by workers' compensation were recalled annually by postcard for cost-free follow-up examination, but only 20 % of the patients complied by calling to tell us that their hernia repairs were fine but they did not want to take time to come for an examination. All patients, including those covered under workers' compensation, were instructed to return if they suspected a recurrence or were bothered by significant discomfort. To the best of our knowledge, the total number of recurrences in our series of 12,000 patients since April 1998 is 18. Even if we assume there are three times as many recurrences that we are not aware of, our percentage is below one-half percent. Seven of our recurrences were in the medial triangle. There were three femoral recurrences, one that was missed and two that developed following repair of type 2 indirect hernias. Eight recurrences were at the internal ring—all after indirect hernia repairs. Two were in patients that did heavy labor, one in a weight-lifter. One patient who had a repair of a large type 3 recurrent hernia developed severe bronchitis that lasted for 6 weeks 4 months after surgery and re-recurred. He was referred for a LAP repair of the second recurrence. Because of its ease of use and short learning curve, general surgeons trained in the PHS technique by our surgeons have been able to reproduce our results. In 2004, in a report of 21,791 PHS repairs by 42 trained general surgeons, there were only 28 recurrences, for a failure rate of 0.0013 [7].

Infection: Infection requiring mesh removal occurred in four patients. In one case with findings suspicious for a gas-forming organism, the mesh was removed immediately. In another, infection presented 3 weeks after surgery in a patient who had a history of lymphoma treated with chemotherapy. Cultures grew out a rare *Mycobacterium fortuitum* organism. The prosthesis was removed and a suture repair was done with a mono-filament absorbable suture. After 2 years of follow-up there has been no recurrence of the hernia or the infection. Another patient developed a MRSA infection that presented 2 weeks post-op—the mesh was removed without hesitation and a suture repair done with absorbable sutures—the wound was let open with a wound VAC. At 2 years there has been no recurrence of the infection or the hernia. Follow-up studies with nasal swabs indicated he was a MRSA carrier, but had no clinical history. Superficial wound drainage was handled with dressing as needed in 35 patients. Most of these were seromas with negative cultures—in three patients cultures were positive for *Staph aureus*—all healed with daily dressings, showering, and antibiotics. In all of these cases, the mesh did not have to be removed to get complete wound healing. None of the repairs that involved infection failed. Hematoma that required opening the wound occurred in five patients, one done in the operating room and four in the office. All healed without any infection. One patient developed an atrophic testicle following repair for a second-time recurrent hernia.

Post-op pain—chronic pain: Post-op pain is moderate to severe for 2 days after surgery. Thirty percent of patients used only acetaminophen for post-op pain. The remainder used a prescribed narcotic, on the average taking four tablets over 2 days. Ninety-five percent used no analgesics after the first 2 days. When injectable liposomal bupivacaine (Exparel®) was used, patients' pain scores in the first 2–3 days were reduced, and there was less need for narcotic pain medication. Most patients with ongoing discomfort were given naproxen. Patients who experienced some degree of testicular pain from epididymitis were treated with sitz baths, naproxen, and Cipro®—all reported that the pain subsided in 3–6 weeks. Three percent of workers had ongoing pain that lasted between 3 and 6 months. Ninety patients had chronic

pain, i.e., pain more than 6 months after surgery. Ten patients, including five workers, had significant chronic postoperative pain lasting longer than 6 months, and were referred for pain management. Two patients had a triple neurectomy and mesh removal by us, and one other patient had the mesh removed by a surgeon elsewhere.

Several studies comparing PHS to other repairs including Lichtenstein have shown that the PHS results are comparable to or better than other repairs in terms of cost, OR time, reproducibility and ease of repair, low rate of recurrence, and decreased chronic pain. A study by Nienhuijs showed no significant differences in chronic pain, mesh sensation, and recurrences with a median follow-up of 8 years [8]. A multicenter, multination trial with 2-year follow-up comparing Lichtenstein, plug and patch, and PHS repairs in 1341 patients was reported by Heniford and others in 2015 [9]. Operative time was significantly less for PHS than for Lichtenstein. Recurrence, seroma, and infection rates were equivalent for all groups. At 1-month, PHS had less pain, mesh sensation, and activity limitation compared to the Lichtenstein. At 2 years, PHS had significantly less pain and mesh sensation than Lichtenstein. They concluded that PHS has showed superior 1-month and 2-year QOL outcomes compared to Lichtenstein and plug and patch repairs.

11.17 Other Mesh Products

With some of the focus on the use of lighter weight meshes, the Ultrapro Hernia System®, or UHS, a bilayer connected device made out of Ultrapro®, was developed. This has an overlay of a soft lightweight partially absorbable mesh, and an underlay that is "stiffened" by an absorbable element that dissolves over several days. Some has reported success with it, but we found the stiff underlay difficult to deploy in comparison to the PHS. Other products have been developed such as light weight plugs, and partially or completely absorbable plugs, to try to reduce the bulk of the permanent component, to reduce scarring and hopefully, the amount of post-operative pain. Other concepts such as the use of glue or a self-gripping mesh without sutures, or a light weight macro-porous mesh may reduce the incidence of chronic pain, but these repairs may not be as strong—they may not be ideal for large hernias with a higher risk for recurrence. Preliminary reports indicate that some of these products have sufficient basis to begin implementing them, but further evidence-based studies are needed to document the efficacy of these concepts.

11.18 Conclusions

The low failure rate of the PHS device is due to complete coverage of the MPO. The underlay component covers the existing defect and the MPO from behind, while the overlay adds the protection to prevent recurrences—the connector stabilizes the other two components adding to its strength. The low recurrence rates in the hands of general surgeons using PHS are comparable to those of experts, and the incidence of post-op pain is equal to or less than with other suture and mesh techniques. With its high success rate and ease of use for all surgeons, the PHS will remain an important hernia repair technique in the armamentarium of future generations of surgeons.

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Laparoscopic TAPP Repair

12

Jacob A. Greenberg

12.1 Introduction

Inguinal hernias are one of the most common surgical maladies suffered worldwide. While not all hernias require repair, the overwhelming majority of patients will develop symptoms from their hernia which will lead them to seek surgical intervention [1]. In the United States alone, nearly 800,000 inguinal hernia repairs are performed annually [2]. There are a variety of surgical techniques available for the repair of inguinal hernias, each with their own set of benefits and challenges. In this chapter we will review the laparoscopic transabdominal preperitoneal (TAPP) approach to the repair of inguinal hernias.

12.2 History

The origin of the TAPP repair dates back to the early 1990s and was born out of the developing interest in preperitoneal approaches to the repair of inguinal hernias. In Europe, Rives and Stoppa developed the concept of preperitoneal reinforcement of the myopectineal orifice using prosthetic mesh [3]. Over the next decade as laparoscopic approaches to general surgical problems began to take off, some early laparoscopic enthusiasts began to take interest in the laparoscopic repair of inguinal hernias. Arregui and colleagues published their early experience of a laparoscopic transabdominal approach to inguinal hernias with good results [4]. In Canada and Europe, early adopters of the TAPP approach also began publishing their results with excellent outcomes in the early to mid-1990s [5–8].

Leibl and colleagues compared the TAPP approach ($n=48$) to the Shouldice repair ($n=43$) and found a decrease in postoperative pain and earlier return to normal activities in the TAPP group. At 16 months of follow-up there were no recurrences noted in either group. At 6 years follow-up, the rates of recurrence were 2 % in the TAPP group (1/48) and 5 % in the Shouldice group (2/43) [9].

While TAPP is now a widely accepted repair technique, laparoscopy is utilized in a minority of inguinal hernia repairs worldwide. Trevisonno and colleagues found that laparoscopy was used in only 8 % of all laparoscopic inguinal hernia repairs and only 28 % of bilateral inguinal hernia repairs where its indication is more widely accepted [10]. The underutilization of laparoscopic inguinal hernia repair is multifactorial. Seventy percent of surveyed surgeons who don't perform laparoscopic inguinal hernia repair state that they consider the benefits of laparoscopy to be minimal and 59 % feel that they lack the requisite training to perform the procedure [11].

12.3 Preoperative Considerations

All patients are seen and evaluated in clinic prior to surgical intervention. An in-depth history and physical exam is performed paying significant attention to any previous groin surgeries or prostatic interventions. Both groins are inspected for the presence of hernias with manual examination. In patients with a history suspicious for inguinal hernia but no physical exam findings, an ultrasound is obtained to assess for occult hernias [12]. Patients with asymptomatic or minimally symptomatic hernias are advised that a watchful waiting approach is safe and may be appropriate but is likely to fail with time [1, 13]. Those with symptomatic hernias are offered repair and counseled extensively about the perioperative and long-term risks of repair including bleeding, infection, recurrence, and inguinodynia.

While it is generally accepted that the laparoscopic approach offers significant benefits with respect to recovery compared to open repair for bilateral inguinal hernias, there remains significant debate regarding the appropriate surgical approach for unilateral inguinal hernias. Neumayer and col-

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_12

leagues found significantly higher rates of recurrence associated with the laparoscopic approach compared to open repairs of unilateral inguinal hernias and argued that the open approach should remain the standard of care [14]. Several other randomized controlled trials have found similar results between open and laparoscopic repairs [15, 16]. The European Hernia Society has also written guidelines on the treatment of inguinal hernia and has recommended that unilateral inguinal hernias be repaired with an endoscopic approach if significant expertise with the procedure is available. If not, then a Lichtenstein tension-free open repair should be performed [17]. In the end, surgeons should offer the repair they feel most comfortable performing routinely as this will likely be associated with the best surgical outcomes. Patients with a history of previous repairs utilizing the preperitoneal space, anterior spinal surgery, significant prior pelvic trauma, cystectomy, or prostatectomy are offered open anterior repairs as the preperitoneal plane is generally obliterated in these patients.

12.4 Operative Technique

The patient is laid supine on the operating room table with both arms tucked. In cases of unilateral inguinal hernias, the contralateral arm may be tucked with the ipsilateral arm left at 90°. However, if an occult hernia is found on the contralateral side intraoperatively it will make the repair of the contralateral side more difficult, thus we prefer to routinely tuck both sides. All patients must void prior to moving to the operating room and thus we do not routinely place Foley catheters. Patients with a history of urinary retention or benign prostatic hypertrophy will undergo placement of a Foley catheter for bladder decompression once they have been placed under general anesthesia. Sequential compression devices are placed on both lower extremities for prophylaxis against deep venous thrombosis but due to the relatively short length of case time subcutaneous heparin is not administered. Hair on the abdomen is clipped for a relatively small area surrounding the umbilicus, but the groins are not routinely clipped of hair. The abdomen is then prepped and draped.

Pneumoperitoneum is obtained using a Hasson open technique via a 1.2 cm infraumbilical incision. A 12 mm Hasson port is placed and secured to the anterior fascia using an 0 vicryl suture which will be used for fascial closure at the completion of the case. If there is a concomitant umbilical hernia present then the defect is utilized for port placement and a formal repair is performed utilizing 0 PDS suture at the completion of the case. Larger umbilical defects (greater than 2 cm) will also be reinforced with mesh during the repair. The abdomen is insufflated to a pressure of 15 mmHg and the patient is then placed in steep Trendelenburg in order to improve visualization of the groin. Both groins are then inspected for the presence or absence of hernias. Two additional 5 mm ports are then placed at the level of the umbilicus in the right and left midclavicular lines. A 30° 5 mm laparoscope is then moved to the 5 mm port on the ipsilateral side of the hernia so that the operating surgeon can improve their ergonomics by utilizing the contralateral 5 mm port and the umbilical port for the procedure.

A generous peritoneal incision is then made from the medial umbilical fold out laterally cephalad to the myopectineal orifice. As the incision is carried laterally it can be arced posteriorly towards the psoas muscle. An example of the peritoneal incision is shown in Fig. 12.1. The dissection then begins laterally on the inferior peritoneal flap. Ample working space is created by mobilizing the peritoneum off of the preperitoneal fat. The peritoneum is grasped through the instrument in the lateral port and retracted towards the contralateral side. The instrument in the umbilical port is used to push the preperitoneal fat laterally off the underlying peritoneum. In male patients, the gonadal vessels will be the first structures of importance that are identified and these are pushed laterally off the peritoneum utilizing the umbilical port. As the dissection is carried towards the internal ring the vas deferens will be identified medial to the gonadal vessels (Fig. 12.2). The vas is also mobilized off the peritoneum and hernia sac and pushed laterally (Fig. 12.3). Once both the vas deferens and the gonadal vessels are mobilized off the peritoneum we transiently stop our dissection of the indirect space and move to the medial dissection. In female patients, the round ligament of the uterus is generally quite adherent to the peritoneum and attempts to mobilize the round ligament off the peritoneum will generally result in a tear of the

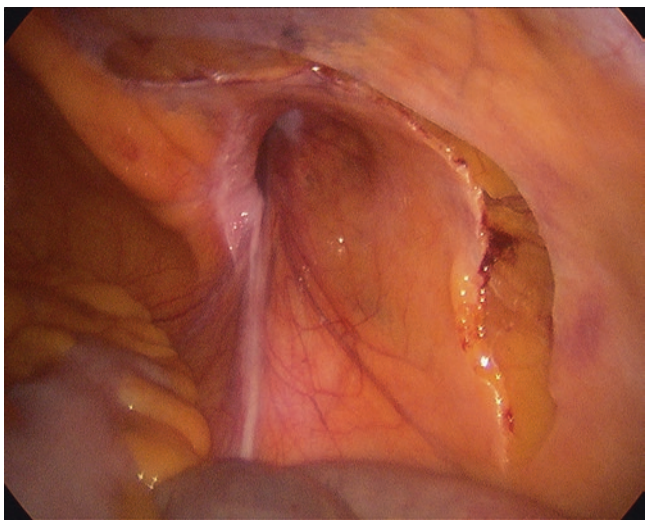

Fig. 12.1 Peritoneal incision for a right TAPP repair (Figure reprinted with permission from Springer Publishing, Inc.)

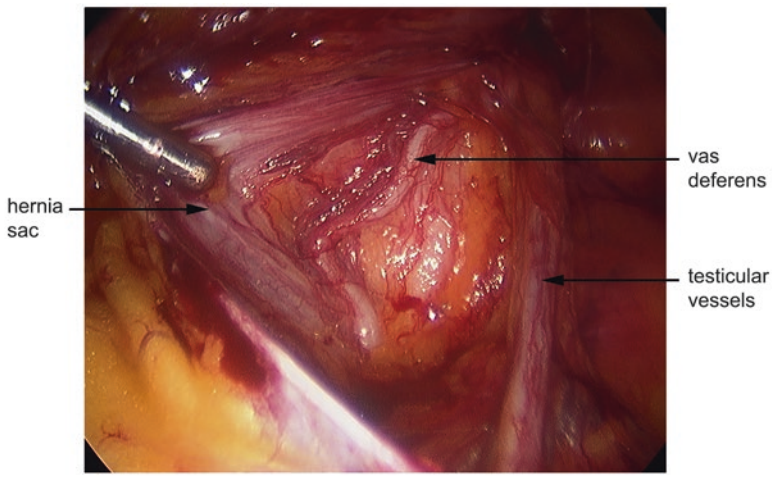

Fig. 12.2 Testicular vessels are pushed laterally off the hernia sac (Figure reprinted with permission from Springer Publishing, Inc.)

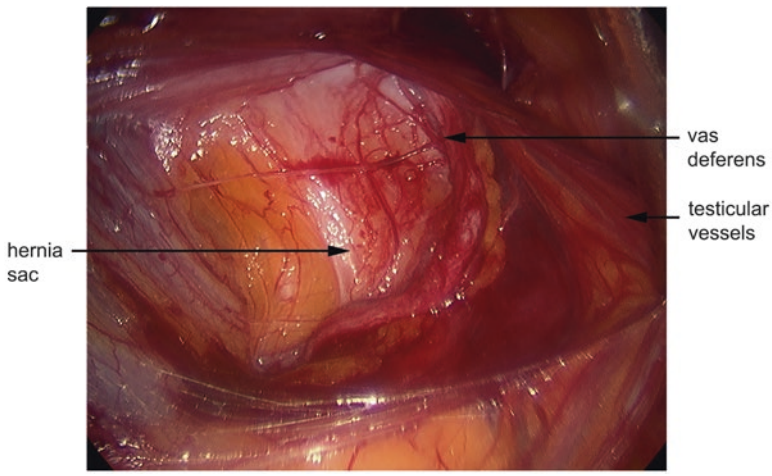

Fig. 12.3 Vas deferens is pushed laterally off the hernia sac (Figure reprinted with permission from Springer Publishing, Inc.)

peritoneum. Thus, we prefer to clip and divide the round ligament in nearly all patients.

We then move to the direct space in order to mobilize the bladder in the space of Retzius. The inferior peritoneal flap is grasped with the lateral instrument medial to the inferior epigastric vessels. The flap is retracted posteriorly and the medial instrument is used to bluntly spread through the preperitoneal fat until the rectus abdominis muscle is identified. Both instruments are then placed through this area towards the bony pelvis. The lateral instrument is used to mobilize the bladder posteriorly and is held in place while the medial instrument sweeps the bladder off the bony pelvis towards the contralateral side. These two maneuvers should allow for excellent bladder mobilization and visualization of Cooper's ligament on both the ipsilateral and contralateral side (Fig. 12.4).

At this point in the procedure all three potential hernia spaces of the myopectineal orifice are now ready for exploration. For indirect hernias, the sac is grasped with the lateral instrument and retracted medially. The instrument through the umbilical port is then used to push the vas deferens and gonadal vessels laterally off the hernia sac until the sac is completely reduced (Fig. 12.5). In large inguinoscrotal hernias, the hernia sac can be divided leaving the distal portion open in the scrotum and the more proximal portion will be closed during reperitonealization at the end of the procedure. The indirect space should always be assessed for the presence of cord lipomas as failure to reduce a cord lipoma is a common cause of recurrence following laparoscopic repair of inguinal hernias. For direct hernias, the transversalis fascia is identified as an inverted white structure medial to the epigastric vessels. The transversalis is mobilized anteriorly off the underlying preperitoneal fat until Cooper's ligament and the epigastric vessels are easily identified. Lastly, the femoral space is explored between the iliopubic tract and Cooper's ligament medial to the iliac vessels. Any preperitoneal fat herniating through this space is reduced. Once all of the myopectineal orifice has been explored and all hernia contents and sacs have been reduced, a groove is created between the peritoneum and bladder medially and the psoas, gonadal vessels, vas deferens, iliac vessels, and bony pelvis laterally to ensure adequate inferior mesh coverage. Finally,

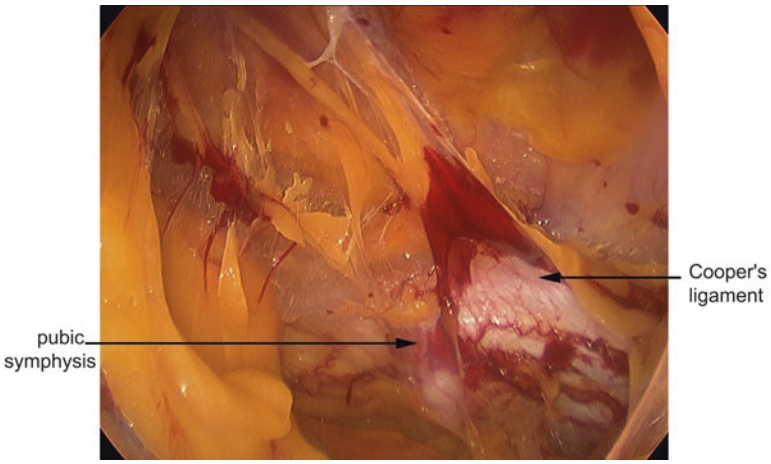

Fig. 12.4 Full bladder mobilization to visualize Cooper's ligaments bilaterally (Figure reprinted with permission from Springer Publishing, Inc.)

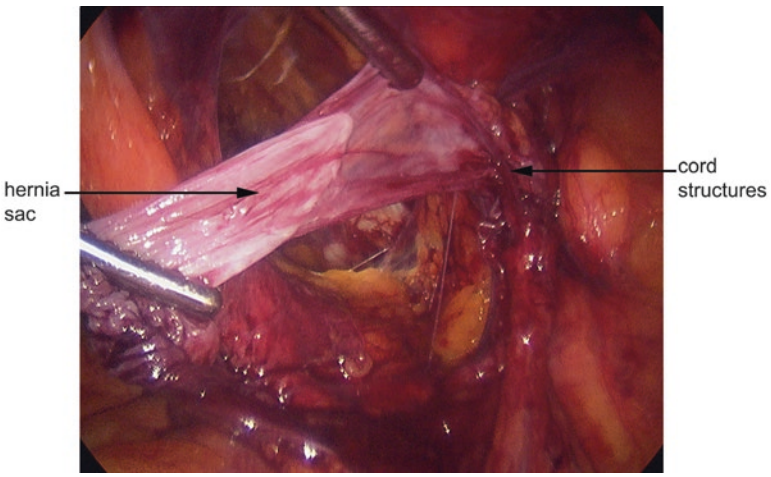

Fig. 12.5 Complete reduction of an indirect hernia sac (Figure reprinted with permission from Springer Publishing, Inc.)

the cephalad peritoneal flap is mobilized so that it hangs down off the abdominal wall in order to facilitate peritoneal closure following mesh placement. A picture of the complete dissection is shown in Fig. 12.6.

Mesh is then brought into the field through the umbilical port and positioned to cover the entire myopectineal orifice with wide overlap in all directions (Fig. 12.7). There are a wide variety of mesh options available for use. As the mesh will reside in the preperitoneal space barrier coated meshes are not necessary. There are also a variety of options for mesh fixation including self-gripping meshes, fibrin glue, permanent or absorbable tack fixation, or no fixation whatsoever. If tack fixation is planned care must be taken not to place any tacks into the major vascular structures within the field or the lateral femoral cutaneous and genitofemoral nerves which run through the field inferior to the iliopubic tract laterally. Care must also be taken not to tack within the area of the inguinal canal as the iliohypogastric, ilioinguinal, and genital branch of the genitofemoral nerve can all be injured anteriorly to transversalis fascia in this location. In general, safe areas for tack fixation include Cooper's ligament and the rectus abdominis muscle medially and the abdominal wall superior to the iliopubic tract laterally. Once the mesh is in position then the peritoneum should be closed in order to avoid exposure of the mesh to the viscera. There are a variety of methods available for peritoneal closure including suture, tacks, and clips. We prefer a running continuous barbed suture closure, which is run from lateral to medial (Fig. 12.8). After peritoneal closure the bed is returned to its normal position and the abdomen is desufflated under direct visualization. The fascia of the umbilical port is closed with interrupted 0-Vicryl sutures and skin sites are closed with 4-0 subcuticular Monocryl and covered with dry sterile dressings. If a Foley catheter was placed it is now removed, and the patient is then awoken from general anesthesia and transferred to the recovery room.

12.5 TAPP Versus TEP

Muschalla and colleagues recently reported their long-term outcomes with the TAPP procedure. Between January of 2000 and January of 2001 they performed 1208 inguinal hernia repairs in 952 patients. Ninety-eight percent of these

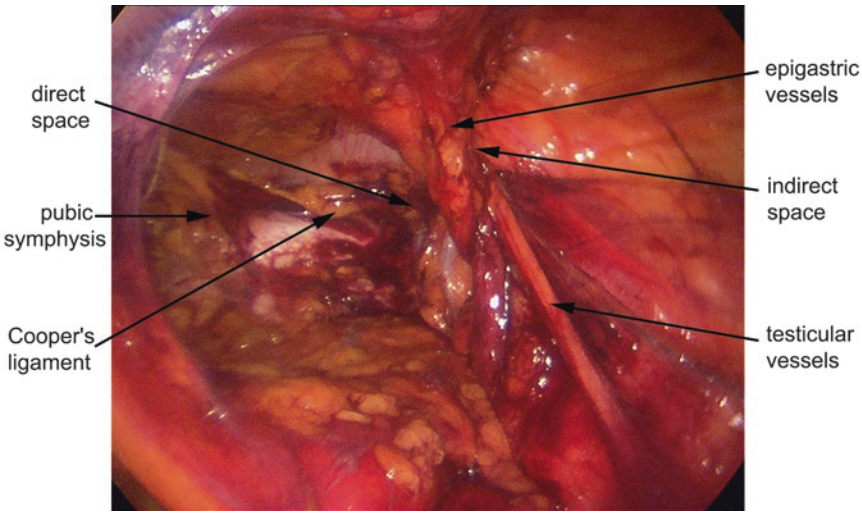

Fig. 12.6 Complete dissection of the myopectineal orifice (Figure reprinted with permission from Springer Publishing, Inc.)

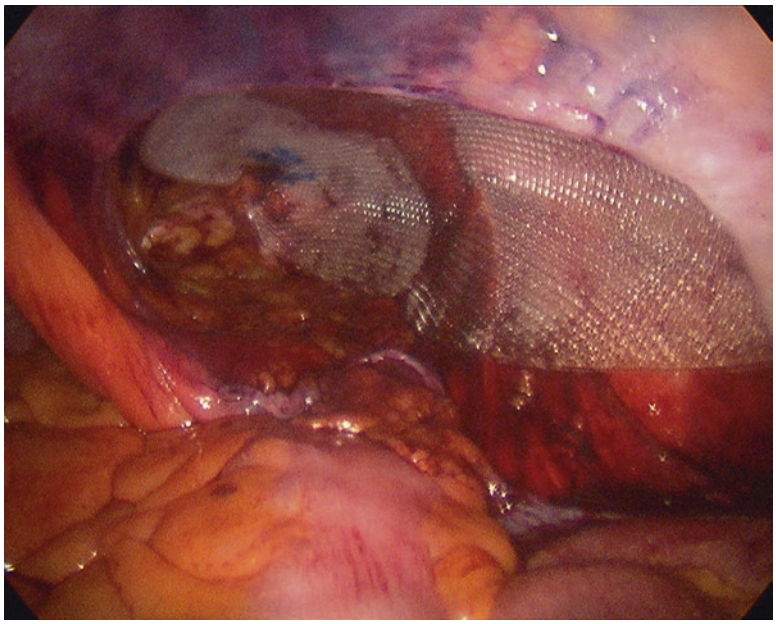

Fig. 12.7 Mesh positioning (Figure reprinted with permission from Springer Publishing, Inc.)

repairs were performed with the laparoscopic TAPP technique. With 85.3 % follow-up at 5 years, they found a recurrence rate of 0.4 % and 0.59 % rate of severe chronic pain [18]. These long-term results support the recommendations of the European Hernia Society Guidelines regarding the treatment of symptomatic unilateral inguinal hernias. They state that the best evidence supports a mesh-based repair utilizing either an open Lichtenstein technique or an endoscopic technique if sufficient expertise in this area is available [17]. Despite these recommendations, there still remains some debate about the best endoscopic method for repair, TAPP versus Totally Extraperitoneal (TEP).

The European Hernia Society has reviewed the literature regarding the differences in both technique and outcomes between TAPP and TEP. They found that both techniques have their own technical differences and each has its own advantages and disadvantages. Overall, however, there are no statistically significant differences in long-term outcomes, including both recurrences and chronic pain, between TAPP and TEP. The authors noted that TAPP may be associated with a slightly decreased learning curve but there is no strong evidence to support this belief [19].

Since the publication of these guidelines several other studies comparing TAPP and TEP have been released. Bansal and colleagues assessed the differences in long-term rates of chronic groin pain and quality of life following TAPP or TEP [20]. With respect to pain, they found that the TAPP repair was associated with higher rates of acute pain but no significant differences in chronic pain between the two techniques. There were improvements in quality of life for both from the

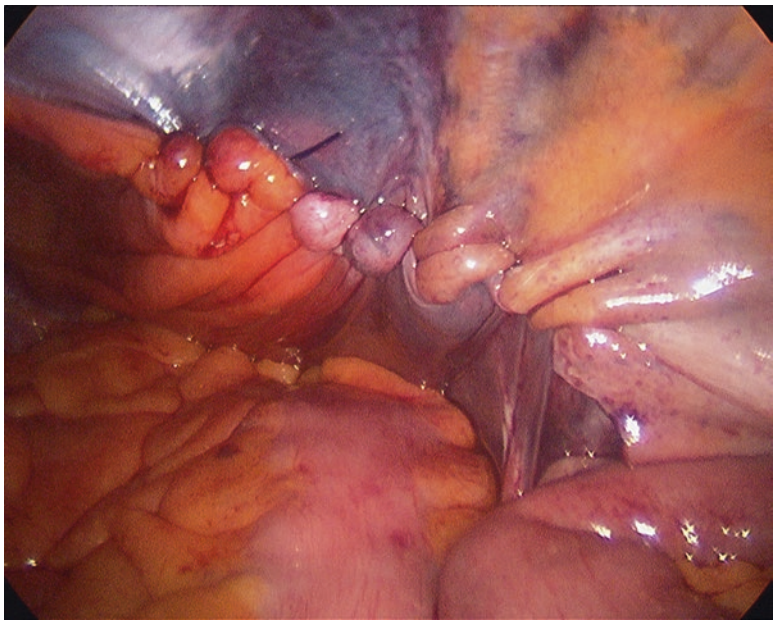

Fig. 12.8 Suture closure of the peritoneal defect (Figure reprinted with permission from Springer Publishing, Inc.)

perioperative period to the postoperative period noted with both techniques but no significant differences in quality of life between TAPP and TEP. Additionally, costs were comparable between the two techniques [20]. Köckerling and colleagues reviewed the outcomes of 17,587 patients who underwent laparoscopic inguinal hernia repair in a large prospectively enrolled hernia registry [21]. 10,887 (61.9%) underwent TAPP and 6700 (38.1%) were repaired with the TEP technique. On both univariate and multivariable analysis, surgical technique was not associated with differences in intraoperative or general postoperative complications. TAPP was associated with higher rates of postoperative surgical complications but this did not lead to a difference in reoperation rate between the two techniques. Overall, they noted no significant differences between the two techniques [21]. In general, the differences between TAPP and TEP are largely technical and do not lead to significant differences in long-term outcomes. Surgeons comfortable with both techniques should choose which to offer to appropriate patients.

12.6 Summary

The laparoscopic TAPP repair is an excellent repair option for primary unilateral, bilateral, and many recurrent inguinal hernias. While there is a learning curve with the TAPP repair, once this learning curve has been achieved TAPP is associated with excellent outcomes with low rates of recurrence and chronic pain. Surgeons should be familiar with the TAPP repair and offer it to patients whom they believe are suitable candidates.

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Laparoscopic Totally Extraperitoneal (TEP) Inguinal Hernia Repair

13

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13.1 History and Introduction

Totally extraperitoneal hernia repair (TEP) is a relatively new technique of repairing inguinal hernias where the dissection and repair are carried out without violating the peritoneal cavity. McKernan and Law first introduced totally extraperitoneal hernia repair in 1993 [1]. They reported 51 cases, of which, 11 were recurrent and 12 were bilateral. The procedure has since been refined, especially with advancements is surgical technology and training.

Some proponents of TEP advocate for this technique over the transabdominal approach due to the potential complications of accessing and working in the peritoneal cavity [2]. When compared to open hernia repair, and in particular for recurrent (after open) and bilateral hernias, many surgeons prefer the laparoscopic approach due to quicker recovery times, and less postoperative and chronic pain [3–5].

Totally extraperitoneal hernia repair is feasible in most patients with inguinal hernias, but in certain situations the open repair might be more appropriate depending on hernia anatomy, surgeon experience, and the patient's medical and surgical history. For example, a surgeon with limited experience in TEP might consider starting TEP with primary inguinal hernias prior to tackling a recurrent or more complex case.

Bilateral inguinal hernias and recurrent hernias after open repair are two well-accepted indications for TEP. In patients with bilateral hernias, both sides can be dissected, examined, and repaired using the same ports, thus the morbidity associated with port insertion and wound complications remains low [3, 5, 6]. Treating recurrent hernias is more challenging, depending on the approach used in the past. Scarring and the presence of mesh or a mesh plug can obliterate planes and make it more likely to injure the peritoneum or other structures. Patients who have had prior repairs that did not invade the pre-peritoneal space, like Lichtenstein repair, are the best candidates for TEP repair if they recur while patients who had repairs that invaded the pre-peritoneal space, like mesh plug repair or open pre-peritoneal repair, may be more challenging with a TEP approach if they recur. In experienced hands, there are no absolute contraindications to totally extraperitoneal hernia repair; however, a careful decision should be made to tailor the approach to both patient and surgeon factors [Bittner, 2015 #5] [7–9].

TEP is technically challenging and the learning curve has been reported to be at least 60 procedures, if not more [7, 8]. In this chapter we will describe the technical steps of totally extraperitoneal hernia repair—including tips and tricks we have learned over the years, the potential complications and troubleshooting when needed.

13.1.1 Preoperative Planning and Patient Preparation

Multiple studies, including a Cochrane review and at least four meta-analyses, have addressed the issue of antibiotic prophylaxis prior to hernia repair [5, 10–16]. These studies included open and not laparoscopic repair. The meta-analyses that were done on mesh repair concluded that antibiotic prophylaxis is beneficial in mesh repair for protection in surgical site infection [14]. Yet, there is not enough evidence to support routine use of antibiotic prophylaxis when repairing inguinal hernias laparoscopically [2, 4, 9].

Totally extraperitoneal hernia repair is associated with a low risk of developing venous thromboembolism (VTE). Thus, appropriate risk stratification based on individual patient risk factors should be practiced, and prophylaxis administered when appropriate [2, 9, 17].

A full bladder can increase the difficulty of the operation by obscuring the view and decreasing the already limited working space [2, 9]. The guidelines published in 2011 by

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_13

the International Endohernia Society (IEHS) recommend that patients undergoing laparoscopic hernia repair should empty their bladders in the immediate period before the operation. They also recommended considering urinary catheterization if the operation is expected to be long or difficult [2]. Another important factor to consider is restricting intra- and perioperative intravenous fluid administration, which also reduces the incidence of postoperative urinary retention (POUR) [2, 4, 9].

13.2 Totally Extraperitoneal Hernia Repair (TEP)

13.2.1 Suggested Equipment

Trocars

- One balloon/space-making trocar (optional).
- One 12 mm balloon-tip trocar is used as a camera port.
- Two 5 mm trocars.
- A 10 mm, 30 or 45° laparoscope.
- Gas insufflation tubing.
- A minimum of two graspers. We use two Reddick-Olsen (blunt black) graspers. This grasper has short jaws and a blunt tip, which is ideal for the type of dissection in the limited working space. Any blunt tip grasper/dissector would work, however the longer the jaws, the more space is needed to clear the trocar prior to opening the instrument. Some surgeons use endoscopic Kitners or laparoscopic "peanuts" or sponges.
- Laparoscopic clips (5 mm).
- Monopolar energy device and cable.
- Synthetic mesh (size may vary).

13.2.2 Positioning and Draping

In our institution, patients are positioned supine with both arms tucked in slight Trendelenburg position. You can also consider turning the patient slightly (approximately 15°) toward the surgeon. The surgeon operates on the opposite side of the hernia, and the assistant is on the side of the hernia (Fig. 13.1).

The hair should be clipped and the patient's skin should be prepped with standard skin prep. Draping should be done in such a way that conversion to an open or transabdominal approach is feasible if necessary.

13.2.3 Incision and Pre-peritoneal Access

Multiple techniques can be used to access the pre-peritoneal space. We prefer the open technique. It is quick, easy, and reproducible. It is widely used and has been reported by multiple authors [1, 18–21]. We make a 10 mm infraumbilical incision, usually on the same side as the hernia, or on the larger side in the case of bilateral hernias, slightly off the midline. The anterior rectus sheath is incised and the rectus muscle is retracted laterally and anteriorly to visualize the posterior rectus sheath. This provides safe and direct access to the pre-peritoneal space. In this technique, care should be taken to avoid injury to the underlying rectus muscle which can lead to bleeding and less than optimal views of the appropriate planes.

Dulucq et al. insert a Veress needle directly into the space of Retzius, followed by carbon dioxide insufflation and direct trocar insertion [3]. In this method, it may be difficult to insert the needle in the correct space and the working space is initially quite limited [5]. Others have also reported establishing pneumoperitoneum first, followed by raising a

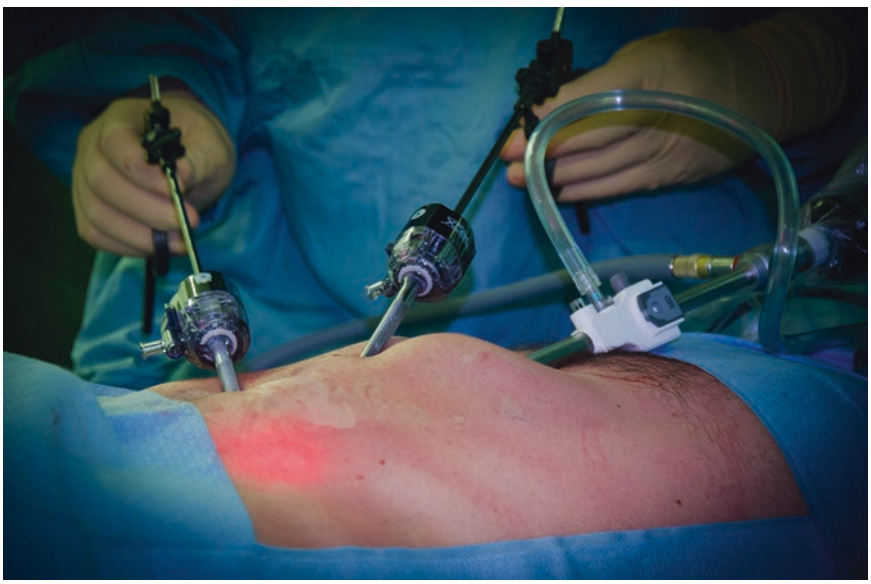

Fig. 13.1 Port placement and settings while repairing a left inguinal hernia. Trocars placed along the midline, surgeon to the patient's right side and assistant to the patient's left side

pre-peritoneal blister using bupivacaine and then inserting the trocars in the pre-peritoneal space [22]. This technique has the disadvantage of the potential morbidity associated with entry into the peritoneal cavity such as bowel injury and port site hernia.

Troubleshooting

1. Inadvertent incision through the Linea Alba:
   - Usually does not lead to significant limitations during the operation.
   - We recommend closing the opening at the beginning or at the end of the case.

13.2.4 Pre-peritoneal Space Creation

Multiple methods to create the pre-peritoneal working space have been described. Our preferred method, and the most commonly used method, is using a balloon dissector [23–25]. A commercially made balloon is inserted just under the rectus muscle and advanced toward the symphysis pubis until the bone is felt at the tip of the introducer. It is then inflated, under direct vision, after confirming that it is appropriately placed in the pre-peritoneal space. This is followed by insertion of a balloon-tip trocar. There are some "2-in-1" trocars which incorporate the functions of these two trocars and this would be a reasonable option if it is available at your institution. A randomized control trial by Bringman et al. showed that using a balloon dissector is easy, safe, and convenient compared to blunt digital dissection [25]. The balloon also reduces operating times, conversion rates, and complications compared to direct telescopic dissection [23]. We highly recommend this method, especially during the learning period. This is also the technique recommended in the IEHS guidelines [2, 4].

In patients with previous lower abdominal scars, attempts should be made to gently inflate the balloon away from the scars when possible to avoid tearing the peritoneum or causing a bladder or bowel injury [26]. The dissection is then completed under direct vision after placing the remaining trocars. Direct telescopic dissection or blunt probe dissection has also been described and is widely used in different institutions [2].

Troubleshooting

1. Extensive scarring:
   - The balloon should be inflated away from the scar to avoid injury to the bladder or intestine.
2. Bleeding from inferior epigastric vessels:
   - Incidence is about 0.4–2.75 % [20, 21, 26, 27].
   - Bleeding is usually from small branches of the vessel and this can be controlled using an electrosurgical device or clips.
3. If bleeding is from the main trunk of the vessel, they can be ligated.
4. Dissection of the inferior epigastric vessels off the abdominal wall:
   - The balloon can sometimes dissect anterior to the inferior epigastric vessels.
   - This can affect visualization and might misguide the surgeon to continue the dissection anterior to the vessels instead of posteriorly.
   - The vessels need to be lifted back to the abdominal wall and dissection should be carried posteriorly. Alternatively, if the working space is compromised by the vessels, they can be ligated and divided.
5. Accidental entry to the abdominal cavity.
   - This can occur during initial incision or during balloon dissection leading to peritoneal tear.
   - Having a previous incision, like a previous open appendectomy or previous violation of pre-peritoneal space, increases the possibility of peritoneal tear.
   - Inflating the balloon away from previous scar helps reducing the chance of peritoneal tear.

13.2.5 Trocar Insertion

There are two common port configurations used in laparoscopic totally extraperitoneal hernia repair. The midline configuration: where the 10 mm camera port is inserted in the infraumbilical position, followed by insufflation of carbon dioxide to a pressure of 12 mmHg of pneumopreperitoneum. Then, under direct vision, two 5 mm trocars are inserted in the midline between the rectus muscles. Enough distance to allow free movement of instruments, usually four fingerbreadths, separates the 5 mm trocars (Fig. 13.1). The advantage of the midline configuration is that the same ports can be used to dissect both sides. The other configuration depends on triangulating the three trocars. A 10 mm camera port is inserted infraumbilical, followed by two 5 mm trocars, one along the midline just below the camera port and one lateral port on the same side as the hernia close to the anterior superior iliac spine [21]. This provides better triangulation and may facilitate the dissection of a large hernia sac [21, 28].

13.2.6 Anatomy and Dissection of the Pre-peritoneal Space

Totally extraperitoneal hernia repair requires the creation of a space that allows insertion of a large enough piece of mesh to appropriately cover the myopectineal orifice without the peritoneal edge slipping below the lower border of the mesh. Familiarity with inguinal anatomy from the pre-peritoneal perspective is essential for safe and adequate dissection of this space and reduction of all hernias.

The inferior epigastric vessels should be identified at the beginning of the procedure and serve as an important landmark.

We then perform lateral dissection of the peritoneum, up to the level of the anterior superior iliac spine, followed by medial dissection of Cooper's ligament and the pubic tubercle past the midline. If there is a direct hernia, it is reduced either at the beginning or at the time of the medial dissection. Care should be taken during the dissection of Cooper's, as there are often vessels draped over the ligament that can be easily damaged and lead to unnecessary bleeding.

The spermatic cord and internal ring are lateral to the inferior epigastric vessels; this is where the dissection of an indirect hernia sac should begin. Laterally and inferiorly, an important landmark is the fascia over the psoas muscle (Bogros space) where the mesh needs to lay laterally. This is achieved by beginning the lateral dissection just posterior to the inferior epigastric vessels and following the characteristic white border of the peritoneum. It is important not to violate the fatty plane directly on the psoas, which protects the nerves as they course over the psoas muscle. Superiorly, the dissection should be carried out up to the level of the anterior superior iliac spine. Posteriorly, the peritoneum is reflected to where the vas deferens courses medially or until enough space has been created for an adequate sized mesh to be placed [2, 9, 22]. If the dissection of the space is not enough to clear the entire myopectineal orifice, the mesh will be susceptible to folding and increase risk of recurrence or pain due to bunching of the mesh [22, 29].

Troubleshooting

1. Peritoneal tear:
   - Incidence is 12–47 % [27, 30].
   - This can lead to pneumoperitoneum, which can diminish the working space and render the operation more difficult. Sometimes there is very little effect from a small peritoneal defect.
   - Small holes do not need to be repaired. The peritoneum can be repaired with clips (we prefer the self-locking Teflon clips), suturing or pre-tied loops.
2. Bleeding from Corona mortis vessels during the medial dissection:
   - The Corona mortis is formed by a vascular communication between the external iliac or the inferior epigastric and the obturator arteries.
   - Injured in 1.5–2 % of cases [31–33].
   - It can cause significant bleeding that may lead to retroperitoneal hematoma, conversion to open or reoperation [31–33].

13.2.7 Dissection of the Hernia Sac

13.2.7.1 Direct Hernias

In direct hernias, the sac is protruding through a defect medial to the inferior epigastric vessels. Direct hernias are often reduced by insufflation of the pre-peritoneal space or by the space-making balloon [2]. If it is not completely reduced, the sac can be easily reduced using a "hand over hand" technique until the interface between the herniated sac and the fascia transversalis is encountered. This will give the appearance of a "reversed hernia sac" being pulled down because of the white appearance of the transversalis [34].

In the case of an incarcerated direct hernia, the hernia defect can be enlarged by making a relaxing incision at the anteromedial side of the defect to avoid injury to the inferior epigastric and iliac vessels [35]. Pressure can also be applied externally to encourage the hernia contents to reduce.

Once reduced, considerable dead space exists where a large direct hernia was. This can lead to the formation of large seromas post-op. The surgeon can attempt to reduce this dead space by fixing the fascia transversalis to Cooper's ligament, using either a tacking device or sutures [2, 36], or by using pre-tied suture around the fascia transversalis after pulling it into the operative field.

13.2.7.2 Indirect Hernias

In indirect hernias, the sac is adherent to the spermatic cord and protrudes through the internal ring, which is lateral to the inferior epigastric vessels. The sac here needs to be separated from the cord structures. The sac has to be gently mobilized off the cord structures both medially and laterally before it is completely reduced from the internal ring. The surgeon needs to visualize the cord structures and protect them during the mobilization to reduce the chance of injuring them [2].

The cord is first identified lateral to the inferior epigastric vessels, followed by identification of the hernia sac. This can be done by following the peritoneal reflection laterally to where it joins the spermatic cord. Then, the surgeon's non-dominant hand holds the sac to provide counter traction. Then, the sac can be separated from the cord structures by gently peeling the cord structures off of the hernia sac [4, 9, 35]. We do not recommend using laparoscopic graspers to hold cord structures, the vas deferens, and the spermatic vascular bundle. The surgeon can, however, grasp the cremasteric muscle fibers adherent to the spermatic cord.

In female patients, the indirect sac is often very adherent to the round ligament. The round ligament can be divided after vascular control, using clips or electrosurgery. In the case of a very large hernia sac, the sac can be divided at the level of the ring as long as the contents have been reduced and it has been separated from the cord structures. It can be ligated using pre-tied endoscopic sutures.

13.2.8 Mesh Application

13.2.8.1 Type and Size of Mesh

There are not enough data documenting the advantages of one mesh over the other in terms of recurrence. Although, the available data suggest using lightweight mesh does not increase recurrence [2, 4, 9]. In our institution, we use a

medium weight (73 g/m^2) self-fixating mesh. The mesh size is tailored to the patient and the hernia type and size but should be at least 10 × 15 cm to cover the entire myopectineal orifice [2, 9].

13.2.8.2 Mesh Preparation

Handling of the mesh should be kept to a minimum and it should be kept in its sterile packaging until it is ready for use. Care should be taken to minimize contact of the mesh with the patient's skin. Chowbey et al. suggest rolling the mesh superiorly and inferiorly for two-thirds of its length, followed by fixing the mesh with two sutures. After introduction, the sutures are cut and the mesh can be unrolled [20]. Other authors [37] roll the mesh laterally and medially and fix it with sutures that can be cut after introduction before unrolling it. In our institution, we mark the middle of the mesh along its vertical access, roll it like a scroll and then unroll it laterally first and then medially. The technique of mesh placement varies with the size of the mesh and the material. It is more challenging to handle a large mesh in a small place and it is important for the mesh to be well positioned.

13.2.8.3 Mesh Introduction and Application

The mesh is rolled like a scroll and introduced through the 10 mm trocar. The previously marked midline of the mesh is aligned parallel to the inferior epigastric vessels and centered around the internal ring for indirect hernias and a little bit more medially for direct defects. The mesh is also aligned to have at least one-third of the mesh lying below the iliopubic tract [2]. The mesh is unrolled laterally and then medially. In the case of large direct hernias, we recommend using a larger mesh to ensure appropriate medial coverage (beyond the midline). In a randomized controlled trial, it was shown that mesh overlap of less than 3 cm can lead to hernia sac protrusion through the defect and so they recommended an overlap of at least 4 cm (even more might be better).

In the setting of bilateral hernia repairs, some authors recommend using one large piece of mesh to cover both sides. This is technically more challenging and might also increase operating time [2, 38]. If using two appropriate size meshes, they should overlap by 2 cm over the midline [2]. There are two randomized controlled trials [32, 38] showing less recurrence when using one large mesh to cover both myopectineal orifices in open surgery but the available data fail to show similar results for TEP repair [5].

13.2.8.4 Mesh Fixation

This is a highly controversial issue when it comes to laparoscopic hernia repair. Multiple studies have shown no clear differences in terms of recurrence between fixation and no fixation, irrespective of the type of mesh used [3, 39]. A meta-analysis of six randomized controlled trials comparing mesh fixation vs. non-fixation in laparoscopic hernia repair revealed reduced operating times, costs, and hospital stay but no differences in recurrence, seroma formation, or time to return to activities [40]. Also, new evidence suggests that fixing the mesh using a laparoscopic tacking device may increase immediate postoperative pain and hematoma formation. Based on this, some authors recommended using laparoscopic sutures or fibrin glue [41] to fixate the mesh. A randomized trial published in 2013 by Tolver et al. demonstrated improvement in immediate postoperative pain with fibrin glue fixation compared to a laparoscopic tacking device in trans-abdominal pre-peritoneal hernia repair [42].

Regardless of the device or method used, tacks or sutures should not be placed below the iliopubic tract and lateral to Cooper's to avoid injuring the nerves in this area in addition to the external iliac vascular bundle. If the surgeon decides to fixate the mesh, it should be done to Cooper's ligament medially and above the iliopubic tract laterally and medially if desired.

13.2.8.5 Repair Check

At the end of the dissection and mesh placement, the repair should be checked before closing and as the air is evacuated from the pre-peritoneal space under direct vision. We highly recommend checking the following:

1. The mesh is laying nice and flat and covering the entire myopectineal orifice.
2. The hernia sac is dissected posterior enough such that the peritoneal reflection is not creeping under the mesh.
3. The mesh stays in place as the space collapses.

Contralateral Side Exploration

The decision to explore the contralateral side in a TEP repair for patients with unilateral symptoms and no contralateral hernia on exam is a decision that we make together with the patient. Additional risks may include longer operative times and a potential increased rate of complications (bleeding, hematoma, seroma, recurrence, and chronic pain) related to an additional hernia repair. Benefits include the potential to repair a contralateral hernia that might eventually cause symptoms using the same incisions at the same operation. If the decision is made not to explore the other side, care should be taken not to violate the contralateral pre-peritoneal space, so that a TEP could be performed in the future if needed.

13.2.9 Special Consideration

13.2.9.1 E-TEP

Enhanced or extended totally extraperitoneal hernia repair was initially described as a modification of TEP by Daes et al. in 2012. In this technique, there are two key differences differentiating e-TEP from the classic TEP: high placement of the camera port and division of line of Douglas. E-TEP can be helpful in large inguino-scrotal and incarcer-

ated hernias, obese patients, and patients with a short distance between the umbilicus and symphysis pubis [43, 44] [Kockerling, 2012 #10631].

13.2.9.2 Obesity

TEP in obese patients can be challenging due to the limited pre-peritoneal working space and trocar flexibility. In such situations, preoperative planning is important. When operating on an obese patient, more Trendelenburg positioning and a slight rotation can help minimize the challenges. Advocates of e-TEP also indicate that this technique can potentially make hernia repair in obese patients easier.

13.2.9.3 Recurrent Hernias

Recurrent hernias can be challenging, depending on the previous approach, whether or not mesh was used, and other patient factors. If there is significant scarring, the balloon dissector could tear the peritoneum or injure the inferior epigastric vessels, bladder, or other organs adherent to the area.

Dissection of the hernia sac can be more difficult in the setting of recurrence, which increases the risk of injury to the cord structures and vessels. Careful, slow, and blunt dissection is used, with occasional sharp dissection or electrosurgery if the scarring is very dense. The femoral space should be examined carefully as a missed femoral hernia is a common cause of a presumed hernia recurrence [45]. Conversion to TAPP or open repair is sometimes required in these cases.

13.2.9.4 Recurrence Post Previous Laparoscopic Repair or Previous Lower Abdominal Surgery

These cases can definitely be more difficult and we do not recommend attempting TEP, in such cases, before performing enough primary hernias using this technique [9]. The space usually has extensive fibrosis from the previous surgery. It can also be more pronounced if the patient had previous mesh placed in the pre-peritoneal space. If the patient did not undergo a previous open repair, it might be safer and easier to attempt an open tension-free repair.

The balloon will often not dissect the pre-peritoneal space completely and can also lead to injuries to the inferior epigastric vessels peritoneum, bladder, or any other organ that might be adherent to the area. The space needs to be dissected with care and the previous mesh can be left in place or removed depending on the patient's symptoms.

13.2.9.5 Incarcerated and Strangulated Hernia

TEP can be attempted in incarcerated or strangulated hernias; however, an exploratory laparoscopy might need to be done as well to rule out bowel ischemia [9]. There is insufficient evidence to prevent using mesh in clean-contaminated procedures, such as small bowel resection, when placed in the extra-peritoneal space [9, 46, 47].

13.2.10 Postoperative Care

13.2.10.1 Hospital Stay and Recovery

The majority of totally extraperitoneal hernia repairs are performed on an outpatient basis. Patients are counseled at the preoperative stage to expect to return home after recovering from anesthesia. Patients who require admission are usually those with preexisting comorbidities that require monitoring after general anesthesia.

In some studies, like the meta-analysis done by Bracale et al., TAPP was associated with longer hospital stay compared to TEP [Bracale, 2012 #10894]. Others failed to show any significant difference [Bansal, 2013 #11034] [Gass, 2012 #11035]. One of the advantages of TEP hernia repair is the quick recovery and return to normal activities [2].

13.2.10.2 Pain

In our experience, pain in the vast majority of patients is controlled with nonsteroidal anti-inflammatory agents (NSAIDS). A minority of patients requires narcotics or other more potent agents for a few days.

A randomized control trial by Bansal et al. [48] showed significantly less pain associated with TEP when compared to TAPP at 6 h, 24 h, 1 and 6 weeks postoperatively. Also, a prospective study by Zanghi et al. [Zanghi, 2011 #11036] showed significantly more pain associated with TAPP when compared to TEP at 1, 7, 30, and 90 days postoperatively.

13.2.11 Complications

13.2.11.1 Major Intra-operative Complications

Urinary Bladder Injury

Urinary bladder injury is a rare complication of TEP with an incidence of less than 0.3 % [49]. A reported risk factor is previous bladder or prostate surgery. The surgeon should practice careful dissection and should have a high index of suspicion. When identified, it can also be repaired endoscopically depending on the surgeon's comfort level and a bladder catheter should be left in place for 5–7 days [2, 21].

13.2.11.2 Postoperative Complications

Urinary Retention

The incidence of urinary retention after TEP repair varies depending on multiple factors. The incidence increases up to 3 % after fixation of the mesh using tacks but can be as low as 1 % without fixation [2, 4, 50, 51]. Risk factors for retention include age >60, history of benign prostatic hyperplasia, anesthesia time exceeding 2 h, and excessive intravenous fluid therapy during the operation [4].

Limited use of intravenous fluids during the operation, not fixing the mesh using tacks and making sure the patient's urinary bladder has been emptied before undergoing general anesthesia are steps the surgeon can attempt to reduce the chance of postoperative urinary retention. In the case of urinary retention, one time catheterization to empty the bladder is sufficient in the majority of patients [2, 4, 9].

Seroma and Hematoma

Seroma and hematoma are well-recognized complications following any type of hernia repair. Seroma has a reported incidence of 5–7 % after laparoscopic repair, while the incidence of hematoma is around 8 %. Careful dissection and hemostasis can help to reduce the incidence of postoperative hematoma [2, 52]. We also suggest holding ASA prior to the operation, although there are no reliable data to support this practice as a way of reducing the incidence of hematoma.

Multiple technical steps can be attempted to reduce postoperative seroma formation. This was mentioned earlier in this chapter, and is particularly relevant for large indirect hernias, and even moderate-sized direct hernias.

Patients might confuse accumulation of fluids in the form of seroma or hematoma with recurrence and failure of hernia repair. It is important to counsel the patients regarding this complication to avoid fear and unnecessary visits to the emergency department and/or unnecessary imaging studies [2, 53].

If seroma/hematoma develops postoperatively, observation is sufficient as it usually resolves with time. In some situations, hematoma might decompress through the trocar site, which can be uncomfortable for the patient. Those collections should not be aspirated or drained without obvious signs of infection [2, 9, 16, 52, 53].

Chronic Pain

Chronic pain is very unsatisfying for both the surgeon and the patient. The incidence of chronic pain is less in TEP repair when compared to open repair and is usually transient [6, 54]. This has been one of the main reasons why laparoscopic hernia repair is becoming more popular. If pain persists more than 3 months after the repair, other causes need to be ruled out. If other causes have already been ruled out, then a diagnosis of post-herniorrhaphy neuralgia should be entertained [4, 48, 55].

In recent studies, the use of endoscopic staple or tack mesh fixation increases the incidence of chronic pain [Sajid, 2012 #11037] and in rare cases, removing them may be necessary. The European Association of Endoscopic Surgeon published the recommendation after their consensus development conference and recommended that then endoscopic surgeon should strive for chronic pain rates of less than 2 % 5 years after the repair [9].

Genitourinary Complications

Different potential complications related to the testicles and spermatic cord can occur, especially if there is dissection of a large indirect hernia sac. These can include direct injury to the vas deferens or spermatic vessels, which can lead to ischemic orchitis, testicular atrophy, chronic testicular or ejaculatory pain, infertility, or retrograde ejaculation [2, 4, 9] [Hawn, 2006 #11046].

Mesh Infection

Mesh infection after TEP is rare. In a Cochrane systematic review published in 2003 by McCormack et al., only 1 mesh infection was reported among 2179 patients [53]. Mesh removal is rarely necessary after mesh infection, and an attempt of medical therapy with antibiotics should be carried out first, depending on the mesh material used [2, 4, 9]. If Medical therapy fails, then mesh excision might need to be performed.

Recurrence

Multiple studies including the LEVEL-Trial, a randomized control trial comparing TEP to Lichtenstein repair, found recurrence post TEP to be similar to that after open repair [16]. The incidence of recurrence is around 3 % with a mean follow-up of 49 months, but this incidence might be higher during the surgeon's learning curve [9, 56]. There is no evidence that mesh fixation or non-fixation affects recurrence rates.

Experts agree, however, that one important step in preventing recurrence is creating a space wide enough for the mesh to lay flat, have complete coverage of the myopectineal orifice and enough inferior and medial coverage. One study found that recurrences after TEP repair tend to be more indirect recurrences possibly related to superior migration of the mesh. Recurrences can be managed with open repair, TAPP or TEP. The surgeon should have enough experience before attempting to repair a recurrence post TEP using a laparoscopic technique.

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14 Emerging Technology: Open Approaches to Preperitoneal Inguinal Hernia Repair

Frederik Christiaan Berrevoet

14.1 Introduction

Up until late in the nineteenth century, treatment of inguinal hernias consisted of reducing protrusions through the external inguinal ring or femoral canal, and applying a truss for maintenance. Bassini's repair, which failed to divide the transversalis fascial floor of the inguinal canal, became the standard of care in the 1890s for inguinal herniae. Preperitoneal approaches to the groin began a century earlier.

Already as early as in 1823 the anatomist *Bogros* [1] described a transverse 5-cm incision, above the inguinal ligament, midway between the anterior superior iliac spine and the pubic tubercle to use an anterior preperitoneal repair of inguinal and femoral herniation.

The posterior preperitoneal approach to the groin was described by *Cheatle* in 1920 [2], who introduced the transabdominal paramedian approach to the space of Bogros. His operation was ignored until 1936, when *Henry* [3] used it to treat a femoral hernia, while operating extraperitoneally on the pelvic ureter for stones.

In 1950 *McEvedy* [4] reported an oblique lateral incision, dividing both the rectus sheath and transversalis fascia with medial retraction of the rectus muscle and in that way used the lateral transverse incision to reach the preperitoneal space.

Using the preperitoneal approach to repair groin herniation facilitates entry into the retro-fascial transversalis space, providing direct access to the posterior inguinal structures. Hernial protrusions are exposed along with the myopectineal orifice of Fruchaud.

Using a mesh in this preperitoneal space, a strong barrier is created against the continuous intra-abdominal pressure. The prosthesis, pressed by intra-abdominal pressure against the parietal wall, replaces the damaged floor of the inguinal canal to which it quickly becomes attached as connective tissue infiltrates its pores. The need for fixation devices, which can cause postoperative pain, might be reduced, as abdominal pressure, according to Pascal's hydrostatic principles, stabilizes the prosthesis.

When we discuss the current emerging technologies and techniques for open preperitoneal approaches to the groin, its historical background is essential to understand and interpret the evolutions correctly.

Jean Rives [5] described his unilateral inguinal hernia repair using the preperitoneal space already in 1967. He approached the hernia initially as in the Bassini technique, ligated the sac, and incised the transversalis fascia transversely. Dissection of the preperitoneal space was performed with the finger, first at the top behind the wall and thereafter down behind the horizontal ramus of the pubis. A prosthesis of dacron 10 × 10 cm was used and split laterally for passage of the cord structures. He then sutured the mesh down on the Copper ligament at a distance of 3–4 cm from the inferior edge. The mesh was then folded and slipped behind the transversalis fascia and again fixed by some transmuscular sutures, both through the rectus abdominis muscle and laterally on both sides of the cord. The transversalis fascia was then closed to cover the mesh.

René Stoppa [6] introduced his giant prosthetic reinforcement technique of the visceral sac (GPRVS) initially for bilateral complex inguinal and femoral hernias, but later on it was also reproduced for unilateral hernias. The preperitoneal space can be reached by a transverse incision extending from the midline laterally for 8–9 cm. It is made 2 or 3 cm below the level of the anterior superior iliac spine and should be well above the deep ring and any hernias that might present. Then, the rectus sheath and the oblique abdominal muscles are incised over the length of the incision. The rectus muscle is bluntly dissected from the rectus sheath and the lower abdominal wall retracted. Incising the transversalis fascia along the border of the rectus muscle frees the muscle,

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_14

permits entrance into the preperitoneal space, and exposes the inferior epigastric vessels that do not necessarily require division. The prosthesis is drawn into place under the rectus muscle and the superior abdominal wall by three absorbable synthetic sutures appropriately placed along the upper border of the mesh. The sutures secure the mesh to the abdominal wall 2–3 cm above the incision. The medial corner suture is near the linea alba, the middle suture is in the semilunar line of Spiegel, and the lateral corner suture passes through the oblique abdominal muscles near the anterosuperior iliac spine.

George Wantz [7] modified the unilateral GPRVS by approaching the inguinal canal and the preperitoneal space in exactly the same way as in the classical hernioplasties. In his report the division of the cremaster muscle and cremaster vessels was reported not to be essential. Wide cleavage of the preperitoneal space is easily accomplished bluntly with the index finger in all directions, while division of the inferior epigastric vessels facilitates the dissection and the implantation of the prosthesis, but is not mandatory. An essential feature of the technique is parietalization of the elements of the spermatic cord. Normally, the vas deferens and the testicular vessels are tightly attached to the parietal peritoneum by the transversalis fascia. Consequently they accompany the peritoneum when the preperitoneal space is cleaved and the visceral sac retracted. Separating the vas deferens and the testicular vessels from the peritoneum allows the elements of the cord to lie freely against the parietal wall of the pelvic area. The vas deferens and the testicular vessels should be dissected from the peritoneum for a distance of about 6–8 cm. The prosthesis is then drawn into the preperitoneal space underneath the superior abdominal wall using four or five sutures. The sutures not only facilitate the correct placement of the prosthesis superiorly, but also ensure its position during the manipulation required to insert the inferior portion of the prosthesis. The inferior border of the prosthesis is implanted with long curved clamps that grasp the prosthesis on the corners and in the middle of the distal edge. The long curved clamps push the prosthesis medially deep into the space of Retzius and laterally far up into the iliac fossa. A clamp in the middle edge aids implantation of the prosthesis over the peritoneum facing the obturator canal.

14.2 Development of Mesh Devices and Other Technologies

Over the years and most probably also influenced and stimulated by the introduction of the laparoscopic inguinal hernia techniques, the open preperitoneal techniques have their revival. As the critical point, or less convenient part of the procedures described above is to adequately deploy the prosthetic material in the created space, several mesh devices were developed over time to facilitate this part of the procedure. Currently, several techniques are being used worldwide, all of them following the anatomical and surgical descriptions of our predecessors, and each using their own specific type of mesh. Accordingly, the grid-iron repair described by Franz Ugahary, the Prolene hernia system™ repair reported on by Arthur Gilbert, the Kugel™ mesh repair, promoted by Robert Kugel, the transinguinal Polysoft™ mesh repair as introduced by Edouard Pélissier, the transrectus sheath preperitoneal mesh technique by Willem Akkersdijk, and the ONSTEP™ procedure by Augusto Lourenço will be described and discussed.

14.2.1 Indications and Contraindications

All patients, male and female, with a primary inguinal, femoral, or obturator hernia are eligible for these open preperitoneal techniques. In case of previous preperitoneal surgery, e.g., open prostatectomy with lymphadenectomy, bladder surgery, and pelvic trauma surgery, or in case of previous inguinal hernia surgery using the preperitoneal space for the location of the mesh, these techniques might succeed in only 50 % of cases. No other contraindications seem apparent.

14.2.2 Preoperative Preparation

For all techniques approaching the preperitoneal space, it is helpful and advantageous that the patient empties his/her bladder just prior to surgery. This way, mobilization of the lateral and ventral wall of the bladder will be facilitated and no Foley catheter is needed.

14.2.3 Anesthesia

The procedure can in all cases be performed under local anesthesia (with sedation) or using spinal anesthesia. Straining and coughing might help to spread the different types of devices and enables the surgeon to check the correct position of the mesh at the end of the procedure. Because manipulation of the peritoneum during dissection can lead to additional stress and pain, it might be more troublesome to use local anesthesia in younger patients as they are generally more anxious during surgery. Spinal anesthesia, using ropivacaine 0.2 % without admixture of opioids does not induce unacceptably high urinary retention rates leading to unplanned admissions. An additional local incisional block with ropivacaine 0.2 % can be very useful, especially in day-care treatment. In other situations general anesthesia might be the option of choice.

14.3 The Grid-Iron Repair

Franz Ugahary [8] reported in 1998 on the use of a rather lateral oblique incision, not transecting the rectus abdominis fascia. He used a kind of mesh device "avant la letter" specifically manufactured to assist in performing this technique, the so-called Vypro II Visor mesh™. One of the crucial points of this technique is the skin incision. The position of the inguinal ligament is marked by drawing a line between the SIAS and the pubic tubercle. The lateral margin of the rectus muscle is identified. A line is then drawn perpendicular to the inguinal ligament, starting from the femoral artery, which is easily palpated. This line indicates the position of the inferior epigastric vessels and above the inguinal ligament. The skin incision is made about 1 finger's width above and lateral to the internal ring and should be slightly oblique and about 3–4 cm long. The external oblique aponeurosis is then divided along the line of its fibers and a grid-iron approach is used down to the peritoneum.

Once the preperitoneal space is identified the patient is put in a Trendelenburg position and turned slightly over to the opposite side. The preperitoneal space is developed by blunt dissection of the peritoneal sac from the abdominal wall, using a swab. The inferior epigastric vessels are identified but should not be separated from the abdominal wall. Progressing medially, the inguinal ligament and the symphysis are identified. This will reduce a direct groin hernia. The cord structures should then be examined for the presence of either a preperitoneal lipoma or an indirect hernia sac. If an indirect sac is present, it should either be removed from the inguinal canal or divided at the level of the anterior abdominal wall closing the proximal defect with a purse string suture. The peritoneal sac should be separated from the cord over a length of at least 7 cm, because the cord will be parietalized as described by Wantz earlier. The 10 × 15 cm mesh is then rolled up on a 25 cm long forceps and introduced in the preperitoneal space in such a way that the center of the mesh (marked) lies medial to the epigastric vessels and just above the inguinal ligament. Long retractors (Langenbeck's retractors) are then used to position the mesh correctly. However, this is the relatively difficult step of the procedure as this mesh is a flat large pore mesh. At that point care must also be taken to ensure that the cord is lateralized between the mesh and the anterior abdominal wall without involving the peritoneum.

The retractors are then removed and the lateral corners of the mesh folded out with a forceps. The mesh is fixed at the lateral corner of the incision to the traverse muscle with an absorbable suture. No scientific data have been reported on this type of technique, except the ones from Ugahary himself.

14.4 Bilayer Mesh Device Repair (Prolene Hernia System™/Ultrapro Hernia System™)

Considering the recurrences observed after plug repairs, plug-and-patch repairs, and anterior mesh-only repairs in the past and the hypothesis that these might occur because: (1) the posterior wall remains unprotected after plug-only repair, (2) the tails that accommodate the spermatic cord might be too short, or they were not overlapped, allowing exposed posterior wall tissue to protrude between them, and (3) neither plugs nor anterior patches afford any protection against femoral herniation, *Arthur Gilbert* [9], in collaboration with a medical company, developed a bilayer prosthesis with an intermediate connector to overcome these issues. Its underlay (preperitoneal) component is designed to protect the canal's posterior wall from behind and covers the femoral canal as well. It is intended to reach inferiorly to beyond Cooper's ligament, superiorly to well above the transversus arch, medially to behind the rectus muscle, and laterally to well beyond the internal ring. The connector sits within the defect and is flat, connecting the underlay with the onlay graft. The onlay covers, again, the full width and breadth of the canal, creating a double layer mesh reinforcement (Fig. 14.1).

Technically, a low 3–4 cm transverse incision is made in the groin. It is a transinguinal approach, opening the aponeurosis of the external oblique muscle like in classical repairs. The first important space is created by dissecting beneath the medial and lateral flaps of the EOA, then down the inguinal ligament clearing its shelving edge to the pubic tubercle. This anterior space will eventually house the onlay patch of the device. To actualize the posterior space, the peritoneum is freed from its attachments to the posterior wall by inserting a gauze through the internal ring. For direct types, the hernia in Hesselbach's triangle is opened and its protruding contents are dissected from it with a sponge to create space. The latter approach can also be used for indirect hernias. Cooper's ligament can be visualized after completion of the dissection through the posterior wall. The deep epigastric vessels are not disturbed unless the hernia has a pantaloon presentation, in which case, they are divided and the two defects are converted to one.

The device is then slid down into the preperitoneal space. The two leaves of the onlay patch are extracted holding a finger in the connector to keep the underlay patch in place. After the onlay leaves have been extracted they are held like a bridle and the expanded position of the underlay patch is ensured. Different than the laparoscopic approach, in which the mesh is placed flat against the inside of the anterior abdominal wall, the device is placed into a space containing

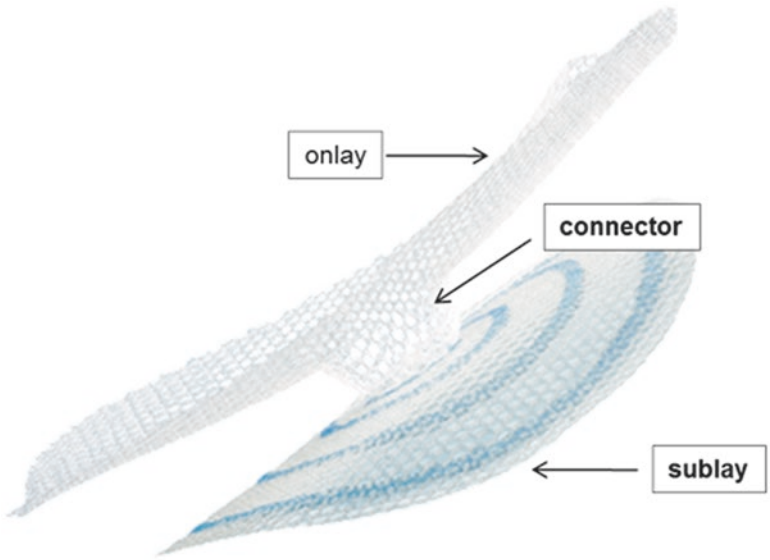

Fig. 14.1 The Ultrapro™ a bilayer patch device

fat. The technical goal of the deployment is to spread the edge of the underlay graft circumferentially at maximum distraction from the connector. The connector remains in the internal ring or the direct defect. Next, the lateral leaf of the onlay graft should be placed in the anterior space beneath the external oblique aponeurosis. This flattens it and greatly facilitates the remainder of the procedure. The medial part of the onlay graft is flattened against the transverse arch and the end of its medial leaf is positioned 2 cm over the pubic tubercle. The underlay graft will be pushed against the anterior muscular wall by the patient's intraabdominal pressure. Effectiveness of the underlay graft alone can be evaluated by having the patient cough and perform the Valsalva maneuver before sutures are placed in the onlay graft. It is suggested that the onlay graft will be sutured over the pubic tubercle, at the middle of the transversus arch and at the middle of the inguinal ligament. To accommodate the spermatic cord through the onlay graft, a central slit is created, for most indirect hernias, and a lateral slit for most direct hernias. Any excess of the onlay graft can be trimmed before closing the EOA.

14.5 The Kugel Approach

A comparable lateral incision is made as in the grid-iron approach, at a point estimated to be about 2–3 cm above the internal ring. This point is located approximately halfway between the anterior superior iliac spine and the pubic tubercle as described by *Robert Kugel* [10]. The 3–4 cm incision (in an average-size patient) is made one-third lateral and two-thirds medial to an imaginary line drawn between these two structures. The abdominal wall incision is made similar to the "muscle-splitting" approach. The dissection is then carried down to the external oblique aponeurosis, which is opened a short distance parallel with its fibers. The underlying internal oblique muscle is bluntly separated exposing the transversalis fascia deep to it.

The cord structures are carefully separated from the adjacent peritoneum and hernia sac (parietalization). Using blunt and limited sharp dissection, an oval-shaped pocket is created in the preperitoneal space just barely large enough to accept the mesh patch. The pocket created sits between the peritoneum, superior and posterior, and the internal ring, cord structures, femoral canal, and Hesselbach's triangle, inferior and anterior. This pocket should extend from behind the pubic tubercle medially to a point about 3 cm beyond the transversalis incision laterally and roughly paralleling the inguinal ligament.

The specifically designed Kugel patch™ (Fig. 14.2) for this procedure should be sufficiently large to cover and overlap the hernia defect, including Hesselbach's triangle and the femoral canal, and lie parallel with the inguinal ligament. About three-fifths of the mesh should sit above (anterior) the level of the inguinal ligament and the other two-fifths below (posterior) the ligament. Two separate oval-shaped sheets of mesh material (small pore polypropylene) are attached to each other near the outer edge of the smaller piece, while leaving a 1-cm "apron" free at the outermost edge of the larger piece. A transverse cut is made in the mid portion of the anterior layer of mesh. This transverse cut allows insertion of a single digit or instrument between the two layers of mesh and greatly facilitates positioning of the patch. Inserting a single finger between the layers of mesh will allow placement of the patch into the preperitoneal space. The fingertip should be directed toward the superior aspect of the pubic bone. The finger is then removed from the mesh and a narrow malleable retractor inserted, if needed, to complete

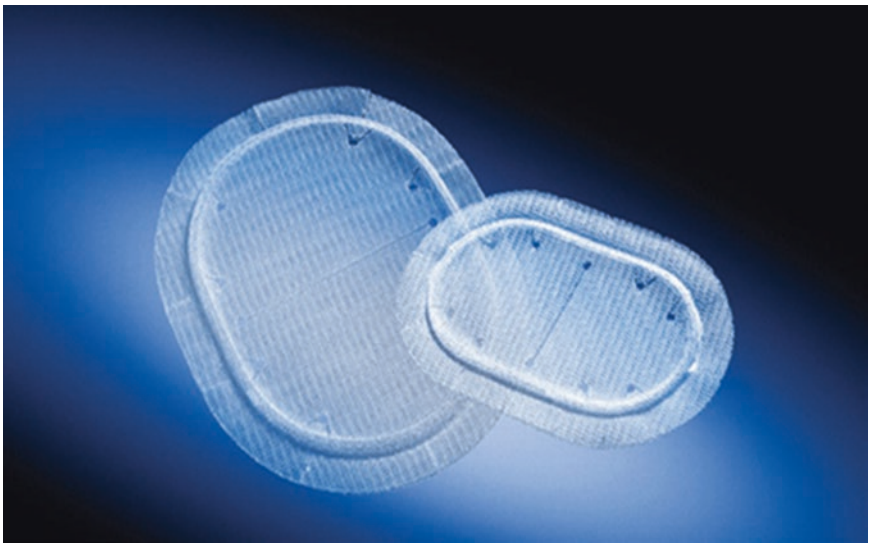

Fig. 14.2 The Kugel mesh™

placement of the medial edge of the patch behind the pubic bone. The lateral edge of the mesh can then be tucked into the lateral portion of the preperitoneal pocket. The mesh lies between the cord structures (or round ligament) and the peritoneum and does not surround the cord structures. The posterior edge of the patch should fold back under the peritoneum and onto the iliac vessels. This edge must extend well below (posterior to) the level of the inguinal ligament.

14.6 The Transinguinal Polysoft™ Technique

As the traditional anterior approach is the most commonly known and therefore best reproducible by many surgeons the transinguinal preperitoneal repair (TIPP) is a good alternative to approach the preperitoneal space through the deep inguinal ring or through the medial inguinal defect by incising the transversalis fascia [11]. This type of mesh repair is facilitated by the use of a memory containing prosthesis. The memory ring offers, in contrast to some other techniques, an easy deployment of the patch in the preperitoneal space under good visualization of the groin structures.

After disinfection and sterile draping of the groin area, the operation starts by drawing a line between the lower edge of the superior anterior iliac spine and the pubic tubercle. The distance is then measured. For most patients this will range between 10 and 13 cm. Halfway this line we start the incision and proceed medially for 3 cm in an angle of approximately 30°. By doing so, the incision is precisely centered over the deep inguinal ring and the epigastric vessels. The iliac vessels will then always be just at the lateral edge of the incision and serve as an important reference point at the time of mesh introduction. The external oblique aponeurosis is opened, taking caution not to harm the ilioinguinal nerve, and the inguinal canal is exposed. An important modification compared to the initial description of this technique by *Edouard Pélissier* [12] is *not* to perform extensive dissection to locate the hernia defect. There is absolutely no reason to completely section the cremasteric muscle and to skeletonize the cord structures. This may only increase the harm done to the inguinal nerves. As for other techniques the approach for indirect versus direct hernias might slightly differ entering the defect through the dilated internal ring, our personal preference, versus entering the space through the direct defect itself. From that moment on the epigastric vessels will be retracted softly upwards. After palpation of both Cooper's ligament and the pubic bone to ensure the dissection will be done in the right avascular preperitoneal plane, gauze can be introduced into the preperitoneal space towards Retzius' space. The next step is then again to reduce the hernias present and to parietalize the cord structures as far as possible, even inside the abdominal cavity where the spermatic cord separates from the spermatic vessels. In very obese patients this can be a hard nut to crack through a 3 cm incision. By doing this there is no need to create a new internal orifice by incising the mesh laterally.

A last critical point in using this technique is to obtain a sufficient pocket at the lateral side of the internal orifice. To facilitate this part of the dissection, it sometimes can be helpful to introduce gauze laterally. One should only be satisfied with the created pocket once the index finger can reach the superior anterior iliac spine easily. After creation of the appropriate pocket, a malleable flat retractor is introduced medially to recline peritoneum, preperitoneal fat, and the lateral aspect of the bladder. Introduction of the mesh can now be performed, sliding the mesh over the malleable retractor.

The use of a mesh with a memory facilitates the introduction and fast placement. Different meshes are available. The Polysoft™ mesh (Fig. 14.3) consists of a polypropylene mesh

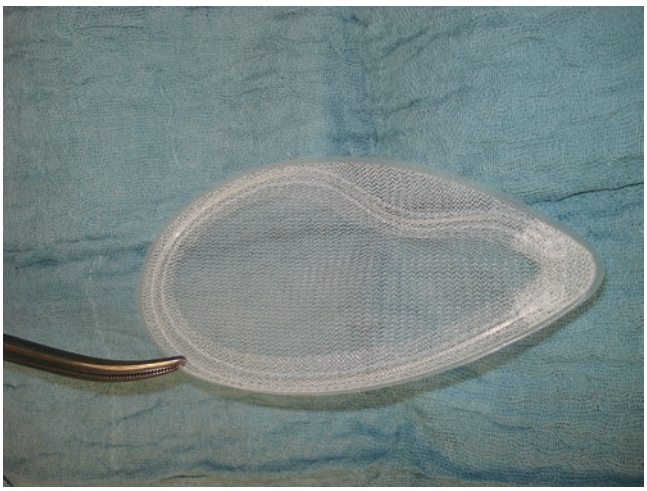

Fig. 14.3 The Polysoft™ mesh

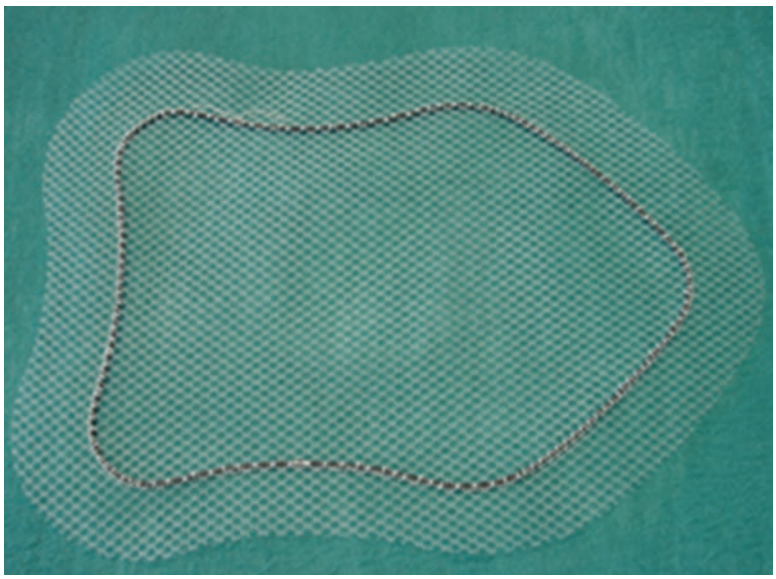

Fig. 14.4 The Rebound mesh™

with a resorbable memory ring. It has an oval shape and exists in two sizes: medium (14×7.5 cm) and large (16×9.5 cm). Laterally a notch has been manufactured in the mesh to allow proper deployment over the iliac vessels. The main disadvantage of this mesh is the interrupted memory at the lateral side, which limits the complete deployment of the mesh in some cases that might lead to pain or long-term recurrences.

Another possible mesh frame is the Rebound HRD Shield™ (Fig. 14.4), which consists of a large polypropylene mesh with a non-resorbable nitinol frame. This mesh has a continuous memory ring that facilitates lateral flat mesh placement [13]. Although the created pocket is medially large enough to do so, it is important not to introduce the mesh too medially. Especially for indirect hernias, an adequate overlap of the mesh lateral to the deep internal ring is necessary.

From that point the mesh has to be manipulated by two forceps at its edges to allow perfect placement.

14.7 The Transrectus Sheath Preperitoneal Mesh Technique (TREPP)

As the previous TIPP technique still uses the inguinal canal as the entrance site to the preperitoneal space the TREPP technique was described in detail by *Akkersdijk* et al. [14], using the same approach as described by McEmedy, Wantz, and others. The access should be cranially to the internal ring, in order to ascertain easy and secure inspection and exploration of the spermatic cord. This point is determined as the crossing point of a line through the internal ring, parallel to the midline, and the skin lines, that originate from the superior ante-

rior iliac spine. The incision should be approximately 4–5 cm long. It is caudally from the linea semicircularis, where there is no posterior rectus sheath present. The aponeurosis of the external oblique muscle is opened parallel with the groin. The anterior layer of the sheath of the abdominal rectus muscle is identified and opened and the rectus muscle is identified. The inferolateral border of the muscle is separated from its surrounding fibrous structures. The rectus abdominis is retracted medially with a small Langenbeck retractor. In most cases the entrance of the preperitoneal space will be laterally from the epigastric vessels. The finger should push gently behind the muscle layers of the abdominal wall, towards the anterior superior iliac spine. When it reaches the iliac spine, the finger will be reflected over the anterior border of the iliopsoas muscle. During this movement, the iliac artery is used as a landmark. The further dissection and parietalization is then performed as in the other techniques.

For its introduction, the memory ring containing type of mesh is grasped at its tail with forceps and pushed into the lateral compartment, directed towards the anterior superior iliac spine. Keeping the mesh fixed with a finger against the abdominal wall laterally, the inferomedial part of the mesh is grasped by the forceps, and rotated behind Cooper's ligament and the pubic bone. The mesh should overlap Cooper's ligament and the symphysis by at least 1 cm. The anterior rectus sheath can be closed.

14.8 The Onstep Technique

Comparable with the bilayer mesh technique as described by Gilbert, the Onstep technique as described by *Lourenço* and Costa [15] also utilizes both the anterior and posterior inguinal plane for mesh placement. The surgical technique is comparable or even identical to the one described above using the bilayer mesh technique.

A 4-cm horizontal incision line is measured and marked. The incision site is identified by two straight lines being drawn superior and lateral to the midpoint of the pubic symphysis; the index and middle fingers are then placed against each line. The intersection point of the index fingers marks the medial edge of the incision line. A sterile gauze is inserted into the incision and digitally guided down towards the pubic bone to bluntly dissect the space required for insertion of the hernia patch in the Retzius space as mentioned in other techniques. An axial slit is cut into the patch (Onflex™, Fig. 14.5) between the interrupted ends of the memory recoil ring, down to the apex of the curved notch of the patch, taking care not to cut the recoil ring. The tails of the patch are placed around the elevated spermatic cord with the curved edge of the patch orientated medially. The tails of the patch are then joined together using three interrupted sutures: one adjacent to the spermatic cord, one at the end of the lateral tails of the patch, and one at the midpoint of the slit. The gauze is then removed. This is completely identical to the way Pélissier described his Polysoft™ patch technique. The medial apex end of the patch is grasped on the periphery between two fingers, and the patch is inserted into the incision and pushed obliquely down into the space of Retzius under the pubic bone, leaving the tails of the patch outside the incision. The lateral tails of the patch are then inserted into the previously dissected space between the external oblique aponeurosis and the tissues below it, ensuring correct placement.

Fig. 14.5

14.8.1 Postoperative Recommendations

These are not specified for all available techniques, but can be summarized as follows:

Patients are advised to take analgesics for 2 days and mobilize from day 1 without limitations. The time patients need to return to their normal daily activity is mostly between 2 and 4 days and the time to return to full activity, including their job and sports is around 10–14 days.

14.9 Literature and General Considerations

Regarding acute and chronic postoperative pain issues the treatment of inguinal and femoral hernias using mesh in the preperitoneal space might have several advantages: minimal dissection around the inguinal nerves, location of the mesh in the avascular preperitoneal space, being more towards the human physiology, and not in contact with the nerves, minimal or no fixation of the mesh necessary and no extensive amount of material to prevent severe local inflammation and fibrosis around the nerves and the cord structures during

tissue ingrowth. Considering the latter, the type of mesh, more than the surgical technique itself, might lead to different outcomes. Double layer prostheses should be avoided to decrease foreign body reaction, shrinkage, and mesh deformities, which on itself might lead to severe patient complaints and worse quality of life. Problems with some of the available memory ring devices might be an argument to stay away from these devices, although some of them have been developed using absorbable materials.

Entering the inguinal canal to reach the preperitoneal space still includes the risk of harming one or more inguinal nerves. This might be an argument not to choose for the TIPP technique, the Onstep technique or the bilayer mesh technique using PHS/UHS devices. However, although the transinguinal approach still includes dissection around the inguinal nerves, minimal dissection around the hernia sac only is recommended as well as not to take down all cremasteric muscles, nor to free all boundaries of the inguinal canal itself as in a Lichtenstein repair. Staying outside the inguinal canal might be beneficial regarding nerve damage, but usually limits visualization of the working space and techniques like the grid-iron repair and the Kugel mesh technique are therefore not so easy to teach to other surgeons, fellows, or trainees.

In most techniques a minimal sized incision is used, reflecting the minimally invasive laparoscopic inguinal repair techniques, and therefore, to allow quick and adequate placement of a mesh through this limited incision in the preperitoneal space, a mesh with enough memory is advisable. Older preperitoneal mesh techniques as described by Rives, Stoppa, Wantz, and even Ugahary used the same anatomical dissection techniques, but efficient deployment of the mesh in the created pocket is rather difficult using a flat mesh.

Fixation still is one of the main etiologies for postoperative pain in all mesh augmentations for abdominal wall surgery. Therefore, we consider it favorable, as in laparoscopic inguinal hernia repair, that the mesh needs no or minimal fixation. The intraabdominal pressure as well as the forces of the abdominal muscles will keep the mesh in place considering Pascal's law. Compared to the Lichtenstein method or the plug and patch techniques, this might most probably decrease the amount of postoperative pain. However, also in the modern techniques some of them (PHS/UHS, Ugahary and ONSTEP) still use several nonabsorbable or slowly absorbable sutures to stabilize the mesh, which might be unnecessary using any kind of mesh memory.

There is absolutely no need to create a new internal orifice by splitting the mesh. This implicates, however, and this needs to be stressed, a complete parietalization of the cord till the level where the vessels separate from the spermatic cord "intraabdominally." The same idea is true for laparoscopic techniques, where the mesh is never split. To deal with possible shortcomings on the lateral border of the patch, large sized patches are appropriate for most indirect hernias.

In the literature there are no data comparing the open preperitoneal techniques with each other, so no recommendation can be made about the preferred open preperitoneal technique as is stated in the recently updated guidelines of the European Hernia Society [16]. Most of the data involves the comparison between open preperitoneal techniques and the Lichtenstein technique. Looking at currently available data, a 2009 Cochrane Systematic Review included three eligible trials with 569 patients [17]. Both preperitoneal and Lichtenstein repairs were seen as reasonable approaches since they resulted in similarly low hernia recurrence rates. There is some evidence that preperitoneal repair causes less, or at least comparable, acute and chronic pain when compared with the Lichtenstein procedure. However, the authors emphasized the need for homogeneous high-quality randomized trials comparing elective preperitoneal inguinal hernia repair techniques with the Lichtenstein repair to assess chronic pain incidence. Another recent study comparing TIPP versus Lichtenstein randomized 301 patients and used chronic postoperative pain at 1 year as the primary outcome measure [18]. Significantly fewer TIPP patients had continuous chronic pain, 3.5 % versus 12.9 % in the Lichtenstein group ($p = 0.004$). No significant intergroup differences were noted for other severe adverse events, including recurrences.

Considering the PHS™, a meta-analysis of six RCTs was published comparing PHS and Lichtenstein (follow-up ranging from 12 to 48 months) [19]. One long-term follow-up study (5 year follow-up) was included [20]. No differences in recurrence or chronic pain were found. As both the anterior and posterior compartment are entered and scarred, making a subsequent repair for recurrence more difficult and the amount of foreign material is higher than for a simple flat mesh, these devices were not considered superior to Lichtenstein repair according to the recent EHS guidelines [16].

From the summed evidence, it can be concluded that open preperitoneal repairs seem as effective as the Lichtenstein repair in terms of recurrence and may possibly result in less postoperative pain and faster recovery. However, the caveat is that mainly the anterior transinguinal preperitoneal technique (TIPP), the PHS repair and the posterior preperitoneal technique as described by Kugel have been compared to the Lichtenstein repair.

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Emerging Technology: SILS Inguinal Hernia Repair

15

Hanh Minh Tran and Mai Dieu Tran

15.1 Introduction

Laparoendoscopic repair of groin hernias has become increasingly popular in some Western countries since it was first performed by Gerr in 1988 [1]. In Australia, the uptake of laparoscopic inguinal herniorraphy was relatively slow but progressive such that it was 9.7 % in 2000, 20 % in 2004, and 51 % in 2014 [2]. Indeed, in the States of New South Wales and Queensland, it has exceeded 56 %—making laparoscopic repair the gold standard groin hernia operation at least in terms of percentage.

The increasing popularity of laparoscopic repair has been justified by the recent publication of the "International Guidelines for the Management of Adult Groin Hernias" [3] which suggested laparoscopic repair over open anterior repair due to reduced postoperative pain (both early and chronic) and earlier resumption of physical activities as long as the surgeon is very experienced with laparo-endoscopic inguinal herniorraphy. Furthermore, when community costs are taken into account, the laparoscopic repair is highly cost-effective compared to the open anterior repair [4].

In the quest for reduction in parietal trauma and scarless surgery, natural orifice transluminal endoscopic surgery (NOTES) has been touted as the ultimate goal [5, 6]. Yet, the use of prosthetic mesh has virtually precluded its application in hernia surgery [7]. Single incision laparoscopic surgery (SILS), an off-shoot of NOTES, has been far more successful owing to the use of existing technology including the laparoscope and conventional dissecting instruments. This has resulted in its widespread application in general, colorectal, bariatric, gynecological, and urological surgery. Indeed, in some specialized hernia centers [8, 9], single incision laparoscopic repair has become their technique of choice.

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Performing any new procedure is associated with increased stress for the operator but it is hoped that the lessons learned by the author, who has performed in excess of 1500 single incision laparoscopic hernia repairs to date, will assist the readers in easy transitioning from conventional multiport to single-port laparoscopic total extraperitoneal inguinal herniorraphy.

Suggested instrumentation for successful adoption of single incision laparoscopic (SIL) total extraperitoneal (TEP) inguinal herniorraphy:

- Single-port device—Triport+ (Olympus, Winter & Ibe GmbH, Hamburg, Germany) (Fig. 15.1).
- Curved S-shaped retractors ×2 (Fig. 15.2).
- A blunt metal rod (Fig. 15.2).
- A broad blunt pair of tissue forceps (Fig. 15.2).
- A 5 mm non-disposable port (Fig. 15.3).
- A pair of straight "Dolphin" and "Merrylands" grasping forceps with diathermy pin underneath (Precision Endoscopic Instruments, Baulkham Hills, NSW, Australia) (Fig. 15.4).
- 30° angled, 5 mm and 52 cm laparoscope (Karl Storz, Tuttlingen, Germany) (Fig. 15.5).

15.2 Methodology

During the initial learning phase, it is important to obtain informed consent from the patient explaining one's current experience with both conventional multiport TEP and SIL TEP repair. The discussion should focus on current literature on safety of the SIL TEP technique as well as the potential for improved outcomes and the fact that conversion to multiport TEP repair would not jeopardize patient safety whatsoever. Before attempting SIL TEP repair, it is important to learn about the technique as much as possible including reading this chapter and the referenced literature, as well as being mentored by a SILS expert.

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_15

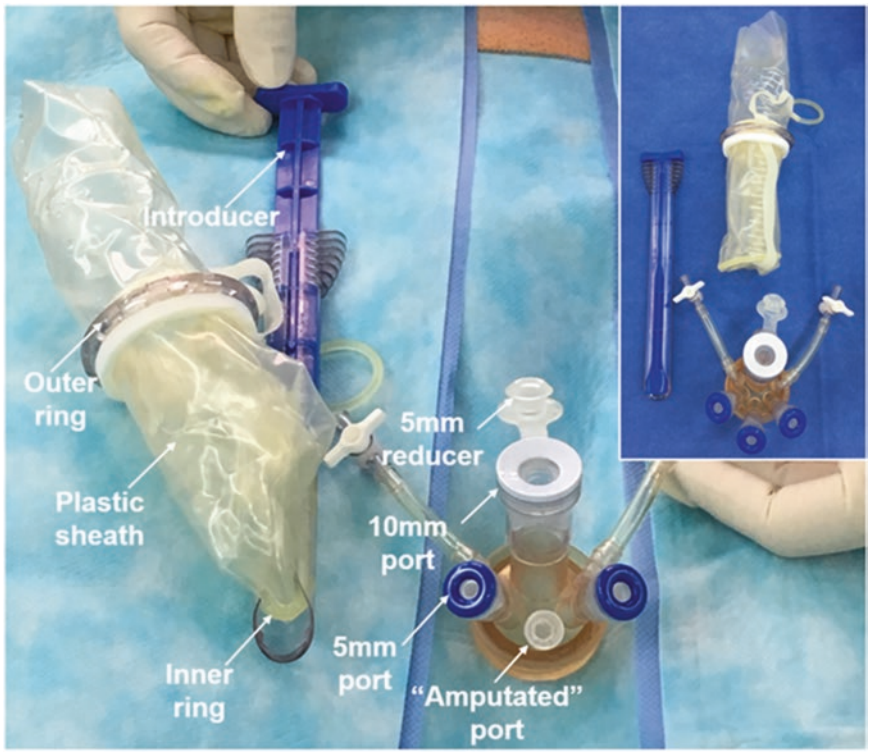

Fig. 15.1 Photo shows placement of inner ring into the introducer and middle 5 mm port of top platform amputated and plugged with a bung, while insert shows components of Triport+

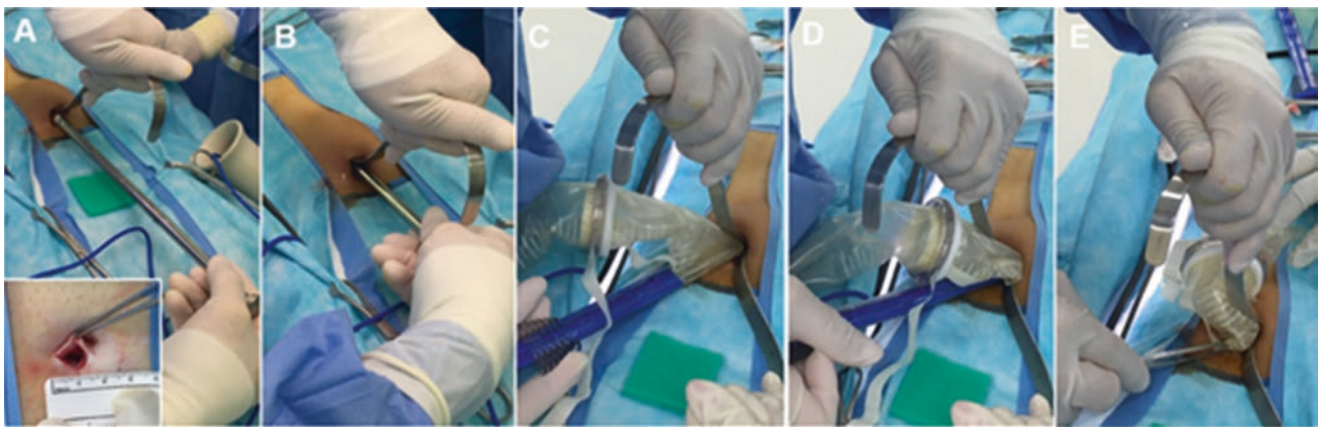

Fig. 15.2 (**a**) and (**b**) show insertion of a blunt metal rod into the extraperitoneal space with insert shows 1.5 cm infra-umbilical incision, (**c**) shows introducer placed at entry into extraperitoneal space, (**d**) shows inner ring deployed into extraperitoneal space, and (**e**) shows use of forceps to insert remainder of inner ring into extraperitoneal space

The patient is placed on an operating table which allows sideways as well as Trendelenburg and reversed Trendelenburg positioning. The patient's arms should be tucked in along the sides with pillow cases. While there is no evidence for routine urinary catheterization during laparoscopic inguinal herniorraphy [3] it should be considered in patients with a known history of prostatic symptoms, large inguinal or inguino-scrotal hernias, recurrent inguinal hernias, or bilateral inguinal hernias, where prolonged operation time can be expected to result in bladder distension, which may complicate the operation with the potential for accidental damage. Emptying the bladder immediately before the operation and judicious fluid administration, by the anesthetist, may negate the need for catheterization without increasing the risks of postoperative urinary retention. The patient is shaved from 5 cm above the umbilicus to both upper thighs and prepped with aqueous Iodine solution with care taken to thoroughly clean out the umbilicus. The patient is then draped with just 2 cm of skin exposed from 2 cm above the umbilicus to pubic symphysis allowing minimal skin exposure. The area around the umbilicus is infiltrated with either 20 mL of 0.5 % Bupivacaine with

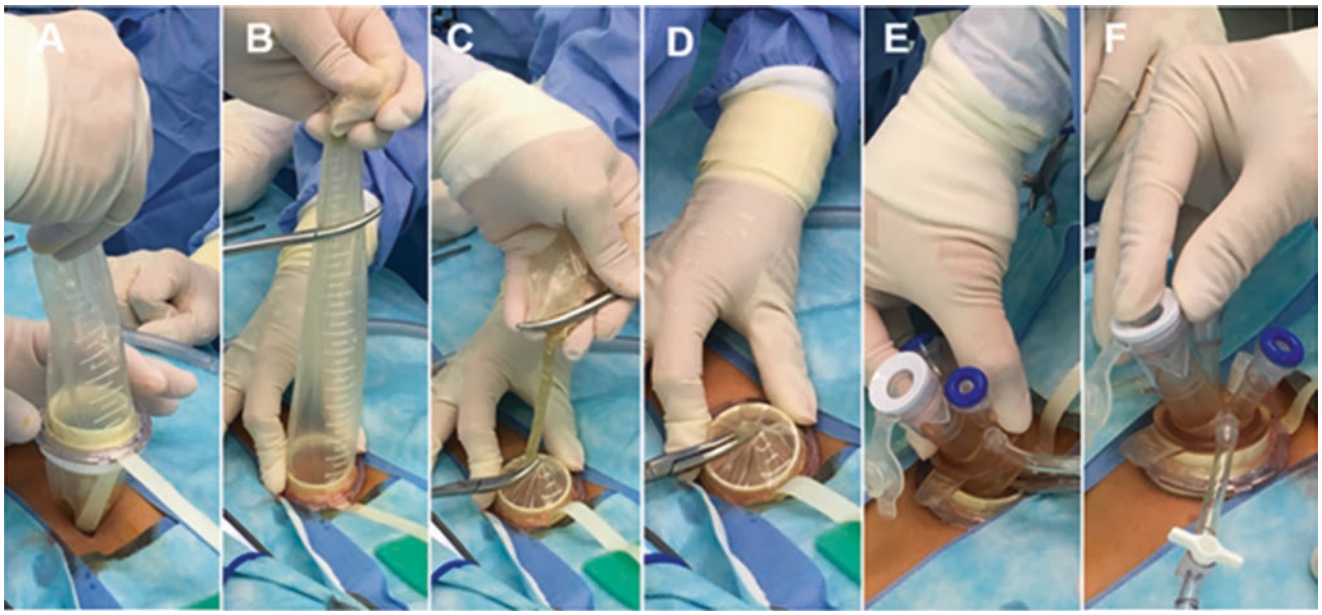

Fig. 15.3 (**a**) shows outer ring being pushed down, (**b**) shows outer ring fully snugged down against abdomen and Kocher forceps applied to plastic sleeve, (**c**) shows plastic sleeve twisted down to outer ring and second pair of Kocher forceps applied, (**d**) shows excess plastic sleeve removed, (**e**) shows top platform applied to inner ring, and (**f**) shows top platform fully in place

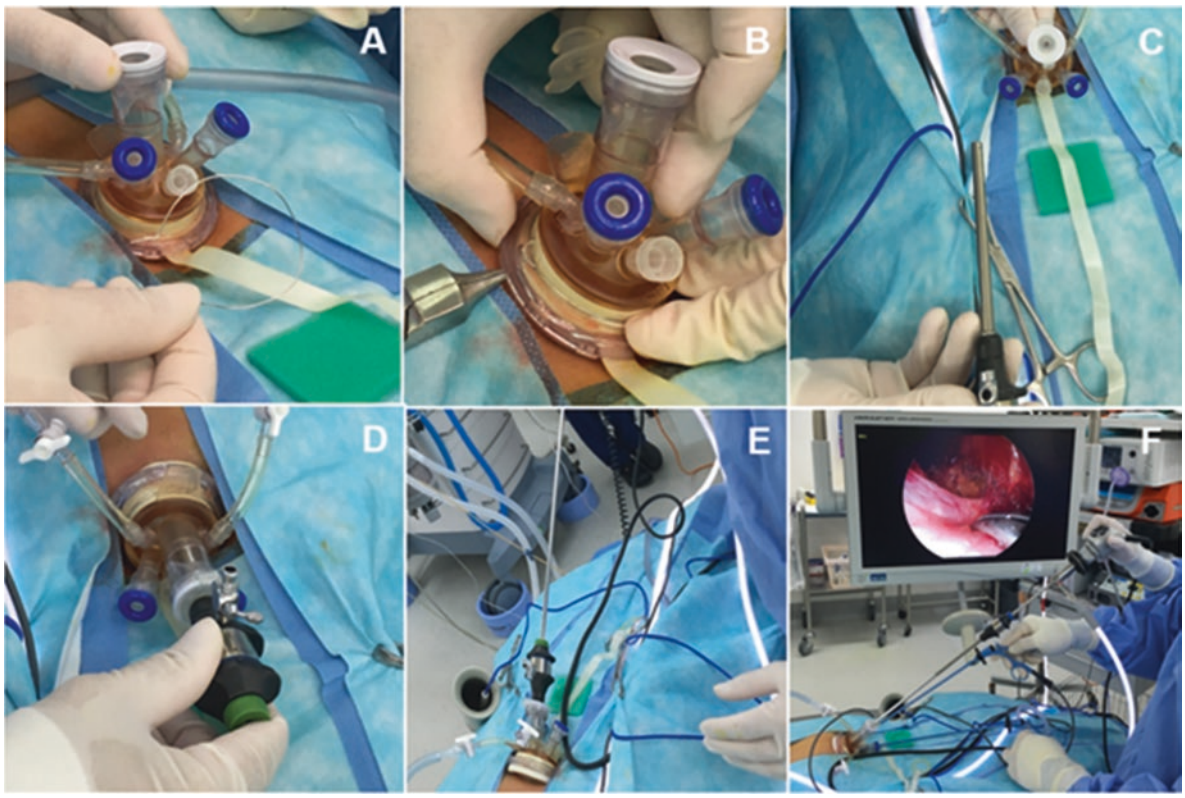

Fig. 15.4 (**a**) and (**b**) show wire loop tightened around outer ring, (**c**) shows placement of 5 mm reducer into 10 mm port, (**d**) shows placement of non-disposable 5 mm port into extraperitoneal space, (**e**) shows insertion of 5 mm laparoscope into extraperitoneal space, and (**f**) shows 5 mm non-disposable port pulled back along 5 mm laparoscope during dissection (note the diathermy pin underneath the handle of graspers)

1:200,000 Ephedrine or 0.25 % Ropivacaine. Irrespective of the side of the hernia operated on, the surgeon stands on the left side of the patient and an infra-umbilical incision is made approximately 1.5 cm in length, although due to the elasticity of the skin, it will usually stretch without increasing skin incision length.

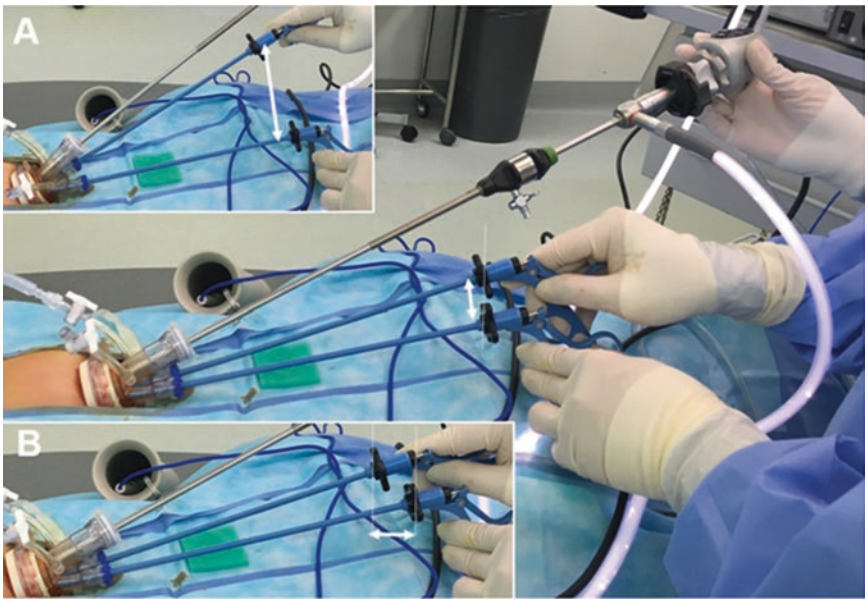

Fig. 15.5 Conventional straight dissecting instruments below the laparoscope with the side arm of the long laparoscope well removed from the handles of the graspers: (**a**) shows "chopsticks" dissection technique with instruments moving in opposite direction on either side of laparoscope shown by increased width of the double arrow and (**b**) shows "Inline" dissection technique with instruments moving in and out in opposite direction shown by increased separation of the rotating wheels of dissecting instruments (*double arrow*)

15.2.1 Using the S-Shaped Retractors

With a combination of blunt dissection with the S-shaped retractors and electrocautery the subcutaneous layer is dissected deeper until the anterior rectus sheath is encountered. It is recommended that for unilateral hernia the same sided unilateral rectus sheath is dissected because laparoscopic repair of a future contralateral hernia will be made easier. In the vast majority of patients, the muscle belly of the rectus can be seen through the anterior rectus sheath and a 1.5 cm transverse incision is made. If the rectus muscle is not visible then it is likely that one is dissecting at one of the intersections of the rectus in which case dissection should be made 1 cm proximal or distal to the initial entry to avoid it (which otherwise would result in entry into the peritoneal cavity). The inferior cut edge of the rectus sheath is then grasped with blunt forceps and the rectus muscle belly is retracted laterally with a pair of blunt Metzenbaum scissors and the inferiorly placed S-shaped retractor is then positioned under the rectus muscle, i.e., anterior to the posterior rectus sheath at this level. The surgeon then repositions the superiorly placed retractor under the rectus muscle and using this to bluntly dissect the space proximally for another 2 cm as this will allow the inner ring of the single-port device to sit evenly deep to the incision. At all times the retraction must be gentle as overzealous retraction will result in tearing and widening of the rectus sheath incision which may increase the risk of dislodgement of the inner ring later. The patient is then placed in the Trendelenburg position at 10–15° before the next step of the procedure which is either insertion of the dissection balloon or insertion of a blunt rod for dissection of the extraperitoneal space under direct vision.

15.2.2 Balloon Dissection of the Extraperitoneal Space

It is suggested that during the initial learning phase of SIL TEP inguinal repair the surgeon, who is used to balloon dissection, continues with the same technique in order to minimize overcomplicating the procedure. A balloon dissector (Covidien, Norwalk, Connecticut, USA) is inserted in the extraperitoneal space toward the pubic symphysis on the side of the hernia to be operated on. The assistant applies external pressure to the contralateral groin before the balloon is progressively distended with air (usually with 25–30 pumps of air) under direct vision with a 10 mm laparoscope placed inside the balloon dissector. Once deflated the balloon dissector is removed before the single-port device is inserted [8, 10].

15.2.3 Telescopic Dissection of the Extraperitoneal Space

Once sufficiently competent with SIL TEP repair (after some 25 cases) the surgeon may attempt to dissect the extraperitoneal space under direct vision using the single-port device (Fig. 15.1). Here, to facilitate the dissection, a blunt metal rod is first inserted in the same way as the balloon dissector toward the pubic symphysis (Fig. 15.2). The next step involves insertion of the Triport+ into the extraperitoneal space.

15.2.4 Preparation of the Triport+ Device

This should be done by the assistant while the surgeon is prepping and positioning the patient so as to not to impact on overall operating theatre time. The top platform of Triport+ has three 5 mm ports, and as supposed operations such as SIL cholecystectomy, where the third 5 mm port is necessary for grasping and retracting the gallbladder, SIL TEP repair only requires two 5 mm ports for insertion of dissecting forceps. Furthermore, the third 5 mm port restricts the movements of the dissecting instruments and hence the middle 5 mm port is removed and plugged with a bung (Saesite® injection site, B. Braun Medical Inc. Bethlehem PA, USA) and taped to maintain an air seal (Fig. 15.2). The plastic sleeve connected to the inner ring of Triport+ is now lubricated with jelly and the inner ring is then placed inside the introducer (Fig. 15.2).

15.2.5 Placement of the Inner Ring of the Triport+

With the assistant retracting the superior S-shaped retractor laterally and the surgeon retracting the inferiorly placed retractor inferiorly, the introducer containing the inner ring is placed at the entry into the extraperitoneal space and the inner ring is deployed. Care is taken not to attempt to place the introducer into the extraperitoneal space because the relatively large diameter of the introducer will lead to enlargening of the rectus sheath incision, thus increasing the risk of dislodgement of the inner ring later on. Once deployed the inner ring is only just over half way in the extraperitoneal space and the rest of the ring can now be pushed in with a broad blunt pair of grasping forceps (Fig. 15.2). With the retractors removed the inner ring can be manipulated with an index finger so that it sits evenly deep to the rectus sheath incision. The outer ring is then firmly snugged down against the skin. With the assistant holding down the outer ring firmly, the surgeon applies a pair of Kocher forceps to the top part of the plastic sheath and with continuous twisting motion to the level of the external ring, then another pair of Kochers is applied to the plastic sleeve and the excess sheath is removed (Fig. 15.3). The assistant then inverts the tip of the Kochers holding the stump of the plastic sleeve inside the external ring the surgeon now places the previously prepared top platform pressing into the outer ring inferiorly away from the Kochers and as the assistant removes the Kochers the top platform is pressed snuggly inside the outer ring (Fig. 15.3). Compared to the older Triport™ device, which had an outer locking ring [10], the Triport+ does not have this and this can result in the top platform dislodging from the outer ring, or more likely the plastic sleeve will progressively slip through, and create redundancy of the sleeve under the outer ring making insertion of the instruments more difficult. One solution to minimize this is to apply a wire around the outer ring and plastic sleeve with just enough pressure so that it indents the outer ring (Fig. 15.4). This step is especially important in bilateral hernia repairs or in difficult and prolonged cases where the risk of slippage and/or dislodgement is high. Further, should the top platform dislodges another new Triport+ will be needed thus unnecessarily increasing the cost of the procedure. The narrowest point of the plastic sleeve is at the level of the anterior rectus sheath and together with the cut and inverted plastic sleeve mean that insertion of the 5 mm laparoscope usually results in smudging. This can be avoided by inserting a non-disposable 5 mm port through the 10 mm port, with a 5 mm reducer (Fig. 15.4), so that it passes directly into the extraperitoneal space. During dissection, the 5 mm non-disposable port can be pulled back along the scope to reduce clashing with the scope and instruments due to the bulky "head" (Fig. 15.4). This non-disposable port can be slid back into the extraperitoneal space each time the scope needs to be cleaned.

15.2.6 Modified Dissection Techniques: "Chopsticks" and "Inline" for SILS

An important limitation of SILS is the relative loss of triangulation as all the instruments and the scope go through the single-port device. However, this can be overcome by modifying the dissection techniques. In the "chopsticks" technique (Fig. 15.5), the fulcrum of the movement of the dissection instruments is at the level of the rectus sheath. Therefore, by moving the instruments in the opposite direction, on either side of the scope, relatively unrestricted dissection can be achieved. Due to the relative mobility of the top platform, there is a 180^0 range of rotational movement of the Triport+, which further increases flexibility. In the "inline" dissection (Fig. 15.5), the dissecting instruments are moved in the opposite direction to each other in the same plane. This movement is particularly useful for reducing an indirect sac. In practice, a combination of the above dissection techniques, in varying proportions, is employed with the result that the supposed loss of triangulation with SILS is well and truly overcome. Consequently, the learning curve for an experienced laparoscopist is relatively short, some 25 cases, and the same operation can be performed with either single-port or multiport with similar operating time [11]. One additional point and that is during the dissection, the assistant may lift the scope up so high that it accidentally comes to lie below and between the dissecting instruments and dissection then becomes almost impossible. This can be remedied either by the assistant slowly pulling the scope back to the fulcrum and then reintroduce along and above the dissecting instruments, or the surgeon pulls both dissecting instruments back proximal to the fulcrum and reintroduce them below the laparoscope [10].

15.2.7 Principles of Dissection During a TEP Repair

Irrespective of whether it is single-port or multiport surgery, a standardized dissection must be followed to minimize the risks of accidental damage to the urinary bladder, blood vessels, abdominal viscera, nerves, and tear in the peritoneum. The steps are as follows: the first land mark is the pubic symphysis and the dissection continues laterally and, staying high on the anterior abdominal wall, the inferior epigastric vessels can be seen, and the dissection continues laterally taking care to preserve the pre-peritoneal fascia overlying the retroperitoneal nerves, and then down to the testicular vessels and vas deferens. An indirect sac, if present, can be reduced at this stage and even if it is not present it is very important to retract back the spermatic cord to ensure that there is no lipoma of the cord which can result in persistent pain if left and is in fact classified as a recurrence. For a large and chronic indirect hernia sac, the "inline" technique may be difficult due to clashing of the rotating wheels of the dissecting forceps, in which case replacing the normal Dolphin graspers with an extra-long (50 cm) pair of blunt graspers will assist with the dissection. It is important to ensure the peritoneum is dissected sufficiently proximally so that when the mesh is placed it does not roll up causing a recurrence. The dissection of the peritoneum can be aided by gentle grasping of the testicular vessels, but more medially the vas deferens should not be directly grasped, as this can be a cause of postoperative inguinodynia. There is no need to resect or tie an indirect sac. A temptation during the initial dissection down the pubic ramus is to attempt to reduce the direct sac totally, if present. However, the danger here is potential accidental damage to the external iliac vein and/or vas deferens. Therefore, while it is acceptable to start reducing a direct sac, especially if it is big, complete reduction should take place from lateral to medial for the above mentioned reason. For a large direct hernia, it is advisable to grasp its apex and pull it back firmly and the sac can be fixed on to the pubic ramus with nonabsorbable tacks (Fig. 15.6). Alternatively, it can be tied at its base with an endo-loop although this will add extra cost to the procedure. Here, the aim is to reduce the dead space in the direct sac to minimize the risks of postoperative seroma formation, although the latter nearly always disappears within a few weeks.

15.2.8 Telescopic Dissection of the Extraperitoneal Space

During balloon distension, some of the extraperitoneal dissection can be accomplished, but this may also strip away the preperitoneal fascia overlying the retroperitoneal nerves, thus increasing the risks of nerve entrapment by direct contact of the mesh. Telescopic dissection starts with insertion of the dissecting instruments inserted directly into the extraperitoneal space which is then dissected under direct vision providing an opportunity to cauterize any blood vessels as well as preserving the preperitoneal fascia. The tunnel, previously created by the blunt metal rod, will provide a safe path down to the pubic symphysis (Fig. 15.2). Initially, there is limited space and care must be taken to visualize the entire metal part of the dissecting instrument before electrocautery is applied, and the assistant must be trained to recognize this and pulls back the scope until the metal part can be seen in its entirety to prevent damage to important viscera and/or blood vessels. As the dissection progresses, it becomes easier as more space is created. As supposed to balloon dissection of the extraperitoneal space, where further manual dissection takes place in a caudal to cranial direction, telescopic dissection is the reverse with the dissection from above down and this allows dissection lateral to the rectus muscle high up, in the "Spigelian hernia belt," and this can result in identification and repair of incidental Spigelian hernias, which have been shown to be associated with direct hernias in up to 10 % of cases [12]. The rest of the telescopic dissection of the extraperitoneal space follows the standardized sequence of steps as enumerated above. For a unilateral indirect inguinal hernia, telescopic dissection across the midline by about 1 cm may be sufficient. However, for unilateral direct inguinal hernia, the dissection of the contralateral space above the pubic symphysis must be at least 2–3 cm across the midline, and this is best accomplished by the surgeon and assistant moving to the opposite side to facilitate dissection as if the contralateral hernia is being dissected. In fact, for bilateral inguinal hernias, the surgeon and assistant move to the opposite side and in contrast to the initial side where the dissection occurs in a cranio-caudal direction, dissection of the contralateral side is best accomplished in caudo-cranial direction as the supra-pubic space has already been partially dissected. Again, it is important to stay high on the anterior abdominal wall to prevent accidental entry into the peritoneum which will cause pneumoperitoneum and make the procedure more difficult. The linea alba extends for a variable distance from the umbilicus to the pubic symphysis and this will need to be divided usually by firm tearing, but sometimes sharp division with laparoscopic scissors is required. It is important to note that introduction of sharp scissors risks perforation of not just the plastic sleeve of the Triport+, but more importantly of abdominal viscera. Consequently, with one dissecting instrument fully inside the extraperitoneal space, the laparoscope is pulled back inside the plastic sleeve so that the introduction of the laparoscopic scissors can be carefully observed. It is usually better to place the mesh one side at a time as with time the dissected side tends to be darker due to capillary leakage resulting in reduced visualization. Furthermore, placing the mesh on the

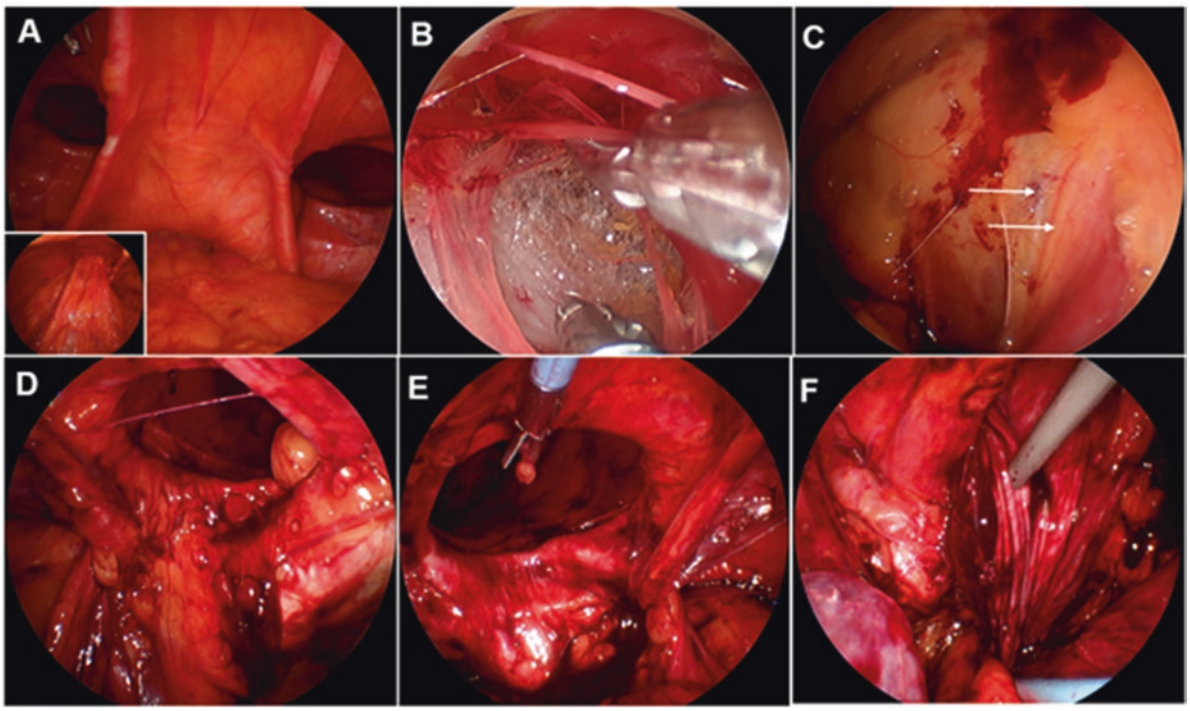

Fig. 15.6 (**a**) shows intraperitoneal view of very large direct inguinal defects with insert shows incarcerated omentum in the right sac which was reduced prior to laparoscopic total extraperitoneal dissection, (**b**) shows telescopic extraperitoneal dissection, (**c**) shows preperitoneal fascia preserved overlying the retroperitoneal nerves (*unlabelled arrows*), (**d**) and (**e**) show large left and right direct defects respectively, and (**f**) shows direct sac being reduced and stapled onto pubic ramus with nonabsorbable tacks

first side allows any natural clotting and hence gluing to take place further enhancing mesh fixation. The risks of accidental entry into the peritoneum increases for bilateral and recurrent inguinal hernias, and for those new to *SILS*, it is suggested to do the smaller or nonrecurrent side first.

15.2.9 Insertion of the Mesh

The dimension of the mesh used is 15 cm transversely and 11–15 cm vertically depending on the size of the patient. The mesh is rolled in the smaller diameter dimension and it is grasped with a pair of Dolphin graspers midway with application of some jelly to the outside of the mesh for easy sliding. The scope is then removed and placed in one of the 5 mm port and advanced until the inner ring is visible. The 5 mm reducer is then flicked off the 10 mm port and the latter is positioned to lie parallel to the scope, in the direction of the pubic symphysis, so that with one swift but firm movement the mesh can be introduced directly into the extraperitoneal space (Fig. 15.7). Temporary loss of pneumoperitoneum ensues but this is reestablished once the introducing Dolphin forceps are removed. The 5 mm non-disposable port is then reinserted via the 5 mm reducer in the 10 mm port for placement of the scope. The mesh can now be unrolled and manipulated into the correct position. It is the author's preference to place two tacks in the midline and one laterally 1 cm superior and medial to the anterior superior iliac spine (to prevent damage to the lateral cutaneous nerve of the thigh). In bilateral hernia repair, overlapping of the meshes in the midline by 1 cm is sufficient especially for indirect inguinal hernias. For bilateral direct inguinal hernias, especially if big, it is the author's preference to place a 15–15 cm piece of mesh to cover both direct defects centrally with tacks placed in the midline and directly onto the pubic rami (Fig. 15.7). The respective side can then be repaired in the usual manner (Fig. 15.7). For bilateral inguinal hernias, difficult cases where bleeding reduces vision, or in patients whose antiplatelet therapy has not been stopped (as is the author's preference), fibrin sealant can be used to provide additional fixation to the inferior edge of the mesh (Fig. 15.7) and it may help to reduce postoperative bruising.

15.2.10 Deflation of the Pneumoperitoneum

Throughout the procedure, the patient has been in Trendelenburg position and it is now time to place the patient in 15° head up. As this takes place, the surgeon positions two blunt instruments, usually the Dolphins and tack applicator, on either side of the spermatic cord as insufflation is stopped and gas is released by opening one of the valves. The scrub

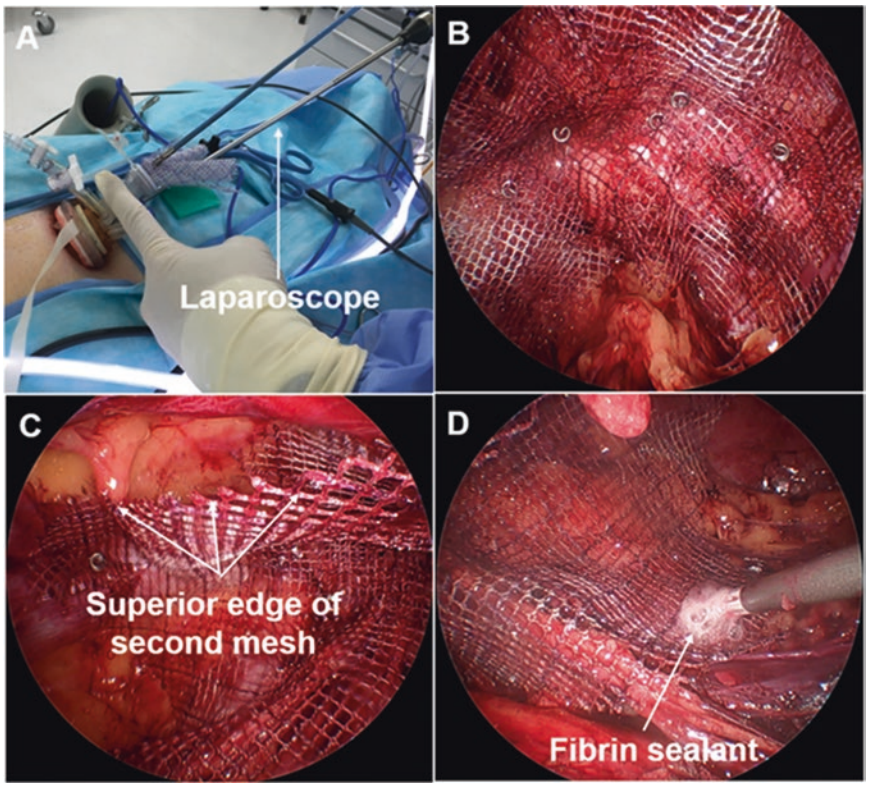

Fig. 15.7 (**a**) shows 5 mm laparoscope inserted into one of the 5 mm ports for direct visualization of the extraperitoneal space while the rolled up mesh is introduced into extraperitoneal space via 10 mm port, (**b**) shows 15–15 cm mesh positioned centrally over the direct defects and fixed onto pubic rami with nonabsorbable tacks, (**c**) shows additional 12–15 cm mesh placed on the left side to fully cover the deep inguinal ring, and (**d**) shows an additional mesh placed on the right side with fibrin sealant sprayed along inferior aspect of the mesh

nurse is asked at this stage to place a finger over the open tap and release in a controlled manner so that the peritoneum can be observed descending onto the mesh without lifting its inferior edge up. This crucial step can take place in just a few seconds and therefore all team members must work in synchrony to ensure complete success. Should the surgeon be unable to visualize the descent of the peritoneum onto the mesh without lifting it up then it is imperative that the extraperitoneal space is reinflated and the deflating process repeated to ensure satisfactory mesh positioning.

For bilateral hernias this step is slightly trickier and needs to be even more controlled. The peritoneum on the left side will descend first because of the sigmoid colon and once this has taken place the side arm of the scope is rotated to observe the right side next. In this respect, application of fibrin glue to the right side during bilateral inguinal hernia repair assists with adequate fixation and minimizes the risks of displacement of the right mesh.

15.2.11 Closure of the Umbilical Wound

Having removed the single-port device and instruments the anterior rectus sheath is now closed using slowly dissolved monofilament in a continuous fashion. Due to the small incision and with repeated insertion of instruments and/or overzealous retraction, the inferior edge of the umbilical wound is almost always traumatized and it should be excised to healthy tissue without lengthening the incision. The author considers this step paramount in achieving virtually zero wound infection and a highly cosmetically pleasing scar. The skin wound is now closed with dissolvable monofilament continuous in two layers. Tightening of the subcuticular stitch will usually shorten the wound at this stage, and in time, the wound will become even smaller (Fig. 15.8). The wound is then dressed with tapes and a waterproof dressing.

15.2.12 Discharge Instructions and Follow-Up

Up to 95 % of cases can be discharged on the same day under the supervision of a responsible adult with instructions to wear supportive briefs and to take analgesics and an aperient with a view to be seen in 1 week for follow-up. Patients are encouraged to mobilize on discharge with progressive return to normal activities within 1–2 weeks depending on pain threshold. Further, they are warned of possible scrotal bruising but are reassured that it will subside within a week, and an emergency contact number should be provided to allay their fears.

15.3 Discussion

Unlike the transition from open to laparoscopic surgery, such as cholecystectomy, where the advantages were overwhelmingly in favor of laparoscopy [13], single-port compared to

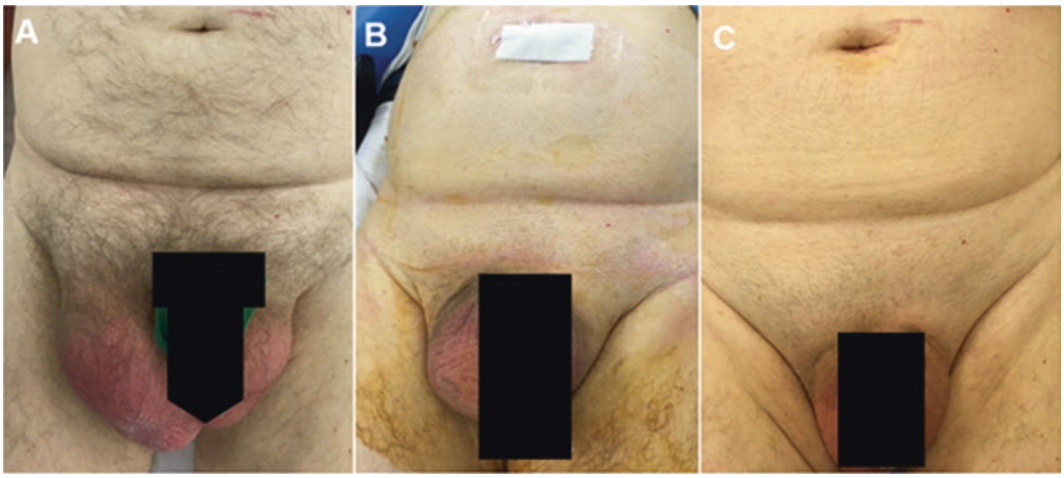

Fig. 15.8 The photographs of the same patient illustrated in Fig. 15.6: (**a**) shows bilateral inguino-scrotal hernias, (**b**) shows immediate post-op appearance after SIL TEP inguinal herniorraphy, and (**c**) shows appearance 4 weeks post-op with invisible infra-umbilical scar

multiport surgery is never going to have as much an impact. However, any incremental improvement, albeit small, when magnified by the very large number of patients undergoing a common procedure, will have significant overall impact in patient outcomes.

Evidence-based medicine dictates the performance of well-designed prospective randomized controlled studies with sufficient power to detect small differences in outcomes. In SIL TEP inguinal herniorraphy, there are currently only three RCTs all with about 100 patients each [10, 14, 15]. In addition, there are many other smaller prospective comparative studies which include the learning curves in their results. Despite these shortcomings, a recent meta-analysis of single-port compared to multiport TEP inguinal herniorraphy has shown the former to be safe [16]. The author's own RCT [10] showed significant improvement in postoperative pain on day 1 and 7, reduction in analgesic intake, earlier return to work or physical activities by 1 week, better cosmesis, and more importantly similar operation times for single-port compared to multiport inguinal herniorraphy. Of note is the fact that the RCT was conducted after the principle operator, a dedicated laparoscopic herniologist, had performed in excess of 1500 cases of multiport and 300 cases of single-port repairs, truly past the learning curve, and that the study uptake rate was 100 %. Furthermore, all study parameters were kept identical between the study groups, i.e., same mesh prosthesis, fixation device, conventional dissecting instruments, and similar port devices for either study group; the only difference was one versus three incisions.

In the quest for advancement of surgery, any alternative procedure which increases the repertoire of the surgical skills should be applauded as long as its safety is assured. Of fundamental importance is that telescopic dissection of the extraperitoneal space during SIL TEP repair mimics the dissection achieved by transabdominal preperitoneal repair (TAPP), one contested advantage of TAPP versus TEP. The author had also shown that omitting the (expensive) balloon dissection actually made SIL TEP repair highly cost-effective [17]. This is often an argument used against introduction of new technology.

The use of purpose designed single-port devices with low profile internal ring and collapsible plastic sleeve, such as the Triport system, means that the skin and fascial incisions are as small, if not smaller, than the infra-umbilical incision for multiport repair. Of significance is that it will not cause any increase in the incidence of port site hernias which is quite rare for TEP repairs. Further, elimination of the insertion of two additional sharp trocars, as is necessary in multiport repair, will negate any risks of trocar-induced vascular and/or bowel injuries. At least one additional advantage of SIL TEP inguinal herniorraphy has already been identified and that is that it not only diagnoses incidental Spigelian hernias but that the latter can be successfully treated at the same operation [12].

The relatively high incidence of groin hernias allows general surgeons to upskill in SILS relatively quickly and such skills can then be applied to more difficult abdominal wall hernias such as ventral and parastomal hernias [18–20]. Given the safety of single-port compared to multiport TEP repair, and the relative cost advantage of the former when telescopic dissection is employed, this should encourage more surgeons to convert to SILS and become the "young guns" whose quest is to push the boundary of medical science for the benefit of patients. In the end, the plethora of freely available information on the internet will allow primary physicians and patients to make up their mind whether SIL TEP repair will propagate and become the gold standard in the future.

What has been written so far concerns SIL TEP repair. However, the same single-port devices (including home-

made ones) and modified dissection techniques can be applied to SIL TAPP repair with similar safety profile. However, due to the loss of triangulation with SILS, closure of the peritoneal defect by suturing, as mainly occurs in conventional multiport TAPP repair, will significantly increase operative time [21]. There is also evidence to suggest that single-incision laparoscopic surgery that involves entering the peritoneal cavity via the umbilicus is associated with a higher incidence of trocar-site hernias [22]. Additionally, there are currently no randomized controlled studies comparing single-port versus multiport TAPP inguinal herniorraphy, and therefore strong recommendations for single-port as an acceptable alternative to multiport TAPP repair must await further studies.

15.4 Conclusion

In this chapter, the technical aspects including tips and tricks of SIL TEP inguinal herniorraphy have been described in detail to enable any competent and motivated surgeon, in conventional endoscopic repair, to rapidly convert to single-port repair with minimal effort. The author truly believes that this transition is highly rewarding both personally and having the potential to improve patient outcomes.

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Emerging Technology: Robotic Inguinal Hernia Repair

16

Zachary F. Williams, W. Borden Hooks, and William W. Hope

16.1 Introduction

Inguinal hernia repair is one of the most common general surgical procedures. Many techniques have been described ranging from open anterior and posterior repairs, primary tissues repair, to laparoscopic repairs. There is no general consensus concerning the ideal technique to repair inguinal hernias. Therefore, surgeons should be skilled in several techniques and should tailor the surgical technique used to individual patient requirements.

The most common outcome measure related to inguinal hernia repair is recurrence. Increasingly, other outcome measures including pain and quality of life are applied to this patient population. Several described techniques for open and laparoscopic repair of inguinal hernias have proven long-term efficacy with low recurrence rates and other favorable outcome measures. In an ongoing effort to improve patient care, surgeons continue to improve on surgical techniques for repair of inguinal hernias focusing not only on recurrence rates but also on quality of life, pain, and applicability of techniques to the general population.

The use of robotic surgery is an important milestone in surgical history. Although initially used in gynecologic and urologic surgery, general surgeons are adopting robotic techniques for general surgical operations. With more availability and access to robotic equipment and the commonality of hernia surgery, robotic surgery is increasingly used for hernia repairs. Although still considered an emerging technology in hernia surgery, some surgeons have embraced this technology and use robotic techniques for these operations daily. As robotic technology is more widely used and robotic technology and outcomes are critically appraised, we can more fully evaluate the role of robotic surgery in inguinal and hernia surgery in general.

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16.2 Rationale

The rationale for using robotic surgery techniques for inguinal hernia repair is similar to that for other surgeries with a few caveats. The traditional proposed advantages of robotic surgery include improved visualization, dexterity, and ergonomics for the surgeon [1]. Another potential advantage is that robotics may facilitate using minimally invasive techniques for technically difficult surgeries that may otherwise be difficult to accomplish laparoscopically. This may be an important advantage for minimally invasive or laparoscopic inguinal hernia repair. Although many surgeons are skilled with laparoscopic inguinal hernia repair, it is a difficult procedure to learn with reported learning curves up to 250 cases [2]. Adoption of the laparoscopic approach to inguinal hernia repair has also been slow, even as indications have broadened to include recurrent and bilateral inguinal hernia repairs. Although in some patient populations the use of laparoscopic inguinal hernia repair is growing [3], the relative slow adoption of the technique is likely due to some educational and technical gaps with learning the procedure [4, 5]. If the robotic technique can shorten the learning curve or improve adoption of the minimally invasive approach to inguinal hernia, then it must be considered a viable approach, and efforts to evaluate this technology for inguinal hernia repair are warranted.

16.3 Techniques for Robotic Inguinal Hernia

The technique for robotic inguinal hernia repair is based on the laparoscopic transabdominal preperitoneal (TAPP) approach and should replicate this well-described procedure. As with the TAPP procedure, several key principles must be adhered to in the robotic approach to achieve similar outcomes. These include dissection of the entire myopectineal orifice and all potential hernia spaces (including inferior

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_16

dissection of the peritoneum off of the vas and deferens/cord or round ligament), placement of a large mesh prosthetic that extends below the pubis and is fixed properly.

The following description uses the Da Vinci Si robot model. Laparoscopic access is obtained per the surgeon's preference and is typically done through an open cut-down technique (either a Hasson or umbilical stalk technique [6]) just above or below the umbilicus. An 11- or 12-mm trocar is placed and the abdomen inspected with a 10-mm 30° camera. After the presence of an inguinal hernia is confirmed, the patient is placed in Trendelenburg position, and two 8-mm ports are placed bilaterally approximately 10-cm lateral to the supraumbilical port (Fig. 16.1). The robot is then docked from a side position (Fig. 16.2), allowing for repair of bilateral inguinal hernias. The newer Da Vinci Xi model facilitates easier set up and more inferiorly placed ports.

A 30° up-facing camera is used along with a grasping forceps (Prograsp™ forceps) and scissors with electrocautery. The peritoneum is incised from the medial umbilical ligament to the anterior superior iliac spine. A preperitoneal flap is then created using primarily blunt dissection with occasional use of electrocautery (Fig. 16.3). After an adequately sized peritoneal flap is made, attention is turned to the pelvic floor dissection, which should be similar to that in a laparoscopic TAPP procedure. At this point, it is useful to change out the scissor arm for another Prograsp™ or Maryland forceps. The dissection starts medially with identification of the pubis and Cooper's ligament. The dissection is then taken laterally, identifying the inferior epigastric vessels and dissecting posterolateral to the hernia sac and cord structures. Using blunt dissection, the hernia sac is detached from the cord structures. Occasionally when working with large hernias, the sac is transected. This will require eventual closure of the peritoneal defect. If a lipoma of the cord is present, it should be reduced and excised or left in the retroperitoneum. After the dissection is complete, the vas deferens, spermatic vessels, iliac vessels, and pelvic floor anatomy should be in plain view (Fig. 16.4).

Attention is then turned to mesh placement. One of the potential benefits of laparoscopic or robotic inguinal hernia repair is the ability to place a large mesh prosthetic in the inguinal region that will cover all potential hernia defects. Usually at least a 10 × 15-cm mesh can be placed, and we often place a 12 × 15 cm mesh (Fig. 16.5). Mesh choice is left to the discretion of the surgeon, but an uncoated polypropylene or polyester mesh is often used. Several mesh technologies are used in robotic inguinal hernia repair. A newer self-fixing polyester mesh is sometimes used, because this mesh may not require fixation. This mesh, which can be difficult to place laparoscopically especially early in the learning curve, is likely easier to place using the robotic technique due to the better dexterity. This is likely why many surgeons have begun using this mesh. Other polypropylene meshes that are pre-shaped and conformed to the inguinal region may also be easier to place compared with flat sheets of mesh. However, currently there has been no evidence of improved outcomes using these newer mesh technologies.

The mesh fixation method is ultimately left to the discretion of the surgeon. However, there is continued debate on the ideal fixation method in laparoscopic/robotic inguinal hernia repair ranging from tack to suture to glue to no fixation. Since the cost of robotic inguinal hernia repair is a valid concern, surgeons should know the cost of various fixation methods in their hospital and try to minimize these

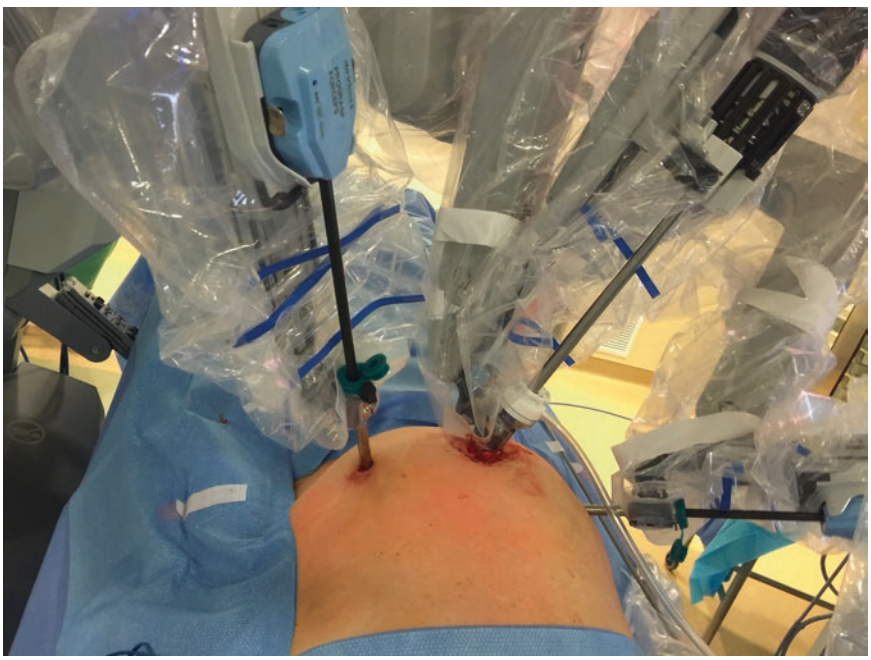

Fig. 16.1 Robotic inguinal hernia port set up, which is similar to that used in the laparoscopic approach (TAPP). An 11-mm trocar is placed either above or below the umbilicus and two 8-mm trocars are placed at approximately the mid-clavicular line just above the level of the umbilicus

Fig. 16.2 Side-docking of the robotic console with the console coming in from the feet on the patient's left side. The robotic surgeon is at the console and has control of the camera and two operating arms

costs if similar outcomes and efficacy can be achieved. Perhaps in an attempt to reduce costs with the robotic procedure and potentially decrease pain, some surgeons that traditionally used tack fixation have adopted suture fixation. In addition, many surgeons have also adopted suture fixation of the mesh due a clear benefit for some surgeons with the use of the robot for suturing compared with laparoscopic suturing. For suture fixation of mesh, the same principles apply as with the laparoscopic technique. Avoid fixation in the triangle of pain and doom to avoid potential vascular and nerve injuries. Our philosophy is to place sutures in a similar configuration to tack fixation. We typically place three-point fixation using slowly absorbable sutures at the pubis/Cooper's ligament and the anterior medial and lateral abdominal wall (Figs. 16.6 and 16.7). Suturing the mesh to Cooper's ligament is sometimes challenging. It can be made easier by switching the 30° camera from up to down-facing. Although suturing with the robotic technique is thought to be easier for most surgeons compared with laparoscopic suturing, there is still a learning curve. This is often the portion of the operation that increases operative time compared with using a laparoscopic approach. Several techniques can be employed to increase efficiency and decrease operative time as surgical skills improve with the robotic technique. Using short sutures often helps with suturing when multiple interrupted sutures are needed; however, placing and replacing needles through one of the robotic ports often increase the time of the operation. Early in mastering the robotic technique, some surgeons add an additional port to facilitate placing and replacing needles, so the robotic ports do not have to be removed. Other surgeons place the mesh and sutures needed into the abdominal cavity through the 11 mm port before docking the robot, so exchanges do not need to be made. However, the surgeon must ensure that these are not out of the field of vision or lost during the operation, since locating these can increase operative time. After the surgeon has mastered robotic suturing, another time-saving technique is to minimize the number of sutures by using longer sutures to fix all points of the mesh, so exchanges of sutures are minimized. After the mesh is fixed, the remaining Vicryl suture and needle are removed, and the peritoneum is closed. Again, peritoneal closure techniques are left to the discretion of the surgeon; however, the same logic for mesh fixation can be applied to peritoneal closure. Many surgeons use sutures to close the peritoneum since this can be done much easier using robotic technology. Although a running absorbable suture with knots placed on both ends is very effective and feasible for peritoneal closure, some surgeons use newer barbed sutures that may not require knot placement (Fig. 16.8). There have been no substantial data on the efficacy of these barbed sutures for peritoneal closure, although they are widely used. Surgeons disagree whether these sutures require knots tied at the end or whether back-tracking several throws at the end is sufficient to secure closure. Additional data are needed to fully evaluate this practice. There have been reports of peritoneal flaps reopening on repeat laparoscopy after using barbed sutures. This can cause bowel obstructions. These and other potential issues and complications related to peritoneal closure are important to consider when deciding which closure technique to use during robotic inguinal hernia repair. Further data on ideal mesh choices and fixation methods will likely be forthcoming as more surgeons adopt this technique using various fixation methods and meshes.

16.4 Literature

Few studies examine robotic inguinal hernia repair. The technique was first described in case reports and case series in conjunction with robotic prostatectomy [7–10]. No published studies compare laparoscopic TAPP with robotic TAPP. Only one published case series, by Dominguez et al., reports outcomes of 78 patients undergoing robotic TAPP without concomitant prostatectomy

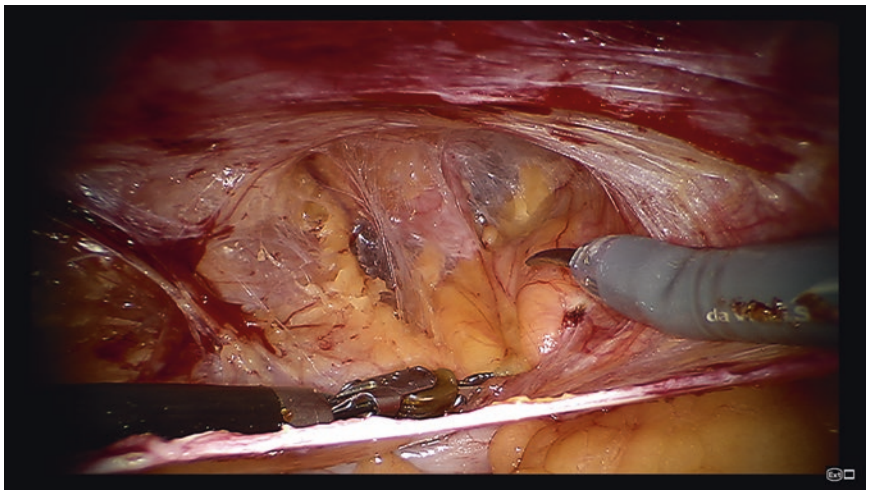

Fig. 16.3 Preperitoneal dissection using a scissors and Maryland dissector. Dissection should follow the same steps as for the laparoscopic TAPP operation

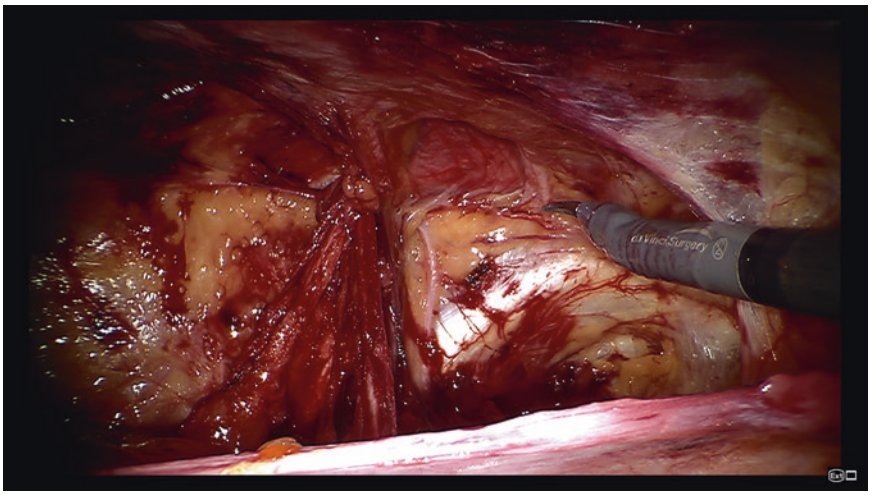

Fig. 16.4 Robotic inguinal dissection with reduction of the direct defect and dissection of the myopectineal orifice. Wide dissection allows for a large mesh placement and coverage of all potential hernia spaces. Inferior dissection of the peritoneum off the vessels and vas also helps prevent inferior recurrences

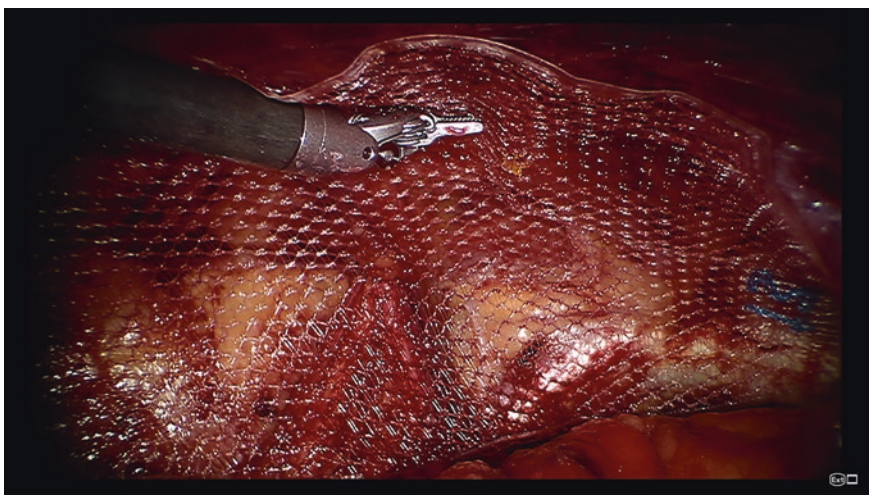

Fig. 16.5 Wide coverage of the direct hernia defect with a polypropylene mesh. The mesh covers and extends below the pubic bone and crosses the midline

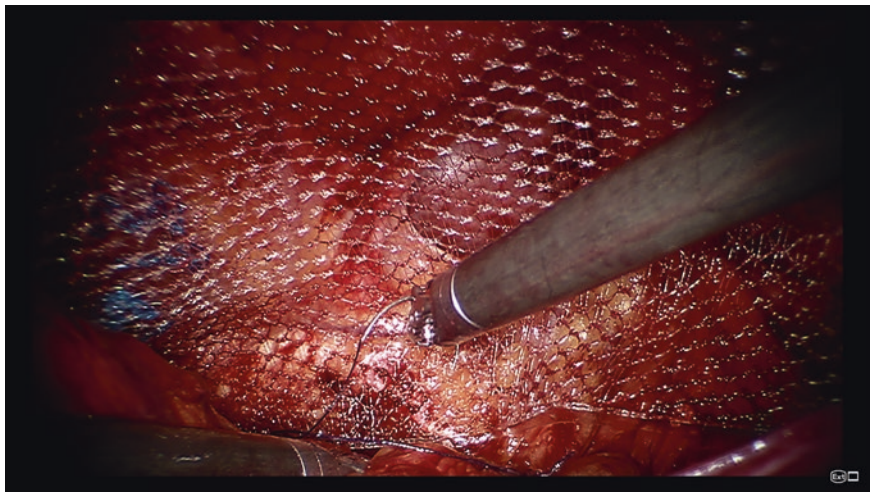

Fig. 16.6 Suture fixation of the mesh at the pubic bone/Cooper's ligament for a direct defect

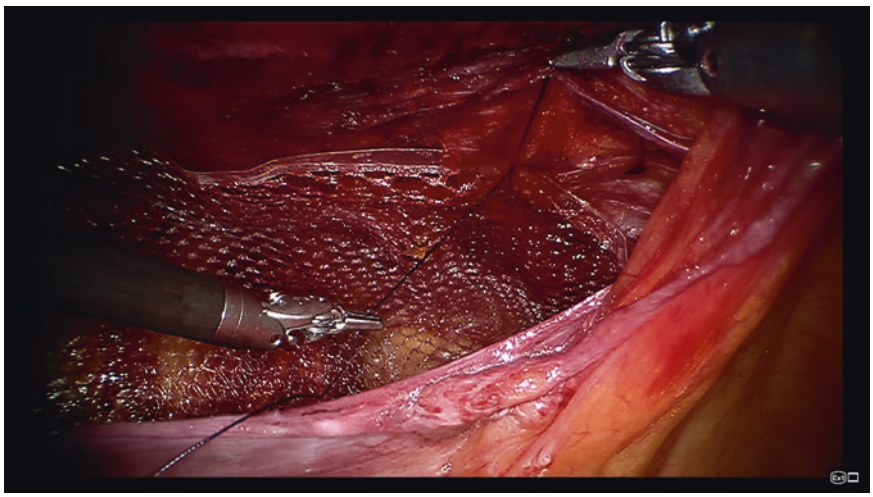

Fig. 16.7 Suture fixation on the anteromedial edge of the polypropylene mesh on the abdominal wall. Three-point suture fixation is similar to the tack fixation described for the laparoscopic approach

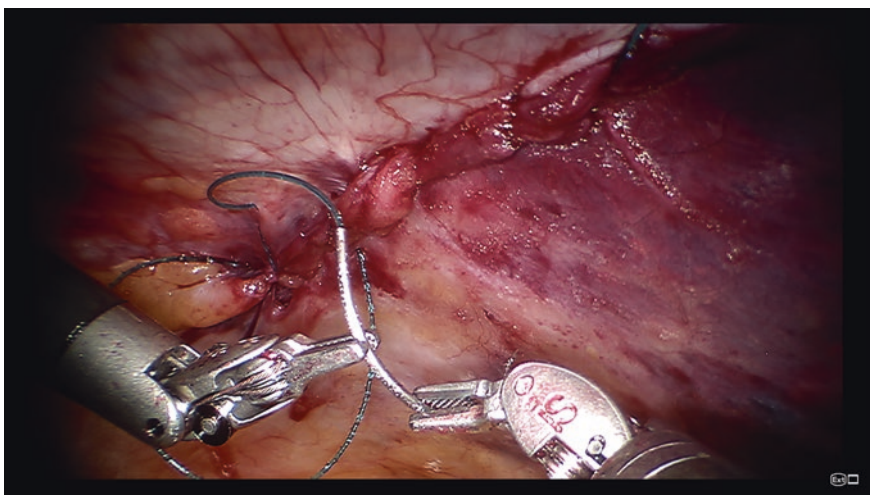

Fig. 16.8 Closure of the peritoneum using a barbed suture. The peritoneum has been closed with this running suture and now is being back-tracked to ensure secure closure

[11]. They report the safety and feasibility of this procedure with a 3.9 % hematoma rate, 2.6 % seroma rate, and 1.3 % surgical site infection rate and no mortalities or recurrences at 4 weeks follow-up [11]. These complication rates compare favorably with laparoscopic totally extraperitoneal (TEP) and TAPP repairs. Randomized studies directly comparing laparoscopic and robotic repairs with long-term follow-up and cost comparisons are needed to draw firm conclusions.

16.5 Controversies for Robotic Inguinal Hernia Repair

Controversies with regard to robotic inguinal hernia repair generally are related to efficacy and associated costs. While critics cite the potential increased cost of the robot in two well-described laparoscopic operations (TAPP and TEP) with good long-term efficacy and outcomes, cost comparison regarding the robotic technique is still in its infancy and may not be accurate. However, if using the robotic technique compared with the laparoscopic technique adds cost without appreciable benefit (i.e., no added value), then the robotic technique will not survive. Cost containment while using robotic technology should be a major focus for surgeons. Several areas of possible cost containment include minimizing instrument use, suturing of mesh and peritoneum rather than using tacking devices, and choosing less expensive mesh prosthetics. Cost calculations, however, can be quite variable among institutions based on several factors such as hospital contracts with industry for mesh and fixation products. Surgeons should be focused on cost reduction at the local level. However, as previously stated, cost should not be the only focus regarding robotic technology since the technology may assist surgeons in successfully completing complex minimally invasive procedures not otherwise possible using other technologies.

The efficacy of robotic inguinal hernia repair will be debated until good, long-term studies are published. Although the robotic approach to inguinal hernia repair should be similar to that of the laparoscopic TAPP, there may be minor differences such as in fixation or dissection of the preperitoneal space. Only comparison data will prove if this technique is efficacious. Currently several randomized, controlled trials are accruing patients and should help address the effectiveness for robotic inguinal hernia repair.

Outcomes related to robotic inguinal hernia repair must be compared with other techniques to identify possible differences in outcome associated with the procedures. One proposed advantage of robotic inguinal hernia repair is that suturing of mesh and peritoneum are easier and may cause less pain than tacking of the mesh and peritoneum. Currently there is no consensus on whether methods of fixation significantly alter pain, and determination of this will require further study.

16.6 Future Directions for Robotic Inguinal Hernia Repair

Future directions for using robotic technology in inguinal hernia repair are multifaceted. Several investigators are evaluating how this technology and methods might be applied to the TEP repair. The use of robotic surgery in inguinal hernia repair continues to be debated. However, after review of how this technology may be applied and the potential benefits of shortening the learning curve and enabling surgeons to use a minimally invasive technique for inguinal hernia repairs, it is clear that robotic inguinal hernia repair should be further investigated. Several randomized trials are underway including a multicenter trial comparing robotic inguinal hernia with conventional laparoscopic inguinal hernia. In addition, several new robotic platforms will likely be available in the coming years that may address some of the current shortcomings with the current devices and may drive cost down. Educational efforts including new robotic curriculums and residency training will no doubt have a large impact on the shortening of the learning curve and familiarity of robotic techniques to the general surgeon. With these efforts, further research, and the addition of registry data to document real world use and outcomes, we can better analyze the role for robotic surgery in inguinal hernia repair.

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Outcomes in Inguinal Hernia Repair

17

Munyaradzi Chimukangara and Matthew I. Goldblatt

Inguinal herniorrhaphy is one of the most common procedures performed by surgeons worldwide reflecting how prevalent the disease process is. In the past, this disease process was managed exclusively by open techniques, but is now seeing a movement towards minimally invasive techniques—more so in the developed world. While the initial focus in inguinal herniorrhaphy was to reduce recurrence, later achieved with the Lichtenstein technique, focus has more recently shifted to other outcomes such as reduced postoperative complications, chronic pain, early return to normal activity, and better cosmesis [1]. The desire to improve outcomes continues to drive the evolution of surgical management techniques. The 1990s brought about the rise of minimally invasive techniques with the adoption of laparoscopy, and more recently the addition of robotics technology continues to expand the field. In this section, we summarize inguinal herniorrhaphy outcomes; postoperative pain, quality of life, recurrence, and complication rates, as they pertain to the open and minimally invasive techniques in repair of inguinal hernias.

Open inguinal hernia repair has been the long-standing technique of choice, and continues to be so in most of the world including the United States [2]. The two popular open surgical techniques based on recurrence data are the Shouldice tissue repair technique and the Lichtenstein tension-free repair technique. Though the two techniques are largely comparable in terms of chronic pain, complications, and hospital length of stay, the Lichtenstein technique is superior in recurrence data [3]. Recurrence rates for open non-mesh repairs have historically been around 4–10 % in the hands of experts, and the adoption of the Lichtenstein technique has brought the rate down to 1–4 % [4–6]. A Cochrane review demonstrated the recurrence rate with the Shouldice technique was high when compared to open mesh techniques (OR 3.80; CI 1.99–7.26), while low when compared to other non-mesh techniques (OR 0.62; CI 0.45–0.85) [7]. On the other hand, when compared to open tissue repairs the recurrence rate following the Lichtenstein technique was low (OR 0.37; CI 0.26–0.51) [8]. Hence, when mesh is not contraindicated, the Lichtenstein technique continues to be the mainstay for open inguinal hernia repair [9].

With the development and introduction of minimally invasive techniques, outcomes based on these techniques continue to be compared amongst themselves and to the Lichtenstein technique. Laparoscopic techniques are increasingly in use, mostly in the developed world, and outcomes data is promising. In the early years when compared to open techniques, laparoscopic techniques had worse recurrence rates, 10.1 % versus 4.9 %, and were more expensive secondary to the required specialized instruments [10]. However, as laparoscopic technology and techniques have developed over the years recurrence rates following laparoscopic inguinal herniorrhaphy have fallen to similar rates when compared to the standard mesh-based open techniques [5]. In addition, a meta-analysis of randomized clinical trials demonstrated that laparoscopic techniques provide benefits when compared to open techniques, evident in shorter hospital stay, diminished acute postoperative pain, improved recovery time with return to normal activities sooner, and better cosmesis [11, 12]. In addition, a long-term randomized study of 314 patients managed with totally extraperitoneal (TEP) and transabdominal preperitoneal (TAPP) repairs demonstrated that the two laparoscopic techniques have similar outcomes pertaining to chronic pain, quality of life, and time to return to work [13]. Thus, minimally invasive techniques have a strong role in the repair of inguinal hernias.

Some degree of postoperative pain is common and expected following surgery. However, persistent pain becomes a problem. Chronic pain has been defined as surgical site pain persisting beyond 3 months [14]. The incidence of chronic pain following open inguinal hernia repair has been reported at 18 %. Meanwhile the incidence following laparoscopic repair is 6 % [15]. Sajid et al. notes that the etiology of chronic pain is unclear, but is thought to include inguinal nerve irritation by suture or mesh, inflammatory reaction to mesh and foreign

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_17

material, scaring incorporating inguinal nerves, and abdominal wall compliance reduction [16]. In a 2014 update to the European Hernia Society (EHS) guidelines based on meta-analysis data there was no difference in chronic pain after Lichtenstein when compared to TEP hernia repair [17]. However, a review of prospectively collected data with 17,388 patients demonstrated worse pain on exertion in the Lichtenstein group (OR 1.420; CI 1.264–1.596) at 1 year postoperatively with a rate of 9.23 % compared to 7.90 % in the TEP group, and overall prevalence of 8.7 % [18]. Hence, laparoscopy seems to reduce chronic postoperative pain compared to open repair.

Research is ongoing in attempt to reduce acute and chronic pain following hernia repair, and to allow for faster return to normal activity. In the minimally invasive realm, investigators are actively experimenting with mesh types and mesh fixation options. A review of a prospective database of 227 patients managed with the TAPP hernia repair approach demonstrated better pain scores at 2 and 4 weeks postoperatively in the group with the peritoneal flap closed by suture compared to the group managed with tacks, and there was no difference between the suture and staple groups [19]. However, in the same study, activity limitation at 2 weeks postoperatively was worse in the stapled group (57.9 %) compared to the sutured group (21.7 %). There was no difference in pain or activity limitation between the tack and staple groups, suggesting superiority in outcome in the sutured group. Other researchers in a prospective comparison between TEP, TAPP, and Lichtenstein repair have shown that use of >10 tacks doubles the incidence of postoperative pain without affecting the recurrence incidence [20]. However, in a meta-analysis of randomized controlled trials Tam et al. found no difference in postoperative pain following staple fixation versus non-fixation in TEP repairs [21]. This goes to show that the current data is non-conclusive on superior mesh fixation techniques or the standard surgical technique to minimize postoperative pain.

The meta-analysis data leading to the 2014 update to the EHS guidelines demonstrated no difference in the recurrence rate following Lichtenstein and laparoscopic repair of inguinal hernias [17]. This observation has also been demonstrated in a review of prospectively collected data with 17,388 patients, with a 1 year recurrence rate of 0.83 % versus 0.94 % when comparing Lichtenstein to TEP repair, respectively [18]. One year postoperative data by Mayer et al. following 11,228 patients who underwent TAPP repair for a primary inguinal hernia demonstrated a similar recurrence when mesh was fixed (0.88 %) versus not fixed (1.1 %) [22]. In addition, the International Endohernia Society (IEHS) has published that there is no difference in recurrent rates when comparing fixed or non-fixed mesh in repair of small hernias (<3 cm) repaired with laparoscopic techniques [23]. This goes to suggest that better mesh options now exist, allowing for less need for mesh fixation thereby reducing potential cost and pain that may come with fixation techniques.

Surgical complications lead to undesired morbidity and potential mortality. Kockerling et al. demonstrated a higher postoperative complication rate following Lichtenstein repair in comparison to TEP repair in their review of prospectively collected data on 17,388 patients (OR 2.152; CI 1.734–2.672), and a prevalence rate of 3.2 % [18]. When comparing TEP versus Lichtenstein repair, the data demonstrated a postoperative bleeding rate of 1.16 % versus 2.46 %, a seroma rate of 0.51 % versus 1.48 %, wound infection rate of 0.06 % versus 0.26 %, and wound healing disorders of 0.07 % versus 0.35 %, respectively [18]. The above study failed to demonstrate a difference in intraoperative complication rates when assessing for vascular injury, bowel injury, and bladder injury, with overall rates <0.28 %. However, intraoperative bleeding was higher in the TEP repair group (0.76 %) compared to 0.41 % in the Lichtenstein repair group. When comparing TEP to TAPP complications, data has largely been of limited quality and suggests overall similarities in outcomes. A recent small prospective randomized trial of 60 patients failed to show a difference in 30 day postoperative outcomes (urinary retention, hematoma, seroma, wound infection, pain, return to normal activity, and recurrence) between the two techniques [24]. However, in a large prospective review of 17,587 patients, Kockerling et al. demonstrated that the overall surgical complication rates were higher for TAPP (3.97 %) when compared to TEP (1.70 %) [25]. The noted difference was largely secondary to a higher seroma rate in the TAPP group (3.06 %) versus 0.51 % in the TEP group. In their discussion, the difference could be explained by the higher number of large defects and scrotal hernias in the TAPP group. The study also suggested a higher postoperative bleeding rate in the TEP group (1.18 %) compared to the TAPP group (0.82 %). Overall, it appears laparoscopic techniques have lower postoperative complications relative to open techniques, while TEP and TAPP outcomes are largely comparable.

Minimally invasive techniques continue to evolve affecting other inguinal herniorrhaphy outcomes such as small bowel obstruction and urinary retention. In a series of 3017 patients undergoing TAPP repair, Kapiris et al. demonstrated a reduced incidence in small bowel obstruction from 0.8 % with closure of the peritoneal flap with tacks to 0.1 % when suture closure was adopted [26]. Others have shown a small bowel obstruction incidence of 0.2–0.5 % following the use of tacks to close the peritoneal flap [27]. This complication of small bowel obstruction is extremely rare following open inguinal herniorrhaphy, only described in case reports with mesh migration as the etiology [28]. Urinary retention incidence following laparoscopic techniques is anywhere between 0.2 and 35 % based on various studies; however, the true rate is thought to be 2–7 %. Ross et al. in a 227 patient prospective database study of hernias repaired using the TAPP approach demonstrated a urinary retention rate of 4.9 % with no statistical difference between peritoneal flap closure with tacks, staples, or suture [19]. A meta-analysis of

Table 17.1 Summary of inguinal herniorrhaphy outcomes by repair type

Postoperative outcomes	Open repair with no mesh	Open repair with mesh	Laparoscopic repair	Robotic repair
Recurrence	4–10 %	1–4 %	<5 %	Limited data
Chronic pain	6 %	6–18 %	6 %	Limited data
Short-term quality of life	–	Inferior to laparoscopic repair	Superior to open repair	Appears to be superior to open repair
Long-term quality of life	–	Similar to laparoscopic repair	Similar to open repair	Limited data
Postoperative bleed	–	2.46 %	1.16 %	Limited data
Seroma	–	<5 %	<5 %	Limited data
Wound infection	–	0.2–0.6 %	0.06 %	Appears similar to laparoscopy
Wound morbidity	–	0.35 %	0.07 %	Appears similar to laparoscopy
Urinary retention	<2 %	<2 %	2–7 %	Limited data

randomized controlled trials by Tam et al. demonstrated an incidence of urinary retention following TEP with mesh fixation at 3.10 % compared to 1.01 % without fixation [21]. In a prospective study of 471 patients, Vigneswaran et al. demonstrated a urinary retention rate of 3.3 % in patients <65 years and 15.7 % for those older following laparoscopic herniorrhaphy [29]. On the other hand, open repair techniques have an overall lower urinary retention rate when compared to laparoscopic techniques. Such is the case given that general anesthesia, an integral component of laparoscopic techniques, is thought to be the main cause of urinary retention after hernia repair. Following inguinal herniorrhaphy with local anesthesia, Finley et al. demonstrated a urinary retention rate of 0.2 % in comparison to a rate of 13 % among patients managed with general or spinal anesthesia [30].

Lastly, robotic inguinal hernia repair is the new minimally invasive technique in practice. Robotic inguinal herniorrhaphy has largely been described by urologists using the TAPP technique concurrently with robotic prostatectomy [31, 32]. Though some general surgeons are currently implementing the robotic TAPP technique into practice, the role of robotics in inguinal herniorrhaphy remains unclear and literature is lacking. Escobar et al. have the largest general surgery published experience with robotic TAPP and discuss their experience with 123 patients [33]. In their retrospective review of robotic TAPP repairs performed by three minimally invasive surgery trained surgeons, they noted their outcomes were comparable to laparoscopic techniques. The surgical postoperative complication rate was 7.7 % (hematoma 3.9 %, seroma 2.6 %, and surgical site infection 1.3 %). Urinary retention was 1.3 %, and same day discharge was achieved in 76.9 %. Overall mean surgical time was 104.3 min. However, due to the retrospective nature of the study, the authors were not able to assess postoperative acute and chronic pain, nor hernia recurrence. Nonetheless, they concluded that robotic TAPP like laparoscopic techniques offers better overall outcomes in comparison to open repair, and may have a role in increasing minimally invasive intervention options considering the open repair techniques continue to dominate worldwide in this disease process.

In summary, open inguinal hernia repair with mesh remains the main stay of surgically managing inguinal hernias. Laparoscopic techniques are revolutionizing the field by providing better outcomes in terms of postoperative pain, early return to normal activity, quality of life, and surgical site wound morbidity. Recurrence data between Lichtenstein, TEP, and TAPP are similar. Overall outcomes data comparing TEP and TAPP have proven to be similar in experienced hands as laparoscopic techniques are difficult to learn, and one has to achieve the learning curve in order to have meaningful results. Nonetheless, robotic TAPP appears to be safe, effective, and is appealing in this age of increasing technology [34]. However, more data is needed to better understand the role of robotics technology in inguinal herniorrhaphy as it compares to the current mainstay techniques. Hence, based on outcomes, international guidelines recommend inguinal hernia repair with either the Lichtenstein or a laparoscopic approach [9, 35].

Table 17.1 gives a summary of inguinal herniorrhaphy outcomes by repair type.

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Prevention and Evaluation of Chronic Groin Pain

18

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18.1 Risk Factors

Chronic postoperative pain is a fearsome complication after inguinal hernia repair.

Some risk factors for persisting postoperative pain have been identified: increased preoperative Activity Assessment Scale (AAS) score, preoperative pain to tonic heat stimulation [1], early (valuated at 1 week [2] and 1 month [1] after surgery) postoperative pain, nerve damage (assessed as sensory dysfunction in the groin at 6 months) [1], open surgery [1, 2], and younger age [3, 4].

18.2 Selection of Patients

The best way to prevent chronic postoperative pain is, like always in surgery, to do a good diagnosis, select the proper technique (not only the approach but also the mesh and its fixation), and do it in the best way we can.

Patients with unusual preoperative inguinal pain in an imperceptible hernia must be evaluated with attention and often a proper physical examination and clinical history investigation reveal a different cause for their pain: back disease, hip pathologies, pubic bone or tendon injuries, etc.

Among all pathologies that can cause inguinodynia, the so-called pubic inguinal pain syndrome (PIPS) [5] or sportsman hernia is often wrongly labeled inguinal hernia and treat like it were. We want to strongly underline that PIPS is a situation that can occur not only in sportsman, but also in population with normal physical activity and that it absolutely is not a real hernia. This has to be deeply kept in mind when we deal with a case of postoperative chronic pain: indeed this could be the results of a misdiagnosis and an uncorrected treatment.

Pain in PIPS is usually well localized, and tends to be focused on the pubic bone with radiation superiorly to the abdominal rectus insertion and inferiorly to the adductor longus insertion. The pain is typically provoked by the movement of the legs and by athletic activities of kicking, sprinting, and changing directions, the symptoms usually persist all the day after, they improve after resting and recurs if athletic activities are resumed. Physical examination reveals effort and tenderness or pain over the pubic crest on resisted sit-up (abdominal crunch test). The touch of the internal ring can be painful and only a small bulge of the inguinal posterior wall can be detected during coughing, but a palpable lump indicating classical inguinal hernia is absent. During the adductor test patient feels a sharp pain in the groin [6].

So for all these reasons, it is evident that surgery should not limit the treatment to the posterior wall but also includes release of the three nerves of the region and partial calibrated tenotomy of abdominal rectus and adductor longus, otherwise preoperative pain relief cannot be completely achieved [6].

18.3 Selection of Technique and Approach

Different open mesh repairs (PHS, mesh and plug repair and Lichtenstein) have been compared and no clinically relevant differences in chronic pain have been showed at long-term outcomes (follow-up range 6.9–9.2 years) [7].

In order to decrease an extensive dissection in the inguinal canal with less manipulation of the inguinal nerves [8] and to minimize the interaction between the foreign material

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_18

of the mesh and the spermatic cord as well as the nerves, the placement of the mesh in the preperitoneal space is an option to be considered [9]. The preperitoneal placement of the mesh can be reached by laparoscopic approach or by open anterior approach or by open posterior approach.

In a meta-analysis of all randomized controlled trials (RCTs) comparing open inguinal hernia repair and laparoscopic inguinal hernia repair for primary unilateral inguinal hernia there was significantly reduced risk of chronic groin pain in those undergoing laparoscopic repair, but on subgroup analysis, when TAPP was compared with open approach, there continued to be a reduced risk of chronic groin pain, however, when TEP was compared with open approach, the reduced risk in chronic groin pain was not significant [10].

Laparoscopic TAPP surgery is recommended for those patients that, according to preoperative data on Activity Assessment Scale score and response to heat stimulation, are considered to be at high risk for persisting postoperative pain [1].

Willaert et al. [11] recently proposed with the Cochrane collaboration a review with the aim to compare the efficacy of an elective open preperitoneal mesh repair (Read-Rives technique [12], TIPP [11], and Kugel patch [13]) with the Lichtenstein technique. TIPP and Kugel Patch techniques reported less chronic pain; however, slightly more chronic pain has been reported after Read-Rives technique.

18.4 Identification of the Nerves

Several patterns of nerve injury during elective inguinal hernia repair have been described, including inadvertent suture entrapment, partial division, crushing, diathermy burn, or scar encroachment [14].

Identification and routine excision or division of selected inguinal nerves during inguinal hernia repair has been proposed as a method for avoiding postoperative neuralgia [15].

Studies reporting the results of the role of the identification of all three inguinal nerves [14, 15] concluded that identification and preservation of all the three nerves during open inguinal hernia repairs reduces chronic incapacitating groin pain to less than 1 % and the risk of developing inguinal chronic pain increased with the number of nerves concomitantly undetected [14].

For all these reasons, the authors strongly suggest the identification and protection of all three inguinal nerves and to not remove the nerves from their natural bed as much as possible and to not remove their covering fascia, as recommended in the International guidelines [16] (Figs. 18.1, 18.2, 18.3, and 18.4).

Just in case of a suspected or clear injured nerve or its running in the way of the repair, it could be completely removed and its proximal cut end implanted in the muscle [16].

Pay attention also during the placement of the mesh is suggested in order to avoid mesh bumping into nerve running (the medial edge of the mesh sometimes meets and crosses the ilioinguinal or often the iliohypogastric nerve): in this case neurectomy can be done or, better, a small window in the edge of the mesh can be cut so that the interaction between mesh and nerve is minimalized [17].

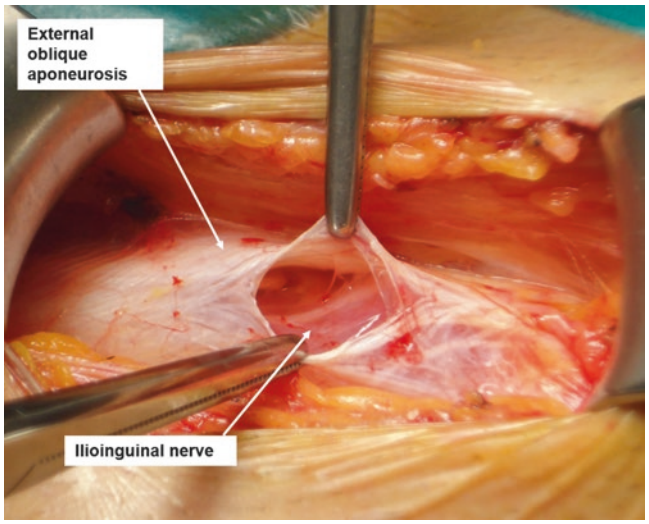

Fig. 18.1 Left inguinal region: ilioinguinal nerve is visible just underneath the external oblique aponeurosis

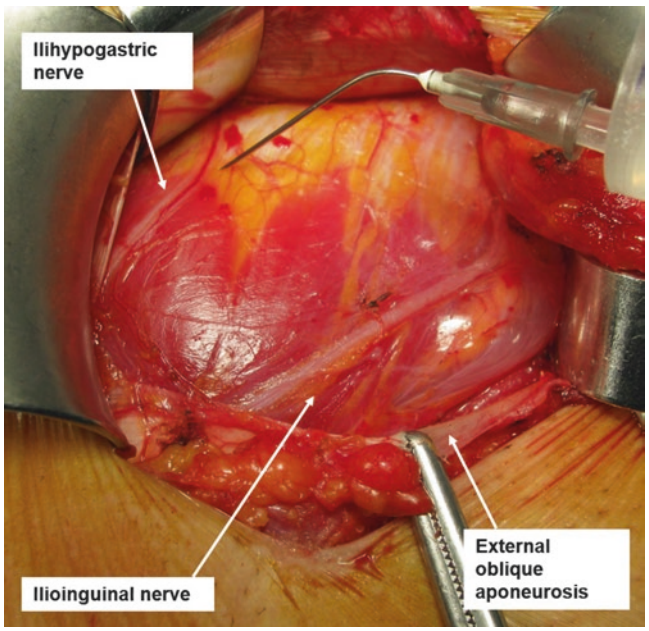

Fig. 18.2 Right inguinal canal: identification and infiltration of ilioinguinal and iliohypogastric nerve

18.5 Choose the Mesh: Lightweight vs. Heavyweight

Although the use of synthetic mesh substantially reduces the risk of hernia recurrence [18], polypropylene meshes have been found to cause chronic inflammatory reactions that

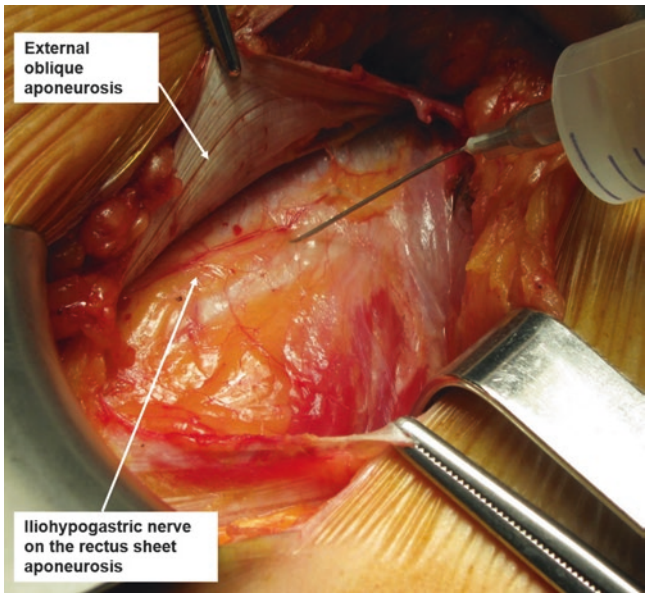

Fig. 18.3 Right inguinal canal: a trick to identify the iliohypogastric nerve is looking medially for the rectus muscle aponeurosis

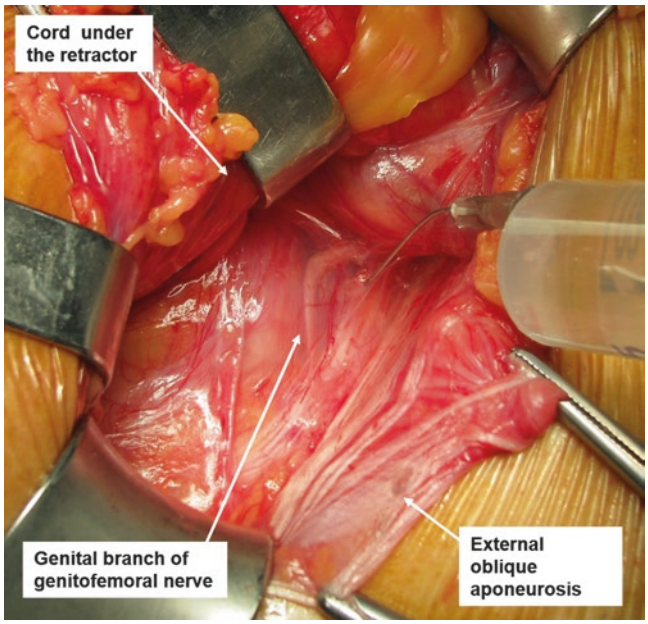

Fig. 18.4 Right inguinal canal: genital branch of genitofemoral nerve identified along the inguinal ligament, closed to the *blue line*

persist for years and can have potentially negative effects, including chronic pain [19].

It has been surmised that the extent of the foreign body reaction with its provoked scar tissue is correlated with the amount of the synthetic material used [20]. This led to the development of the so-called lightweight mesh characterized by a reduction in the polypropylene volume, an increase in the pore size, or different web structure [21, 22].

In open groin hernia surgery, several meta-analyses of randomized trials have now shown that lightweight (flat) meshes do not have an advantage in the short term, but are associated with less chronic (>6 months) pain and foreign body feeling [23, 24], although the incidence of severe chronic groin pain is not decreased [25]. Importantly, this does not increase the recurrence rate (follow-up range 6–60 months), although caution is still needed in large (direct) hernias with a potential increased risk for mesh migration into the defect, especially when some specific points for mesh fixation are not taken into account [26–31].

There is no sufficient evidence for such recommendation in endoscopic groin hernia repair [32], both with respect to short- or long-term outcome.

18.6 Choose the Fixation

Penetrating fixating or traumatic devices like sutures, staples, and tacks cause local trauma that may result in nerve injury and chronic pain and should be used therefore with caution (Fig. 18.1).

A multicenter RCT [33] has suggested that fibrin sealant may have a beneficial effect in chronic pain. In the recent systematic review proposed by Sanders [34], 12 trials comparing n-butyl-2 cyanoacrylate (NB2C) glues to sutures, self-fixing meshes to sutures, fibrin sealant to sutures, tacks to sutures, and absorbable sutures to nonabsorbable sutures were included. Although there was no significant difference in recurrence or surgical site infection rates between fixation methods, there is insufficient evidence to promote fibrin sealant, self-fixing meshes, or NB2C glues ahead of suture fixation.

Although several studies [35–43] proposed comparison between the types of fixation in lap approach (none vs. atraumatic vs. resorbable or non-resorbable fixation devices), analysis is seriously flawed by different factors, such as the way chronic pain is evaluated and the many independent variables (the type of repair, the type of hernia, the type of mesh, and the type, number, and location of the fixation devices). Thus, recommendations from the European guidelines are that, when using heavyweight meshes, traumatic mesh fixation in TEP endoscopic repair should be avoided (with exception for some cases like large direct hernias). Atraumatic mesh fixation in TAPP endoscopic repair can be used without increasing the recurrence rate at 1 year.

18.7 Clinical Assessment

During examination of a patient, a precise demarcation between nociceptive and neuropathic pain is not possible and the complexity of diagnosis is increased by social, genetic, patient, and psychological factors.

For these reasons, evaluation of the patient should always include neurophysiological assessment, preoperative characteristics (nociceptive functions, psychosocial factors, pain in other parts of the body), and the subministration of a validated inguinal hernia repair specific questionnaires.

Dermatome Mapping Test (DMT) has been proposed as a simple and cost-effective technique with the aim to characterize and communicate the multifactorial pain that patients present with and to discuss and form treatment plans in a logical fashion. It additionally provides a tool for postoperative assessment and follow-up to document and communicate the efficacy of interventions.

MMPI-2® (Minnesota Multiphasic Personality Inventory-2®) test has been proposed to value patient personality [44]. It is most commonly used by mental health professionals to assess and diagnose mental illness.

Normally a patient with postoperative chronic pain undergoes various radiologic evaluations, often without get to the cause of the pain. US should not be recommended as a first-line imaging modality to evaluate the postoperative groin after mesh implantation because it does not reliably identify the mesh, especially if it is folded, balled up, or otherwise complicated. Normal mesh material is often indistinguishable from surrounding tissue on CT due to the combination of low material density and minimal profile. On MR, flat mesh materials appear as dark linear bands on T1 sequences, slightly thicker than normal fascial planes, but may be more difficult to identify among their surrounding tissues on fluid-sensitive sequences. Dynamic MR sequences are particularly capable of identifying subtle herniation of peritoneal or preperitoneal fat, which may be missed by CT.

CT and MR can be useful in discerning a meshoma.

Entrapment, perineural fibrosis, and neuroma are all readily apparent on MR, presenting as T2 hyperintensity within the affected nerve. MR neurograms are specifically protocoled non-contrast MR images that allow for high-resolution evaluation of the peripheral nervous system, but suffer from low signal-to-noise ratios and should ideally be performed with a 3T magnet if available.

Moreover, a MR of lumbar-sacral column and pelvis is useful to identify a different cause of pain, other than postoperative pain.

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An Approach to Inguinal Pain

19

Kevin B. Walker

For many patients, pain can be one of the most difficult symptoms they experience. And, for physician, pain can be one of the most difficult symptoms to quantify and diagnose. Pain is defined by Steadman's medical dictionary as "an unpleasant sensation associated with actual or potential tissue damage, and mediated by specific nerve fibers to the brain where its conscious appreciation may be modified by various factors" [1]. Difficulties in diagnosis arise from the fact that pain can come from numerous sources, both physiologic and psychologic. Pain can be referred, meaning it arises from location other than the perceived location. Pain can be classified as acute, chronic, nociceptive, neuropathic, visceral, and even psychogenic. Before one can begin treatment, many questions must be answered regarding the genesis of the patient's pain.

The approach to any patient with a pain complaint should begin with some basic questioning. Where is the pain located? Does the pain move around? What is the character of the pain? What is the intensity of the pain? When does the pain occur? Can the pain be associated with a specific activity or activities? Has the patient ever had surgery or trauma in the area before? The answer to these basic questions will be the foundation of further evaluation of the patient.

Once basic questioning is completed and those findings are addressed, a thorough physical exam should be performed to determine if there is an obvious defect which explains a patient's painful symptoms. These two approaches work together to determine the likely culprit: muscular, nervous, vascular, entrapped viscera, or psychological.

Anatomically, the inguinal region is a transition zone created by the connection of the lower portion of the anterior abdominal wall and the upper thigh. The superior lateral portion of this region is demarked by the anterior superior iliac spine (ASIS) and inferior medially by the pubic tubercle. Connecting these two points is the inguinal ligament formed by the inferior boarder of the external oblique aponeurosis, which creates the floor of the inguinal canal. Coursing within the canal is the spermatic cord in males and the round ligament in females. The frequency of hernias occurs in males more frequently secondary to the weakening of this region to allow for the descent of the testis [2].

The practitioner must determine whether the patient has had any previous surgeries that may refer symptoms to the inguinal region, as prior surgical intervention is likely to alter the native anatomical structures. Therefore, a detailed understanding of the anatomy is of utmost importance in evaluating a patient presenting with pain in the inguinal region.

Innervation of the inguinal region is equally important. The four major nerves are: (1) lateral femoral cutaneous, a sensory nerve to the lateral aspect of the thigh which arises from the L2 and L3 nerve roots. (2) Iliohypogastric innervates the lower abdominal wall and arises from the L1 nerve root. (3) Ilioinguinal innervates the anterior surface of the labia majora and scrotum, the root of the mons pubis and penis. (4) Genitofemoral, which branches into the genital and femoral branches. The genital branch innervates in the scrotum in males and the mons pubis and labia majora in females. The femoral branch innervates the skin of the anterior thigh of the femoral triangle [3].

In a patient without prior surgery and with no obvious hernia noted on physical exam, further diagnostic investigation should occur. Imaging such as CT scan can be done to rule out possibility of a small or occult hernia. Imaging may also provide other explanations for the inguinal pain external to the inguinal region such as changes within the hip joint. Other imaging modalities, such as magnetic resonance imaging (MRI), can provide a detailed view of soft tissue abnormalities and may be necessary in certain circumstances where obvious explanations are not found. Based on information provided by the imaging, history, and physical exam other diagnostic techniques such as injections may be necessary to determine etiology of the patient's inguinal pain.

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_19

If the patient's pain complaints are consistent with neuropathic pain, such as electric or shooting pains, further evaluation should focus on regions which refer pain to the inguinal region. One may consider imaging of the lumbar spine to look for a source. Likely magnetic resonance imaging would be required to determine if any compressive pathology on the upper lumbar spine could help determine the cause of the patient's symptoms. If these findings are in question, diagnostic injections, transforaminal epidural or selective nerve root blocks could provide additional information. If the injections are diagnostic and able to determine the location of the source of the pain, the injections could be repeated with the addition of steroids to hopefully extend their benefit versus starting neuroleptic agents.

If the imaging, intra-articular injections, or diagnostic spinal injections are all inconclusive consider evaluating the peripheral nerves previously mentioned. Utilizing ultrasound guidance these nerves can often be blocked by an injection of short-acting local anesthetic (i.e., 2 % lidocaine). If a specific nerve is determined to be the cause of the pain, options include exploratory surgery, use of a neuroleptic medication, or an ablative nerve procedure.

As the diagnostic workup of the patient may take some time, medications should be considered in an effort to provide immediate relief. Numerous classes of medication have been proven effective in providing relief for somatic, musculoskeletal, and neuropathic pain. More than one class of medication may be appropriate depending on the patient's symptoms. Medication classes include: (1) nonsteroidal anti-inflammatories (NSAIDs), (2) neuroleptic medication including antiepileptic drugs (AED), (3) antidepressant medications, (4) topical agent, (5) acetaminophen, and (6) opioid-based medications.

Nonsteroidal anti-inflammatories (NSAIDs) include numerous medications that can provide anti-inflammatory benefit. These medications were first used in the late 1700s by utilizing extracts from various tree bark and plants that was noticed to reduce fever. This compound was later determined to be salicylic acid, which has been synthesized and has evolved into newer compounds. The mechanism of action of these compounds is to block the production of prostaglandins. The development of inflammatory prostaglandins requires a cyclooxygenase (COX) enzyme. There are two isoforms of the cyclooxygenase enzyme, COX-1 and COX-2. With the blockade of the prostaglandin formation the inflammatory cascade can be truncated. There are numerous concerns when using anti-inflammatories including their disruption of a clotting cascade, the risk of causing gastrointestinal irritation bleeding. In addition to these, the development of selective COX-2 inhibitors showed an increase in incidents of myocardial infarctions and cerebrovascular accidents. The treating provider must keep these in mind when utilizing these medications [4].

Acetaminophen is often placed in the NSAIDs category, but is not truly an anti-inflammatory medication. It has similar antipyretic and analgesic effects compared to aspirin. The exact mechanism of acetaminophen is not known, but it has been shown to inhibit central development of prostaglandins but not peripherally. Acetaminophen is useful because it has very few side effects and does not inhibit the function of platelets. It also has very little effect on the GI tract. The biggest concern with acetaminophen visits liver toxicity with dosages over 4000 mg per day [4].

Neuroleptic medications are very useful in patients who have descriptions of neuropathic, shooting electric-like pain. These medications are used because of their ability to stabilize the membrane at the neural level as well as to inhibit the formation or slow the transmission of the pain. These medications are generally classified based on their site of action. Commonly used calcium channel modulators are gabapentin and pregabalin. These medications have been shown to be effective in painful neurologic conditions, including post herpetic neuralgia, diabetic peripheral neuropathy, complex regional pain syndrome (CRPS), and even in spinal cord injury associated pain conditions. By binding to the L-type voltage-gated calcium channel, neuroleptic medications cause a decrease in the release of numerous neurotransmitters and, therefore, the perception of pain. These neurotransmitters include glutamate, norepinephrine, and substance P. One of the major drawbacks of these medications is a side effect of significant sedation. Because of this, these medications should be titrated up slowly to avoid over-sedation. Thus, it may take some time to reach an effective dose. Common initiating dosages of gabapentin include 300 mg daily and increasing by 300 mg every 3–4 days to a maximum dose of 3600 mg divided 3–4 times daily. For pregabalin, a typical starting dose would be 75 mg a day and titrating up to 450–600 mg divided 2 or 3 times daily. Other medications with similar properties include the sodium channel modulators. Common medications in this category include oxcarbazepine and topiramate. Oxcarbazepine is often started at 150 mg daily and titrated up to 600 mg daily divided twice a day. An additional concern with oxcarbazepine is it can cause hyponatremia. Topiramate has been used for many of the above pain conditions, in addition to migraines. Topiramate is typically started at 50 mg and titrated up to 200 mg a day divided twice daily [5].

Antidepressant medications can also provide analgesic benefit. Tricyclic antidepressants (TCA) have been used since the 1980s when their analgesic effects were discovered. TCAs have numerous modes of action, including altering the reuptake of serotonin, noradrenergic effects, possible opioid effects, NMDA receptor altercations, antagonistic effects of adenosine, sodium channel blockade, calcium channel blockade, as well as other receptor inhibition. In addition to analgesic effects, TCAs have the ability to aid and in combating insomnia. Patients with

chronic pain syndromes often have insomnia, so this is a beneficial side effect [6]. It should be noted that with TCAs, patients often develop tolerance to the medication and their dosage must be increased to achieve or maintain optimal benefit. This can lead to a potential for overdose. Common TCAs used today are Amitriptyline, Imipramine, Nortriptyline, and Desipramine.

Serotonin norepinephrine reuptake inhibitors (SNRIs) are also shown to be beneficial in treating pain. Duloxetine was the first antidepressant to have an indication in the treatment for painful diabetic neuropathy since early 2000s. The medications in this category have been shown to be beneficial and other neuropathic-like pain conditions including fibromyalgia, and post herpetic neuralgia [6].

Recently, topical agents have grown in popularity and acceptance as a viable treatment modality for numerous chronic pain syndromes. These topical agents include anti-inflammatories, TCAs, local anesthetics, NMDA receptor antagonists, as well as capsaicin. Benefits of topical agents include ease of use, low organ toxicity secondary to low serum levels of the medication, and targeted treatment application. Patient-specific cutaneous permeability of the active compound in the topical agents can lead to variability in response. Additionally, cost can be prohibitive with many of these medications. Even with these difficulties, providers should keep this category in mind when treating any patient with localized pain complaints [7].

Opioids have been a standard of care for treating pain for centuries. But over the last two decades concerns have developed regarding the overuse of opioid-based medications. There is a significant increase in opioid prescriptions: from approximately 70 million in 1991 to over 200 million in 2013 [8]. Over this same time period, we see an increase in ER admissions from adverse side effect to opioids [8]. Opioid-based medications are known to block the perception pathways to blockage of opioid receptors which does minimize the awareness of the pain inputs. Opioids have shown positive outcomes in acute pain, such as postoperative and cancer-related pain [9]. Numerous side effects are well known and include respiratory depression, constipation, nausea, vomiting, pruritus, and delirium [9]. Opioid-based medications tend to be chosen based on local perception as well as training but generally without understanding of the pharmacology the medication [9]. Different patients tolerate different forms of opioids better than others, which illustrates the need to consider the genetic variation of metabolism of these medications. For instance, hydrocodone is a pro-drug which must be metabolized to its active forms of hydromorphone and noroxycodone [10]. One should keep in mind that utilization of opioid-based medications can be helpful in the postoperative period or as the beginning of the diagnostic process for the patient. Clear expectations and limitations must be discussed in great detail with the patient, and further the patient must possess the ability to understand and follow these instructions. Prior to prescribing an opioid to a patient with non-cancer pain, strong consideration of the risk and benefit must be evaluated by the practitioner before embarking upon long-term usage (Fig. 19.1).

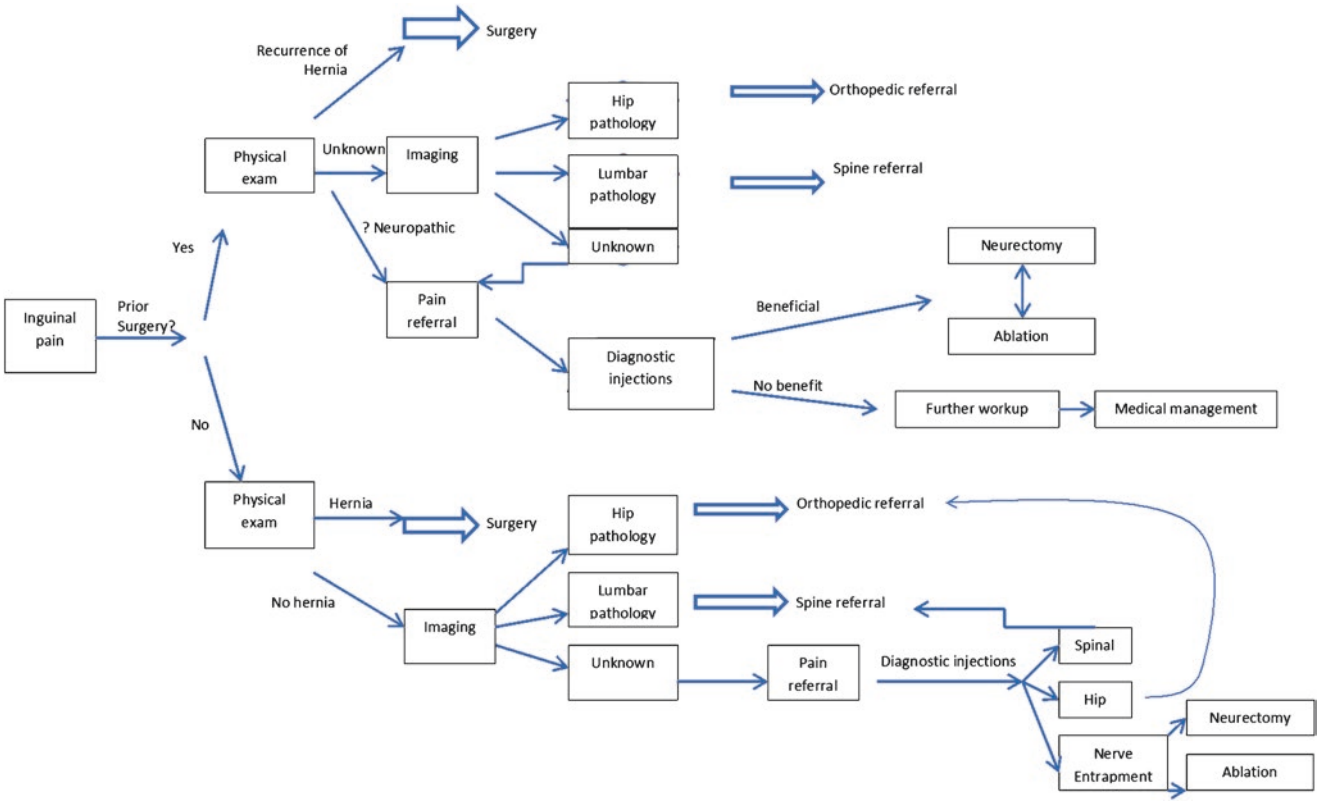

Fig. 19.1 Workup pathway for a patient with inguinal pain

Medication management of patients with pain syndromes often respond better to a multimodal approach. Utilizing medications from numerous categories can improve outcomes. In addition to the improvement of outcomes, this would hopefully minimize side effects to any individual medication and improve compliance [11].

Numerous injections maybe employed in the treatment of acute or chronic pain syndrome, including inguinal pain. Transforaminal epidural injection could be used as selective nerve root blocks for diagnostic purposes or with steroids for therapeutic reasons if the generator is believed to arise from the spine. Intra-articular joint injections may be employed in certain circumstances when the pain is related to an intra-articular problem. Image-guided intra-articular injections can provide valuable diagnostic information in determining the cause of groin pain. If imaging is suggestive of hip articular cause for the pain this can be easily confirmed and proven with an image-guided ipsilateral hip joint injection. Intermittent fluoroscopic guidance is most often utilized; however, the emergence of ultrasound technology has prompted many practitioners to move away from ionizing radiation. Once again steroids may be utilized in this environment to potentially provide longer benefit for the patient. Individual peripheral nerve blocks can be utilized to locate the pain generators. Sympathetic injections including superior hypogastric plexus and ganglion impar can be utilized if necessary. Ablative injections can be employed once the specific pain generator has been localized.

Transforaminal epidural or selective nerve root blocks are used to determine if the cause of the pain is nerve root compression at the spinal level. These procedures are generally done by a trained pain specialist utilizing fluoroscopic guidance. Physicians may consider utilizing steroids with these injections to improve the length of time the benefit will last. Local anesthetics such as 2 % lidocaine can be used for diagnostic only purposes [12].

Specific peripheral nerve blocks including ilioinguinal, iliohypogastric, genitofemoral, and lateral femoral cutaneous should be performed with image-guided technology. With the recent improvements of ultrasound guidance, most of these nerve injections can be performed when used in a continuous manner.

The ilioinguinal nerve block can be performed either blindly or by utilizing fluoroscopic guidance. The patient is positioned supine and the anterior iliac spine (ASIS) is palpated or identified with the aid of fluoroscopic imaging. The ASIS is marked; an area measured approximately 2 in. medially and 2 in. caudally is identified and marked. The skin may be anesthetized using local anesthetic if needed. One may utilize a 25-gauge needle to enter the point that is designated and aiming towards the pubic symphysis. Care must be taken not to enter too deeply or inferior to avoid penetrating the peritoneum. Once the external oblique fascia is penetrated, typically 10–15 mL of local anesthetic is injected after negative aspiration. If the pain is being caused by the ilioinguinal nerve, the patient should experience rapid resolution of the discomfort [3].

The iliohypogastric nerve block is performed in a similar fashion as the ilioinguinal nerve. One may perform the procedure blindly or with the utilization of fluoroscopy. Again, the anterior superior iliac spine is identified and a point 1 in. medially and 1 in. inferiorly is identified and marked. Again utilizing a 25-gauge needle, the needle advances in an oblique fashion towards the pubic symphysis. Also similar to the ilioinguinal nerve block, once the fascia at the external oblique musculature is pierced, a total of 10–15 mL of local anesthetic will be injected after negative aspiration [3].

To perform the genitofemoral nerve block, the individual giving the block must keep in mind the genitofemoral nerve branches typically within the inguinal crease into the femoral branch and the genital branch. Therefore, the person performing the procedure must identify the anterior iliac spine, the femoral crease, pubic tubercle, and the femoral artery. To block the genital branch of the genitofemoral nerve one must take care to identify the pubic tubercle and its junction with the inferior portion of the inguinal crease. Again using a 25-gauge needle the needle should be advanced into the skin and just to the subcutaneous tissue, and after negative aspiration 5–10 mL of local anesthetic will be injected. For the femoral branch, the femoral artery should be identified. A point just lateral to the femoral artery is the site for entry, using 25-gauge needle can be advanced just to the skin and subcutaneous tissue. After confirmation the femoral artery was not entered, a total of 5–10 mL of local clinics should be injected [3].

As with the previously mentioned nerve blocks, the lateral femoral cutaneous nerve is also fairly easy to perform. With the patient in a supine position the anterior superior iliac spine (ASIS) is identified, a site 1 in. medial and intersection of the inguinal ligament is identified. Just below this point, using a 25-gauge needle, advance in a perpendicular fashion, until just penetrating the fascia. Again, anywhere from 5 to 10 mL of local anesthetic can be injected after negative aspiration. It is very common with this procedure for the patient to feel a paresthesia corresponding with the distribution of the lateral femoral cutaneous nerve [3]. Currently, most individuals are utilizing ultrasound guidance because of the benefit of real-time observation and the absence of the ionizing radiation.

Chemical ablation is utilized for spinal cord mediated pain, peripheral nerve injuries, and numerous other chronic pain syndromes. Conventional ablation procedures generate temperatures ranging from 65 to 90 °C by creating vibration and oscillation within the tissues which then cause the tissue destruction [13]. Ablative procedures should be done once the affected nerve is determined and localized. The desired outcome of an ablative procedure is to produce more durable

relief or greater than 6 months. Often, these may need to be repeated at some time interval [19].

Sympathetic injection may be necessary if the symptoms fit with a less specific nerve pattern or is more diffuse. Superior hypogastric plexus blocks can provide blockage of the portion of the sympathetic chain arising from L2 or L3 through L5. This plexus generally cover the organs within the pelvis. This sympathetic injection is typically indicated for patient with ongoing pain from gynecologic disorders, postsurgical pain, interstitial cystitis, or neoplastic in nature. This block is done using intermittent fluoroscopic guidance with the patient supine and targeting the anterior portion of the inferior endplate of L5. This superior hypogastric block may be done as a diagnostic procedure when the cause of the inguinal pain has yet to be determined. This block can be then followed with an ablative procedure if thought to be beneficial. The ablative procedure can use radiofrequency technology or chemical ablation [14].

Ganglion impar blocks can cover perineum genitalia and perirectal pain. Generally, this block is reserved for instance in which the pain is in and around the genitals of the patient. This block is performed when the patient is in prone position using fluoroscopic guidance, targeting the sacrococcygeal ligament. Similar to superior hypogastric plexus block this block can be utilized as a diagnostic procedure. If the patient receives benefit the procedure can be done utilizing ablative technology [14].

Spinal cord stimulation is a treatment option that has been employed since the 1960s. Many advancements and indications have occurred since that time. Most of the benefit of spinal cord stimulation is based on the gate theory developed by Melzck and Wall, "neural 'gates' in the spinal cord can be opened or closed by signals descending from the brain as well as by sensory information ascending from the body" [15]. But with continued research on this topic other sources of benefit are identified. In many animal studies, alterations in the GABA and glutamate concentrations within the wide dynamic range cells of the dorsal columns alleviated the pain symptoms [9]. Other theories postulate altering the cholinergic system and the concentration of acetylcholine or even activation of the descending inhibitory pathways may play a major role in symptom relief. Thus, if the pain is determined to be generated spinally, spinal cord stimulation could be considered as treatment option. Stimulation of other portions of the nervous system could be considered as advancements continue with electrical stimulation.

Peripheral nerve or field stimulation could be considered if other therapies have failed and repetitive nerve blocks were successful but not durable. Percutaneous stimulation leads can be placed with image guidance as a trial. If successful this could be implanted to provide longer term benefit. Generally this procedure is well tolerated but has limited studies on outcomes [16].

Further advancement within spinal cord stimulation and its related technology have allowed stimulation of different portions of the central nervous system. Dorsal root stimulation is currently being evaluated with some growing data. Levy and Deer presented a study comparing dorsal root ganglion stimulation to conventional stimulation. The study showed an improved outcome for patients with complex regional pain syndrome (CRPS) and peripheral causalgia [17]. This study showed ability to focus the stimulation to the area of distress compared to conventional stimulation [17].

If the pain is related to the muscular system physical therapy may provide excellent benefit. Once the patient completes an evaluation by the trained physical therapist, a sequence of treatment modalities is developed and the patient is educated on the purpose and frequency to perform these activities. These treatment modalities focus on strength and stability, improved motion, and consistent exercise programs [18]. These modalities often take weeks to develop and implement. Patients must be willing to work diligently with the therapist and continue the regime at home.

Acupuncture, meditation, and cognitive behavior therapy. There may be circumstances where the patient wishes to explore nontraditional methods of treatment for their painful conditions. Acupuncture has been used worldwide for centuries. Over the last few decades, more people in the Western world have turned to acupuncture to aid in relieving their pain. There is growing evidence that acupuncture can be useful in treating numerous painful syndromes including fibromyalgia, back and neck pain, headaches, and even postoperative pain. The true mechanism of acupuncture is still unknown, but changes in the central and peripheral nervous system can be seen in some cases. Most of these changes are thought to be part of the perception of pain pathways. In the Eastern portion of the world, acupuncture is explained by re-establishing the normal movement of energy or "qi" [19].

Another alternative therapy is meditation. Nakata, Sakamoto, and Kakigi have been studying functional MRIs and looking at the changes with meditation and pain perception. These scientists are developing hypotheses that notes significant changes in areas of the brain including the anterior cingulate cortex, insula, secondary somatosensory cortex, and even in the thalamus. The studies show conflicting results with increased neural activity within certain segments of the brain but, in other patients these same area had decreased neural activity. How it works is still a mystery, but there are proven results showing improved pain sensation in people who are well trained in meditation [20].

Psychological treatments should be considered for any patient with a chronic pain diagnosis. Generally any patient who experiences chronic pain will have comorbid psychological diagnoses such as anxiety and/or depression. Also, most chronic pain patient have chronic insomnia, which adversely affects quality of life and tends to worsen anxiety,

depression, and any psychological condition. Some psychological treatments that can be employed include cognitive behavioral therapy, hypnosis, and biofeedback. In many instances, these therapies show improvement in patient's functionality, which ultimately can lead to improvement in their pain descriptions. These therapies are shown to be effective both in individual sessions and in group therapy [21].

Surgery: Surgical colleagues of various specialties must be involved in the care of any patient with a chronic pain syndrome, especially chronic inguinal pain. In the event there are obvious bony abnormalities in the pelvic region, including the hip, the patient should be considered for an orthopedic referral. If the belief is the pain is of spinal origin, then referral to a spinal specialist should be strongly considered. Obviously, patients with hernias that can be surgically corrected should obtain a surgical consultation. A neurectomy should be considered if the patient had a prior hernia surgery and can provide clear documentation of specific neuralgia from diagnostic blocks [22].

In conclusion, inguinal pain, as with any pain syndrome, providers must keep an open mind on the patient's symptoms. More often than not, physicians become too narrowly focused based on their individual training. By doing this, the actual diagnosis may be missed and the patient will end up having an unnecessary procedure or ingesting unneeded medications. Thus, taking a group approach will aid in preventing misdiagnosis, mistreatment, and improved outcomes. Not all treatments will provide benefit, but no treatment should be excluded without consideration. Direct collaboration between surgical specialists, pain specialists, physical and mental therapists will provide the patient with the best outcome.

Table 19.1 shows some things to think about with inguinal and groin pain.

Table 19.1 Some things to think about with inguinal or groin pain

Muscular	Abdominal wall	External oblique	Irritation at any other tenderness insertions could be an explanation of inguinal pain. Could be related to chronic athletic usage versus traumatic event
		Internal oblique	
		Transverse abdominis	
		Rectus abdominis	
		pyramidalis	
	Thigh	Sartorius	
		Petineus	
		Abductor longus	
		Gracilis	
	Other	"Sports Hernia"	
Nerve compression	Inguinal region	Ilioinguinal	Compression from musculature, scarring, entrapment from surgery or even trauma
		Iliohypogastric	
		Genitofemoral	
		Lateral femoral cutaneous	
	Lumbar spine	Upper lumbar nerve root compression	Herniation in the lumbar spine
Referred pain	Joints	Hip	Osteoarthritis the hip joint, labral tear postsurgical or damage to the femoral head
		Lumbar spine	Generally related to facet arthropathy
		Sacroiliac	Osteoarthritis of the sacroiliac joint or secondary to postsurgical changes
Visceral	Abdomen	Colonic	Inflammation or infection within these organ may cause pain located in the groin region
		Appendix	
	Pelvic	Testicular	
		Ovarian	
		Uterus	
Hernias	Inguinal	Indirect	Abnormal protrusion of tissue or an organ through a wall's defect
		Direct	
		Combine	

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Surgical Management of Chronic Groin Pain

20

Alexandra M. Moore, Parviz K. Amid, and David C. Chen

20.1 Introduction

Widespread adoption of tension-free inguinal hernia repair techniques and the routine use of mesh prostheses have dramatically lowered rates of inguinal hernia recurrence [1]. However, with improvement in recurrence rates, chronic groin pain following inguinal hernia repair has emerged as one of the most significant causes of postoperative morbidity, with rates as high as 63 % in some studies [2, 3]. This pain is moderate to severe in 6–8 % of post-herniorrhaphy patients [4]. With 800,000 inguinal hernia repairs completed in the USA every year and a conservative estimated risk of chronic groin pain causing an adverse effect on daily life between 0.5 and 0.6 %, it can be estimated that 4000–48,000 patients develop severe, debilitating chronic groin pain every year [5–9].

The risk of developing chronic groin pain is independent of the method of hernia repair and post-inguinal herniorrhaphy inguinodynia preceded the era of mesh repairs [6, 10, 11]. Chronic groin pain can be classified as either nociceptive, neuropathic, somatic, or visceral. Nociceptive pain is due to tissue injury, meshoma, or inflammation and is typically a dull, deep, and constant pain localized over the entire groin. In contrast, neuropathic pain is due to direct damage to the inguinal nerves and can be constant or intermittent, often radiates, and is characterized by negative sensory symptomatology. In clinical practice, there is often significant overlap between nociceptive and neuropathic pain, making accurate diagnosis of the etiology of groin pain difficult. Somatic pain typically manifests localized tenderness which is maximum at the pubic tubercle, commonly caused by periosteal anchoring of mesh [12]. Visceral pain may be due to intestinal complications or involvement of the spermatic cord and is typically manifested by gastrointestinal complaints or sexual dysfunction.

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20.2 Nonoperative Approach

Nonsurgical modalities for the treatment of chronic groin pain include pharmacologic, behavioral, and interventional therapies. Pharmacologic therapies for nociceptive pain due to tissue inflammation include NSAIDs and steroids, but neither of these is sustainable in the long-term treatment of chronic pain. Pharmacologic therapies for neuropathic pain include GABA analogues (gabapentin and pregabalin), SNRIs, and TCAs [13]. There is no firm evidence to support the use of one over another [14]. Opioids and tramadol are considered second-line treatments for neuropathic pain and should be avoided in the long term, but may be necessary for acute exacerbations. There is no solid evidence supporting the use of topical analgesics such as lidocaine or capsaicin, but they have minimal morbidity and cost and a trial is reasonable [15, 16].

Interventional treatment options include nerve blocks, neuroablative techniques, and neuromodulation. Nerve blocks of the ilioinguinal and iliohypogastric nerves can be used both diagnostically and therapeutically, though there is conflicting evidence regarding their efficacy [17–19]. Ilioinguinal and iliohypogastric nerve blocks can both be performed using traditional anatomic landmarks or under direct visualization with ultrasound guidance. If these blocks are successful in alleviating pain in the short term, but do not provide long-term relief from chronic pain, neuroablative techniques may be considered. These techniques include cryoablation or pulsed radiofrequency ablation. Cryoablation destroys the nerves through Wallerian degradation, selectively destroying the axons and myelin sheaths. Pulsed radiofrequency ablation delivers a high intensity current, causing mild heating of the nervous tissue without neurodestruction. The exact mechanism of analgesia is unclear. Of the neuroablative techniques, pulsed radiofrequency ablation has the most evidence supporting its use [20–24].

For patients in whom chronic groin pain is refractory to the abovementioned therapies, neuromodulatory techniques may be used. Peripheral nerve field stimulators, spinal cord

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_20

stimulators, and dorsal root ganglion stimulators are implantable devices which produce gentle paresthesias in the areas of pain. While the exact neurophysiology of these modalities is not well understood, there have been multiple studies demonstrating successful pain relief [25–30].

20.3 Operative Techniques

For patients in whom conservative pain management therapies fail, surgical intervention may be warranted. In general, surgical treatment for chronic groin pain following hernia repair is recommended at least 6 months after the primary repair to allow for resolution of the normal inflammatory healing process and mesh incorporation and remodeling [5, 6]. However, careful selection of patients is of utmost importance as only patients with discrete neuroanatomic or structural problems correctable with surgery will benefit from operative intervention [5, 6, 10, 31, 32]. Preoperative evaluation should be thorough and include symptomatology, careful review of the operative report from the primary operation (noting especially the type of repair, type of mesh, position of mesh, fixation method, and notes on the handling of nerves), physical examination, dermatosensory mapping, imaging, and response to previous interventions [6, 33].

20.3.1 Recurrence

Hernia recurrence can be a cause of groin pain following inguinal hernia repair. If this is the case, the pain may be ameliorated with repeat surgical repair. The repair of the recurrence may be performed either open or laparoscopically. It is usually recommended to use an alternative approach to that which was originally used to avoid the scarred operative field. The categories of open repair include tissue approximation repair and open tension-free prosthetic repair. Open recurrent hernia repair techniques are preferred if the patient is experiencing concurrent pain from recurrence and neuropathic pain, as neurectomy can be completed at the same time as the hernia repair [34]. Laparoscopic repair of hernia recurrence is another option, commonly used following primary open anterior repair without neuropathic pain as it allows for a surgical approach that avoids the prior surgical field.

20.3.2 Neuropathic Pain

Neuropathic pain following inguinal hernia repair results from direct nerve injury, either to the ultrastructure of the nerve itself or as a result of nerve entrapment (by suture, mesh, or other fixation devices). Common symptoms of neuropathic groin pain include radiation of pain to the scrotum or femoral triangle, paresthesia, allodynia, hyperalgesia, hyperpathia, and hyper- or hypoesthesia. It is often difficult to distinguish neuropathic from nociceptive pain (pain due to tissue injury and inflammation). Careful evaluation and planning is essential as operative interventions for neuropathic pain will not alter nociceptive pain.

Understanding the neuroanatomy of the groin is of paramount importance when considering surgical intervention for neuropathic chronic groin pain [5, 6]. It is also important to note that the neuroanatomy may be highly variable between patients [35, 36]. In the majority of patients, the ilioinguinal nerve may be found lying on the anterior surface of the spermatic cord, covered by the investing fascia of the internal oblique muscle. The iliohypogastric nerve can be found between the internal and external oblique muscle layers, also protected by the investing fascia of the internal oblique. It is identified by exposing the anatomic cleavage plane between the internal and external oblique layers. The genital branch of the genitofemoral nerve enters the internal inguinal ring and continues through the inguinal canal with the spermatic cord, covered by the deep cremasteric fascia. It reliably lies adjacent to the external spermatic vein and is identified by this structure (Fig. 20.1).

Given this anatomy, there exist common sites of nerve injury following inguinal hernia repair. Anterior to the transversalis fascia, the ilioinguinal nerve, the inguinal and intramuscular portion of the iliohypogastric nerve, and the genital branch of the genitofemoral nerve are all within the operative field and may be damaged during open anterior hernia repairs (tissue repair, Lichtenstein repair, bilayer mesh repair, plug/patch repair, transinguinal preperitoneal repair/TIPP) or from the fixation of mesh during laparoscopic repair (totally extraperitoneal/TEP or transabdominal preperitoneal/TAPP repair). Posterior to the transversalis fascia, the main genitofemoral nerve trunk as well as the preperitoneal segments of the genital and femoral branch of the genitofemoral nerve are both at risk and may be injured during open preperitoneal repair (plug repair, bilayer mesh repair, Kugel repair, transinguinal preperitoneal/TIPP) as well as laparoscopic repair (totally extraperitoneal/TEP or transabdominal preperitoneal repair/TAPP). Finally, the retroperitoneal space contains the main trunk of the genitofemoral nerve running over the psoas as well as the lateral femoral cutaneous nerve coursing over the iliacus muscle, either of which may be injured during open preperitoneal or laparoscopic posterior repairs [34, 37].

In patients with chronic postoperative neuropathic groin pain, removal of mesh or fixation devices while leaving injured nerves intact is not sufficient [6]. In these cases, simultaneous neurectomy is the most successful option. Selective neurectomy may be an effective technique for a subset of patients, especially those with an isolated mechanism of injury and a well-documented dermatomal

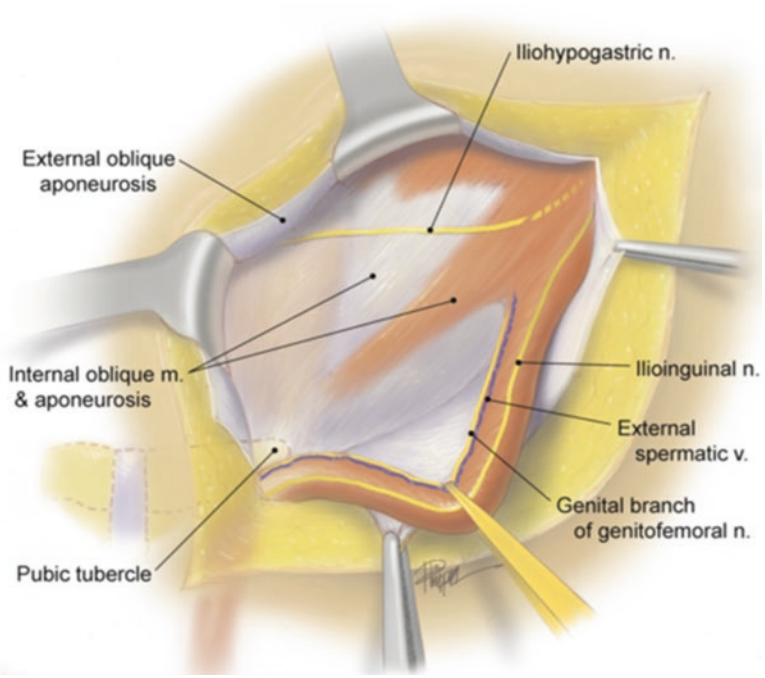


Fig. 20.1 Anterior identification of the inguinal nerves in the inguinal canal

distribution of pain corresponding to a specific nerve distribution [38–40]. However, there is significant variation in the distribution of innervation between patients as well as cross-innervation amongst the inguinal nerves, making selective neurectomy a less reliable technique in the majority of patients [6, 35, 36, 40].

Triple neurectomy is the most effective and definitive surgical treatment for chronic neuropathic groin pain, with a response rate between 85 and 97 % [6, 32, 34, 36, 37, 41–44]. The operation can be completed either open or laparoscopically and consists of resection of the ilioinguinal, iliohypogastric, and genitofemoral nerves proximal to the site of initial hernia repair.

Anterior open triple neurectomy is the standard operative approach using the same groin incision as the original operation. The nerves are identified and neurectomized proximal to the repair accessing the unscarred inguinal canal cephalad and lateral to the prior repair. The ilioinguinal nerve can be found between the internal ring and the anterior superior iliac spine, lateral to the internal ring (Fig. 20.2). The iliohypogastric nerve can be found in the crease between the internal and external oblique aponeuroses (Fig. 20.3). Both nerves should be traced to their respective exits from the internal oblique muscle proximal to the primary repair, then resected. The genital branch of the genitofemoral nerve can be found between the spermatic cord and the inguinal ligament (Fig. 20.4). It should be traced laterally to the internal ring and severed there. Handling of the cut nerve endings is important to prevent sprouting and scarring of the exposed neurilemma. The cut nerve is ligated to close the neurilemma to decrease the likelihood of neuroma formation. The proximal cut end is then inserted into the muscle of the internal oblique to isolate it from the future operative field scarring [6, 32, 34, 36, 37, 42, 43]. In cases of prior preperitoneal open and laparoscopic repair, an "extended triple neurectomy" may be performed by opening the floor of the inguinal canal through the internal ring or internal oblique muscle to access the genitofemoral trunk over the psoas muscle. The advantages to an open triple neurectomy include that it is a single-stage operation, meshoma removal can be performed concurrently, the main trunk of the genitofemoral nerve may be resected at the same time, the paravasal nerve fibers within the lamina propria of the vas may be resected if orchialgia is also present, and recurrence can be repaired. The main disadvantage of the open approach is the technical difficulty of operating in a previously scarred field, making

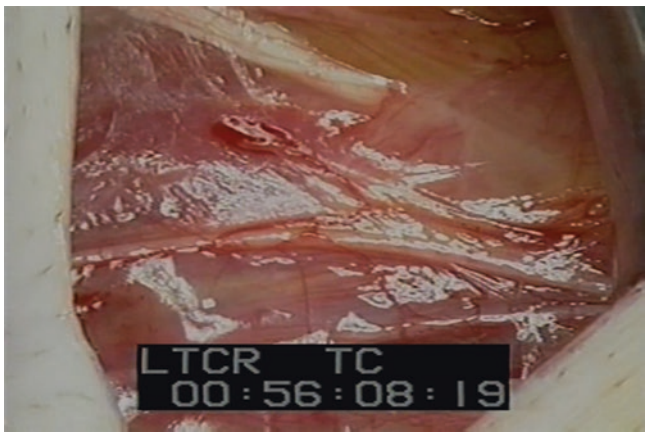


Fig. 20.2 Open neurectomy, identification of the ilioinguinal nerve

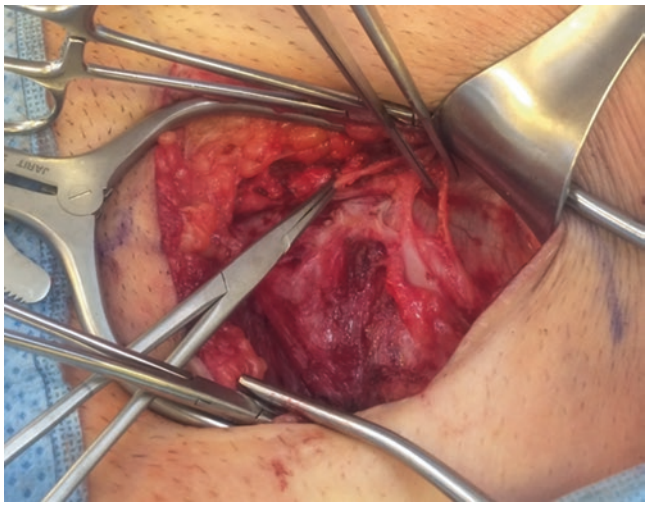


Fig. 20.3 Open neurectomy, identification of the iliohypogastric nerve

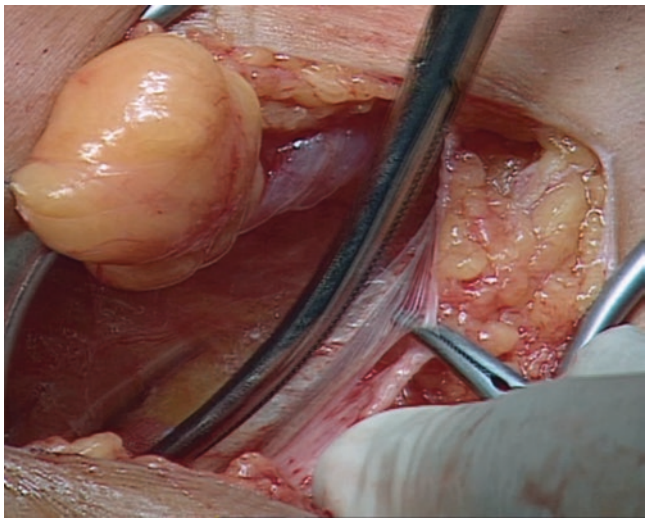


Fig. 20.4 Open neurectomy, identification of the genital branch of the genitofemoral nerve

identification of the nerves more difficult and putting the spermatic cord, vascular, and visceral structures at greater risk of inadvertent injury.

Laparoscopic retroperitoneal triple neurectomy can be performed through either an intraabdominal or extraperitoneal approach [37, 45, 46]. The technique involves accessing the trunks of the ilioinguinal, iliohypogastric, and genitofemoral nerves retroperitoneally within the lumbar plexus and performing the resection in this unscarred location. The ilioinguinal and iliohypogastric nerves are identified lying over the quadratus lumborum muscle distal to L1 and the genitofemoral nerve is found lying over the psoas muscle (Figs. 20.5 and 20.6). The advantages to this approach include easier identification of the nerve roots given avoidance of the previous surgical field and scarring, more consistent neuroanatomy in the lumbar plexus, as well as access to all three nerves proximal to the primary repair prosthetics. Disadvantages specific to laparoscopic triple neurectomy include greater collateral damage with a more extensive field of numbness, increased risk of deafferentation hypersensitivity, and the potential for lower lateral abdominal wall laxity due to denervation of the motor fibers of the ilioinguinal and iliohypogastric nerves at this proximal resection site. Concurrent prosthetic removal or resection to the lamina propria of the vas is possible but the approach may be more challenging from the lateral decubitus position.

It is important to discuss limitations and possible complications of neurectomy with patients prior to surgery. These include failure to identify and resect all three nerves, persistent pain even after a successful neurectomy, permanent numbness in the distribution of the resected nerves, laxity of the abdominal wall musculature, alteration in sexual function, and hypersensitivity from deafferentation [6, 34, 36, 37]. Again, a thorough preoperative evaluation is extremely important as neurectomy will not alter nociceptive pain and successful outcomes are predicated on appropriate patient selection.

20.3.3 Meshoma

Meshoma may cause nociceptive pain due to inflammation and tissue damage and is an anatomic pathology clearly amenable to surgical correction. The pain is typically described as a constant ache, as opposed to the shooting and intermittent nature of typical neuropathic pain. However, neuropathic pain may also accompany nociceptive pain if the meshoma is causing nerve entrapment, compression, or perineural scarring from direct contact with mesh. Imaging (ultrasound, CT, or MRI) can aid in the diagnosis of meshoma [47]. Mesh removal may be performed open, laparoscopically, or robotically (Fig. 20.7). When neuropathic pain is also present, combined meshoma removal and neurectomy through an open, laparoscopic, or hybrid approach provides pain relief in the majority of patients [6, 37].

20.3.4 Orchialgia

The paravasal nerves are autonomic nerve fibers within the lamina propria of the vas deferens. With scarring, entrapment, and inflammation, they may be responsible for postoperative orchialgia. It is important to distinguish testicular pain from scrotal pain, as scrotal pain is often associated with genital neuralgia and is distinct from orchialgia. In patients who have groin pain with associated orchialgia, paravasal neurectomy in combination with triple neurec-

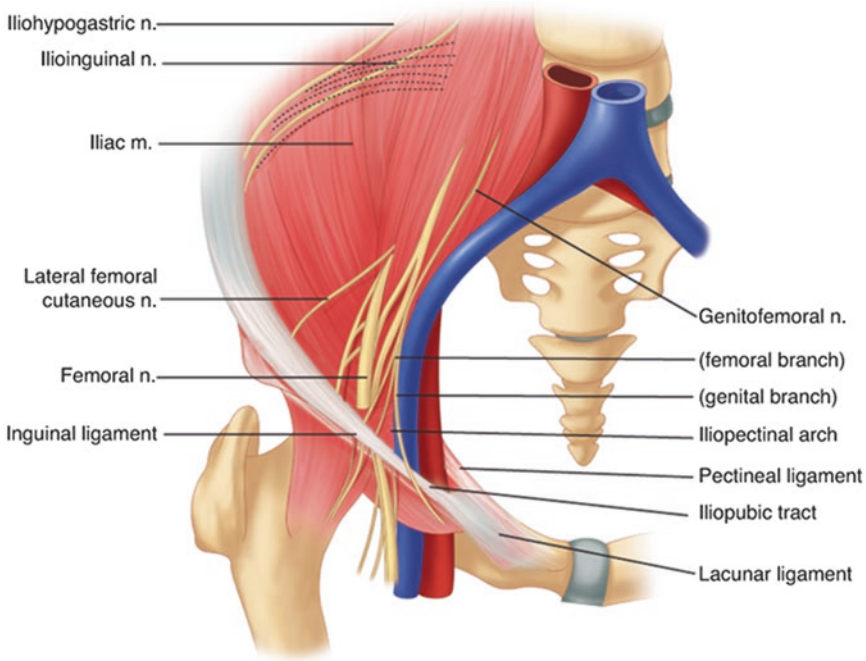


Fig. 20.5 Identification of the posterior nerves in the lumbar plexus

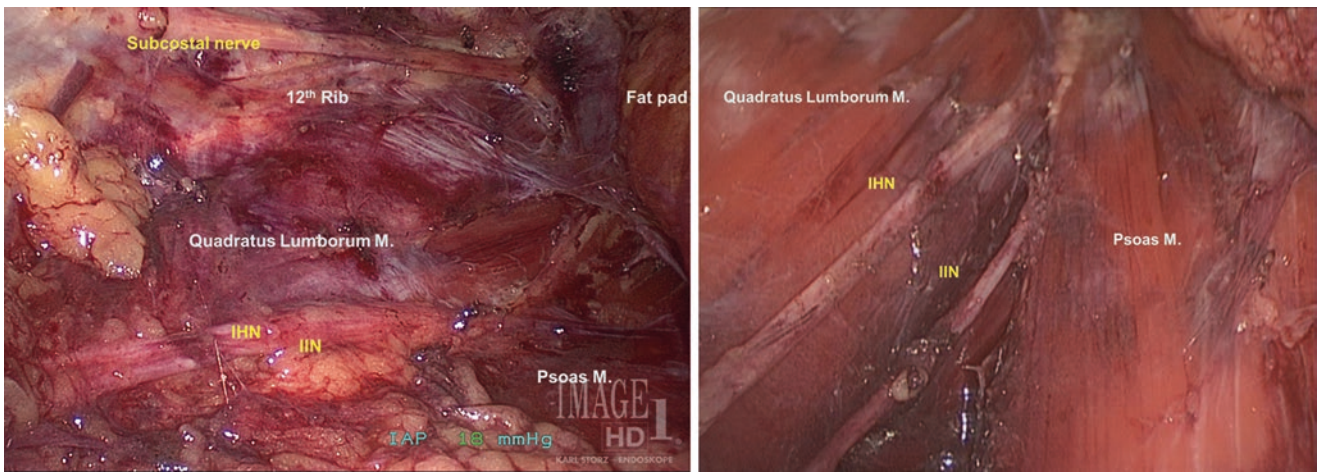
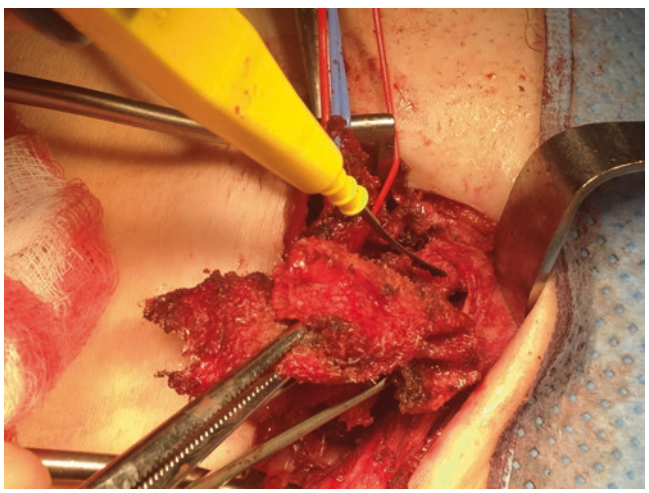


Fig. 20.6 Laparoscopic retroperitoneal triple neurectomy nerve anatomy

Fig. 20.7 Open meshoma removal



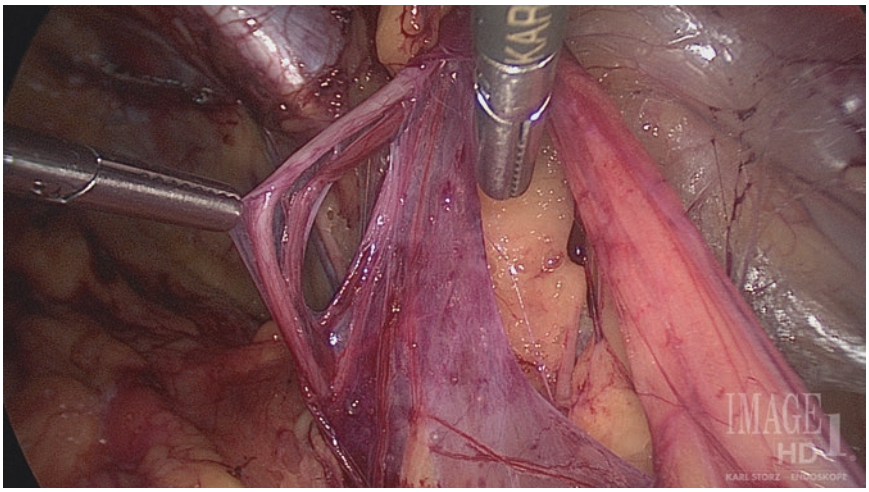


Fig. 20.8 Laparoscopic proximal paravasal neurectomy

tomy may help to alleviate testicular pain [34]. However, orchialgia is complex and surgical intervention is not as predictable or effective as in other types of chronic postoperative groin pain. Open paravasal neurectomy is often performed in combination with triple neurectomy following anterior repair techniques. In cases of orchialgia following preperitoneal mesh repair, however, paravasal neurectomy may be performed laparoscopically or robotically as an open approach would not allow access to the nerve plexus proximal to mesh placement (Fig. 20.8). In cases of orchialgia with pain refractory to paravasal neurectomy, with nociceptive orchialgia, and/or with vascular compromise, orchiectomy is a potential option.

20.4 Conclusions

The surgical management of postoperative chronic groin pain should be reserved for patients who have failed conservative therapy and who have discrete anatomic problems which are amenable to surgical correction. Accurate diagnosis allows for the distinction between neuropathic and nociceptive pain, thus guiding operative intervention. The complications discussed in this chapter are amenable to surgery and include hernia recurrence, neuropathic pain, meshoma, and orchialgia. With careful preoperative evaluation and selection of appropriate patients, the surgical amelioration of chronic pain can be highly successful.

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Groin Pain in Athletes

21

Aali J. Sheen and Adam Weir

21.1 Introduction

21.1.1 Epidemiology

Groin pain is common in athletes who participate in sports with rapid changes of direction, rapid acceleration or deceleration and kicking. Groin pain is a common sporting injury. A recent systematic review on soccer showed that it accounts for between 4 and 19 % of all injuries in males with an injury rate of 0.2–2.1 injuries per 1000 h [1]. In other elite sports it has been found to be a common problem in ice hockey and in football codes especially in positions that involve more kicking [2]. Males have around twice as many groin injuries as females [1, 2].

21.2 How Is Groin Pain in Athletes Defined?

21.2.1 Background

Historically there was no agreement on the terminology or definitions used when describing the causes of groin pain in athletes. Multiple terms or differing definitions of similar terms added complexity to this confusing field, with 33 terms used in 72 studies, in a recent review on the treatment of groin pain in athletes [3]. A Delphi questionnaire survey among 23 experts on the treatment of groin pain in athletes presented two cases and asked the experts to describe the terms they would use to give the diagnosis. Among the 23 experts 18 terms were used to describe the diagnosis for the first case, and 22 for the second highlighting the disparity [4].

To help to address this confusion two consensus meetings have been held recently:

21.2.2 British Hernia Society: Manchester

In 2012, the society convened a special session at the annual academic meeting at which both national and international experts from a multidisciplinary field were invited to speak about groin pain in the inguinal region in athletes. Predetermined questions were asked to all the experts to which they replied, reaching a consensus on the etiology, surgical treatment as well as other possible treatment modalities employed for this condition. Inguinal disruption was chosen as a term, with a description of the clinical findings outlined as well as radiology findings and a treatment algorithm [5]. The statement was the first of its kind as no consensus had yet been established to help define and manage what was initially perceived as a "physiological" entity rather that an actual "pathology," with the realization that to date no real science or data was used to determine the best mode of treatment for "the sportsman's groin."

21.2.3 Doha Agreement Meeting on Terminology and Definitions in Groin Pain in Athletes

In 2014, 24 international experts representing general surgery, orthopedic surgery, sports medicine, sports physiotherapy, and radiology met in Doha, Qatar, following the Delphi procedure described above. They reached unanimous agreement on a set of terms and definitions [6]. Groin pain in ath-

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_21

letes was the preferred umbrella term. This was preferred to others such as athletic pubalgia, or sports groin pain as it is only descriptive and cannot be used as or interpreted to be a diagnostic term.

A clinically based classification system was chosen meaning that a thorough history and physical examination are essential.

The classification system has three major subheadings of groin pain in athletes

1. *Defined clinical entities for groin pain*
   Adductor-related, iliopsoas-related, inguinal-related, and pubic-related groin pain
2. *Hip-related groin pain*
3. *Other causes of groin pain in athletes* (Fig. 21.1)

1. *Defined clinical entities for groin pain*:
   Adductor-related, iliopsoas-related, inguinal-related, and pubic-related groin pain

   An athlete can have more than one entity, in which case multiple entities can be diagnosed.

   Adductor-related groin pain

   Adductor tenderness AND pain on resisted adduction testing

   Iliopsoas-related groin pain

   Iliopsoas tenderness

   Iliopsoas-related groin pain is more likely if there is pain on resisted hip flexion AND/OR pain on stretching the hip flexors

   Inguinal-related groin pain

   Pain location in the inguinal canal region AND tenderness of the inguinal canal. No palpable inguinal hernia is present.

   Inguinal-related groin pain is more likely if the pain is aggravated with resistance testing of the abdominal muscles OR on Valsalva/cough/sneeze.

   Pubic-related groin pain

   Local tenderness of the pubic symphysis and the immediately adjacent bone.

   There is no particular resistance test that specifically provoked symptoms related to pubic-related groin pain that can be used in conjunction with palpation.

   The location of the four entities above is shown in Fig. 21.2.
2. *Hip-related groin pain*

   Pain from the hip joint should always be considered as a possible cause of groin pain . While there are no specific tests that are good at ruling the hip joint in a source of groin pain in athletes, negative tests can be useful at excluding the hip.

   The physical tests for checking the hip are included later in the chapter.
3. *Other conditions causing groin pain in athletes*

   Besides the defined clinical entities and the hip there are many other possible causes for groin pain in athletes. A high index of clinical suspicion is needed to identify these and clinicians need to be alert to the possibilities especially when the complaints cannot easily be classified into one of the common defined clinical entities. There are numerous possible causes, which fall outside the scope of this chapter. These are summarized in Table 21.1. The main categories are orthopedic, neurological, rheumatological, urological, gastrointestinal, dermatological, oncological, and surgical, but this list is not exhaustive as many rare conditions could possibly cause pain in the groin region.

   A careful history and physical exam covering more than only the musculoskeletal system and appropriate additional investigations or referral are critical for identifying other possible causes.

21.2.4 Doha v Manchester

Both statements agreed on the clinical signs and symptoms that would strongly suggest a diagnosis of inguinal-related groin pain/inguinal disruption. Doha and Manchester both also emphasize that the pain predominantly arises from the

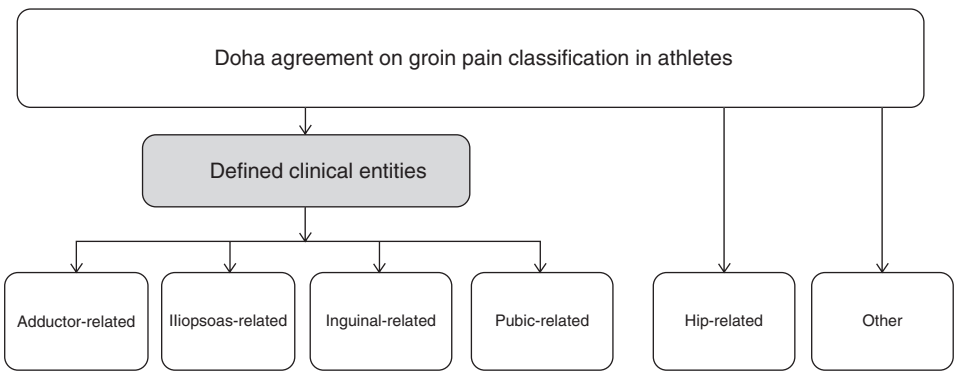

Fig. 21.1 Other causes of groin pain in athletes

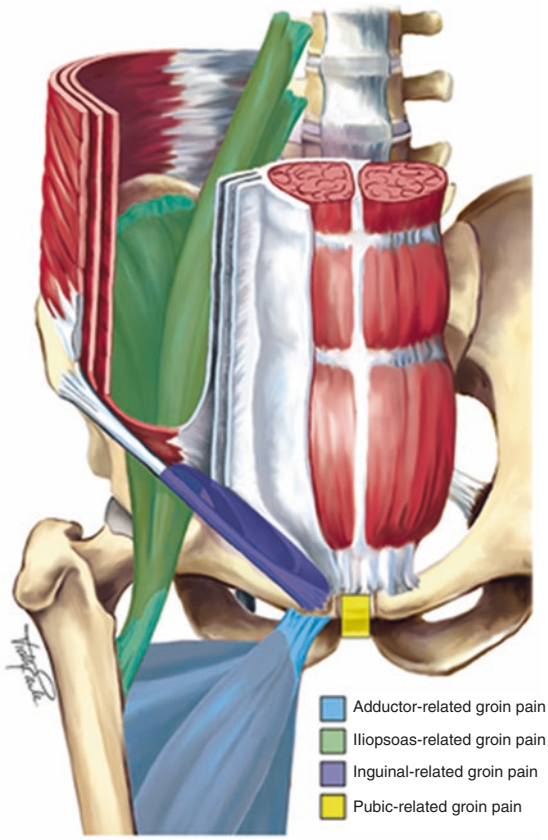

Fig. 21.2 Four entities as defined by the Doha statement. Reproduced with permission of BMJ [4]

inguinal canal "region," thereby concluding that there is an agreement on the location of the pathology. Both use clinical examination to make the diagnosis with the emphasis on palpation of the inguinal canal. They also both agree that no actual inguinal hernia is present, as in this case the diagnosis would be "inguinal hernia."

A difference in nomenclature remains and the reason for this although unclear, essentially can remain unchallenged, as Manchester solely describes inguinal pain and does not cover the rest of the groin. Manchester offers a specific nomenclature to groin pain specifically related to the inguinal canal where Doha simply alludes to the inguinal canal without discussing underlying pathology [7].

This chapter concentrates on inguinal-related groin pain in athletes.

21.3 What Are the Presenting Complaints of Inguinal-Related Groin Pain in Athletes?

As described above, a clear strategy is required in order to make a diagnosis of inguinal-related groin pain. Athletes usually describe pain in the groin, felt in the region of the inguinal canal. This inguinal pain is felt on predominantly fast, explosive, sudden, and dynamic movements. There can also be pain on coughing or sneezing. Athletes sometimes complain of pain on "sitting up" from the resting or turning

Table 21.1 An overview of some of the possible causes of groin pain in athletes

Entities defined during Doha agreement meeting	Other musculoskeletal causes	Not to be missed
Adductor-related groin pain	Inguinal or femoral hernia	Stress fracture
Iliopsoas-related groin pain	Post-hernioplasty pain	– Neck of femur
Inguinal-related groin pain	Nerve entrapment	– Pubic ramus
Pubic-related groin pain	– Obturator	– Acetabulum
Hip-related groin pain	– Ilioinguinal	Hip joint
	– Genitofemoral	– Slipped capital femoral epiphysis (adolescents)
	– Iliohypogastric	– Perthes' disease (children and adolescents)
	Referred pain	– Avascular necrosis/transient osteoporosis of the head of the femur
	– Lumbar spine	– Arthritis of the hip joint (reactive or infectious)
	– Sacroiliac joint	Inguinal lymphadenopathy
	Apophysitis or avulsion fracture	Intra-abdominal abnormality
	– Anterior superior iliac spine	– Prostatitis
	– Anterior inferior iliac spine	– Urinary tract infections
	– Pubic bone	– Kidney stone
		– Appendicitis
		– Diverticulitis
		Gynecological conditions
		Spondyloarthropathies
		– Ankylosing spondylitis
		Tumors
		– Testicular tumors
		– Bone tumors
		– Prostate cancer
		– Urinary tract cancer
		– Digestive tract cancer
		– Soft tissue tumors

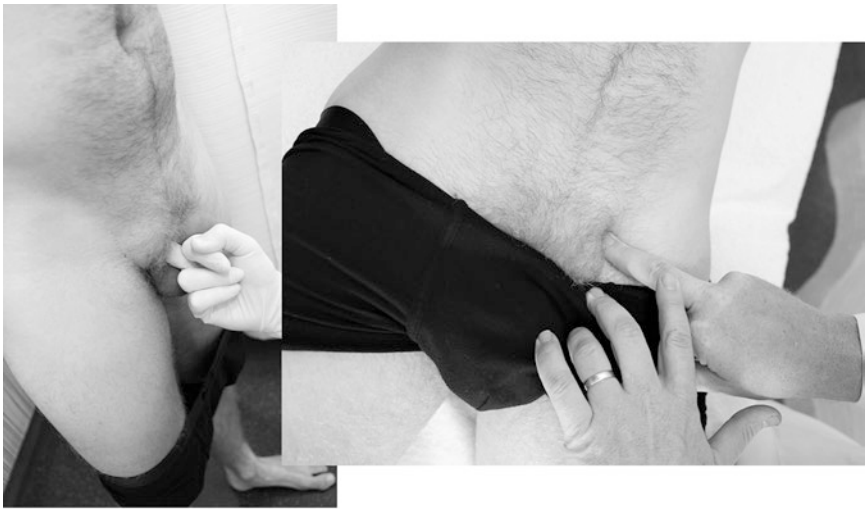

Fig. 21.3 Palpation of the inguinal canal region both via abdominal wall and using scrotal invagination is used to confirm the presence of recognizable injury pain and exclude an actual inguinal hernia

Table 21.2 Cardinal signs of inguinal-related pain—3 out of 5 are required for a diagnosis

Clinical signs on examination
1. Pin-point tenderness over the pubic tubercle at the point of insertion of the conjoint tendon
2. Palpable tenderness over the deep inguinal ring
3. Pain and/or dilatation of the external ring with no obvious hernia evident
4. Pain at the origin of the adductor longus tendon
5. Dull, diffuse pain in the groin, often radiating to the perineum and inner thigh or across the mid-line

in bed. Mechanical symptoms such as locking or clicking are not features of inguinal-related groin pain.

Clinical examination is the cornerstone of diagnosing groin pain in athletes. The Manchester statement defined five cardinal signs on examination, of which at least three needed to be present to diagnose inguinal-related groin pain a shown in Table 21.2. Importantly, it is well recognized that inguinal-related pain or a sportsman's groin does not present with a "true" inguinal hernia [5]. The absence of the bulge therefore leads to the need to exclude another pathology prior to the inguinal canal and the presence of a possible incipient hernia being labeled as the cause of the pain [5]. The definition used in the Doha agreement is listed above and again uses clinical examination to categorize athletes and exclude an inguinal hernia.

Palpation of the inguinal-canal region for the presence of recognizable groin pain and the absence of an inguinal hernia is essential—see Fig. 21.3.

Besides examination of the inguinal region all the musculotendinous groups in the groin region along with the hip joint should be checked, as multiple diagnoses are common in a single athlete.

Adductor and hip flexor muscle group assessments with palpation, stretching, and resistance testing are vital. These can be supplemented with strength testing. Strength testing can be done with a dynamometer of using a blood pressure cuff. These strength or pressure (mmHg) measurements on "squeezing" provide a useful baseline. Hip joint examination has been shown to be useful for ruling out hip joint pathology but less specific at ruling it in [6].

21.4 What Are the Main Investigations That Are Required for Athletes Presenting with Inguinal-Related Groin Pain?

The aim of any imaging investigation is to help determine the correct etiology but also to exclude the other possible differential diagnosis of "groin pain" as outlined above.

In the first instance any imaging investigation that is carried out should be interpreted with the help of the clinical findings, for example, adductor tendinopathy noted on magnetic resonance imaging (MRI) may not necessarily correspond with any adductor-related pain felt by the patient. Multiple studies have found that imaging findings are often present in athletes, but that there is no strong association with pain [8–10].

The pubic bone complex represents the important cross-link between the strong adductor and anterior abdominal wall muscles and tendons; therefore, the pubic bone often shows changes in persons undertaking regular sports, often described as osteitis pubis. Biopsy of athletes with pain and pubic bone marrow edema on MRI showed a lack of inflammation and the formation of new woven bone suggesting that this is not an inflammatory condition [11]. As such the term osteitis pubis should be avoided in athletes with bone marrow edema on the MRI. It would seem that there is a bone stress reaction, which was found to have some association with pain at the more severe end of the spectrum in a case control series [9].

In athletes it is best practice to describe the bone marrow signal pattern observed on MRI with a common parasymphyseal bony edema pattern seen in young footballers as incidental findings but more diffuse and severe bony oedema through a pubic body is a more positive finding [5]. The findings need to be considered clinically and bearing in mind that most bone stress reactions in athletes are not symptomatic.

As already stated, inguinal-related groin pain can only be diagnosed in the absence of a classical hernia on clinical examination.

Ultrasound and MRI can be used to assess weakness of posterior inguinal wall. The diagnostic value of posterior wall weakness or bulging is uncertain. Imaging is not required by either Manchester or Doha consensus. Bulging can be present without pain and a prospective study found it not to be predictive of the onset of groin pain in athletes [10].

On MRI a hernial sac may be visualized and strain scans can be performed but ultrasound is better suited to the assessment of inguinal region for posterior inguinal wall weakness.

An ultrasound examination with graduated valsalva technique and forced valsalva are helpful in assessment for weakness of the posterior inguinal wall just medial to the deep inguinal ring, femoral hernia although less common can be also easily identified.

21.5 What Are the Management Strategies for Inguinal-Related Groin Pain in Athletes?

21.5.1 Active Rehabilitation

The available evidence should always be assessed when considering treatment advice for athletes. A systematic review on the treatment of groin pain in athletes identified 72 studies [3]. There were only four high-quality studies found. It was noted that there were "no studies focused on the conservative treatment with a well-described treatment protocol." Studies with less than ten subjects were excluded from the review. This means that some case series of successful conservative treatment were missed [12, 13]. In a randomized controlled trial where bilateral TEP laparoscopic mesh repair was compared to conservative treatment 60 athletes were included [14]. This study was of high quality, and found better outcomes in those undergoing surgery, but unfortunately the conservative treatment was not described in detail and simply as: total rest from sports, active physiotherapy, steroid injections, and oral NSAIDs. The conservative treatment was carried out at the players clubs 3 times a week for 8 weeks and at 1 year 50 % were back playing sport (compared to 97 % in the operative group), suggesting conservative treatment can be successful. This also fits with our clinical experience.

In practice we recommend commencing an active exercise-based treatment approach. The program is based on strengthening the abdominal muscles with progression through isometric, concentric, and eccentric forms. Exercises for the hip adductors and flexors should also be included. Pelvic stabilization and balance exercises should also be performed.

If symptoms have become quite severe and affected sports participation then athletes need to be prepared to work on a program for at least 8 weeks. During this period general fitness should also be maintained using walking, stationary cycling, and later jogging if these activities do not provoke pain.

Once the exercises and jogging can be performed pain free then sports specific training can be added in a gradual manner. Progression from sports specific training to sports participation should also occur in a gradual fashion until full participation is achieved.

A lack of progression despite progressive exercise-based therapy is a reason to consider a surgical treatment alternative.

21.5.2 Surgical Intervention

Surgery has been performed frequently and is seen by some as a possible mainstay of treatment for patients with inguinal-related groin pain. As mentioned above, a single RCT was found, albeit with poor description of the conservative treatment, which found surgery to be more effective [14]. Whether surgery should be open or laparoscopic, mesh or no mesh with a simple suture, remains undecided with opinion in the surgical fraternity on the etiology as well as the choice of any surgical repair divided [15]. Techniques such as the Lichtenstein, Open minimal repair (OMR), Transabdominal preperitoneal (TAPP), and Transabdominal extraperitoneal (TEP) have all been used to good effect but no comparisons made to date with two techniques [14, 16, 17].

Minimal access surgery is now increasingly becoming the choice of repair especially if the pathology is felt to be secondary to a weakness in the posterior wall and/or the inguinal canal itself [18]. However the open minimal repair (OMR) still appears to have a role in the surgical treatment for a "posterior wall" weakness especially as it promotes the use of no mesh combined with an early return to sporting activity [17]. It therefore seems that perhaps with the one exception of the OMR technique, the evolution of surgical repair for inguinal-related pain is mimicking inguinal hernia surgery with open Lichtenstein repair being replaced with more laparoscopic approaches [17]. Consequently a multi-center randomized controlled trial examining two common techniques (OMR & TEP) is presently ongoing (clinical trial no. NCT01876342) and should provide much needed evidence as to which technique, if any, shows a better outcome of an earlier return to sporting activity [18]. Any surgery for inguinal-related groin pain should be accompanied by an active exercise regime to try and improve core stability as this may

delay or even prevent surgery. However, once surgery is undertaken a tailored rehabilitation program is required to suit the type of surgery undertaken and whether it should differ with open surgery (Gilmore) to minimal access surgery remains undecided? Further questions can also be asked as to whether there are any differences with the TEP [14] or TAPP [19] techniques in recovery and rehabilitation. If a decision is taken for a surgical repair, this has to be weighed up with the risk of potential complications that could occur especially with the minimal access techniques such as bowel or visceral injury [20]. Inguinal hernia surgery though is very safe with a low overall morbidity and with the attraction to an athlete of being possibly pain free, there will eventually be a leaning towards a surgical option.

Many clinicians will of course ask the question of what one does when an athlete complains of recurrent pain, especially after surgery?

In most patients with groin pain dual pathology is recognized as occurring in at least 20–50 % of patients [21]. In cases of groin pain after treatment it is necessary to reinvestigate the other possible causes of groin pain as outlined above. This includes the reassessment for other musculotendinous injuries as well as the hip joint. This can be followed by repeat imaging preferably with an MRI scan to rule out any unusual causes, especially in cases with less typical presentations. Any recognized injuries should be treated as appropriate but there also should be recognition that the athletes may subsequently have reinjured themselves.

21.6 Conclusion

Inguinal-related groin pain is common in male athletes participating in sports with explosive change of directions and kicking. The diagnosis can be made using clinical examination to confirm the presence of pain in the inguinal canal region in the absence of an actual inguinal hernia. Imaging only has a role in excluding other pathology. Active rehabilitation is the first line treatment although there is lack of good data to inform on outcome success. When conservative treatment fails surgery is recommended which relies on strengthening of the inguinal canal.

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The Treatment of Incarcerated and Strangulated Inguinal Hernias

22

Kendall R. McEachron and Archana Ramaswamy

22.1 Introduction

Inguinal hernias are repaired for two reasons: to relieve symptoms such as pain, and to reduce the risk of acute incarceration/strangulation and subsequent bowel ischemia. Therefore, the important questions to consider include:

1. What is the risk of incarceration? For purposes of this chapter, the general term "incarceration" will encompass both incarcerated and strangulated inguinal hernias, except where the difference is pertinent to the discussion.
2. How does the clinical presentation differ, and how does surgical management differ from that of elective hernia repair?
3. How does the presence of acute illness or bowel ischemia affect the repair technique, use of prosthetic materials, and recurrence rates?

22.2 Incidence

The natural history of the acquired inguinal hernia has been in question during recent years. One of the first papers to examine the incidence of inguinal hernia complications (i.e., incarceration) was a 1981 review of the Colombian national health survey from 1969 to 1973 [1]. During this time, there were 248 cases of incarcerated inguinal hernia reported. The incidence of strangulation of an inguinal hernia for a man over age 20 was 2.7–5.7 per 1000, varying with age. The age range with the highest risk was 60–65 years, which carried a 5.7 % risk in men and a 6.7 % risk in women. A landmark paper in determining the natural history of minimally symptomatic inguinal hernias was published in 2006 by Fitzgibbons et al. [2]. Seven-hundred and twenty men were enrolled, with randomization to either surgical repair or "watchful waiting." In the watchful waiting arm, acute incarceration occurred approximately 1.8 times in 1000 patient-years. The study patients were followed for a total of 10 years, and the results of long-term follow-up were reported in 2013. A high crossover rate (from watchful waiting to elective repair) of 68 % was demonstrated in the long-term follow-up study [3], but the risk of acute incarceration remained low, totaling three patients (2.4 %) during the follow-up period. There were no mortalities in this group, suggesting that there may not be a significant penalty to watchful waiting. A population-based study of 4026 inguinal hernia repairs performed between 1989 and 2008 in Olmstead County, MN [4], examined the patient characteristics of those undergoing emergent as opposed to elective inguinal hernia repair. Emergent repair was associated with older age, higher ASA risk factor score, and previous herniorrhaphy. Emergent inguinal hernia repair occurred 7.6 times in 100,000 person years, while the incidence of elective hernia repair was 200/100,000 person years. Abi-Haidar et al. [5] retrospectively reviewed 1034 consecutive groin hernia repairs at a single Veteran's Affairs Hospital from 2001 to 2009. The overall risk for emergent hernia repair was 6.1 % ($n = 63$ vs. 971), and factors identified by multivariate analysis to increase the risk of an emergent operation were patient age, as well as femoral, scrotal, and recurrent hernias. These studies and others have demonstrated that the risk of incarcerated inguinal hernia is quite low, but its management must remain familiar to the general surgeon.

Femoral hernias are less common than other groin hernias. It is commonly taught that this rarer hernia type

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_22

is more prevalent in women, and is associated with higher rates of incarceration. In 2012, Romain et al. [6] published a review of 49 cases of strangulated groin hernia repair, divided into 30 inguinal and 19 femoral hernias. They found a statistically significant predominance of female patients in the femoral hernia group, and men in the inguinal hernia group. Perhaps one of the largest studies demonstrating these principles was based on prospective data from the Swedish Hernia Registry, published in 2005 [7]. Over a 10-year period there were 90,640 hernia repairs registered. Only 6895 of these repairs (7.6 %) were performed in women. However, among this group, femoral hernias were present in 16.7 % of elective repairs and 52.6 % of emergency repairs compared to 0.7 % and 6.5 % in men, respectively. Of note, there was also a statistically significant increased incidence of bowel resection in women undergoing emergency hernia repair, 16.6 % vs. 5.6 %. Although this study did not specifically break down the types of incarcerated hernia leading to bowel resection, another study using data from the Swedish Hernia Registry published in 2009 [8] focused specifically on femoral hernia repairs. Emergent inguinal hernia repairs in this data set required bowel resection 5.4 % of the time, while the rate of bowel resection was 22.7 % for emergent femoral hernia repairs. Also, it was re-demonstrated that femoral hernias have a higher chance of requiring emergent surgery than inguinal hernias (35.9 % vs. 4.9 %), and that more emergent femoral hernia repairs are performed in women than men (40.6 % vs. 28.1 %). This study and others strongly support the long held belief that there is an increased risk of bowel resection for emergency femoral hernia repairs [5, 9, 10].

22.3 Presentation

Well known to the general surgeon, the most frequent presentation of a symptomatic inguinal hernia, whether incarcerated or not, is groin pain [11]. The pain can manifest as a heavy feeling, a sharp pain radiating down the medial thigh, or a dull ache. In many cases of incarcerated hernia, the presentation is generalized abdominal pain, whether radiating from the groin or poorly localized, reflecting the pathophysiology of peritoneal irritation. If the hernia contains bowel, the patient may present with changes in bowel habits such as diarrhea or constipation. Bladder irritation may result in urinary symptoms. Frankly incarcerated or strangulated small bowel will prompt the patient to present with symptoms of bowel obstruction such as nausea, vomiting, and abdominal distention along with constipation or obstipation. Unfortunately, some patients present with ischemia of hernia contents and sepsis.

22.4 Diagnosis

History of present illness may reveal preexisting symptoms of inguinal hernia. These symptoms have usually worsened or changed acutely at the time of presentation of acute incarceration. There is a small subset, however, for whom the pain and illness of incarceration may present without prior symptoms of a hernia. Inguinal hernias are routinely diagnosed by physical exam [11–13], though in some individuals imaging studies may be required due to body habitus. In the case of incarcerated hernias, patients presenting with diffuse abdominal pain and other symptoms of bowel obstruction will often undergo abdominal X-rays (Fig. 22.1) and computed tomography scanning to rule out other sources of intra-abdominal pathology (Figs. 22.2, 22.3, and 22.4). This imaging modality is useful for characterizing the fascial defect and may provide information as to the viability of hernia contents, such as whether a loop of small intestine is obstructed, appears inflamed, thickened, or perforated. Other abnormalities such as pneumatosis, free air, or free fluid also can be picked up by CT scan, making it the imaging study of choice for inguinal hernias with acute symptom changes [13].

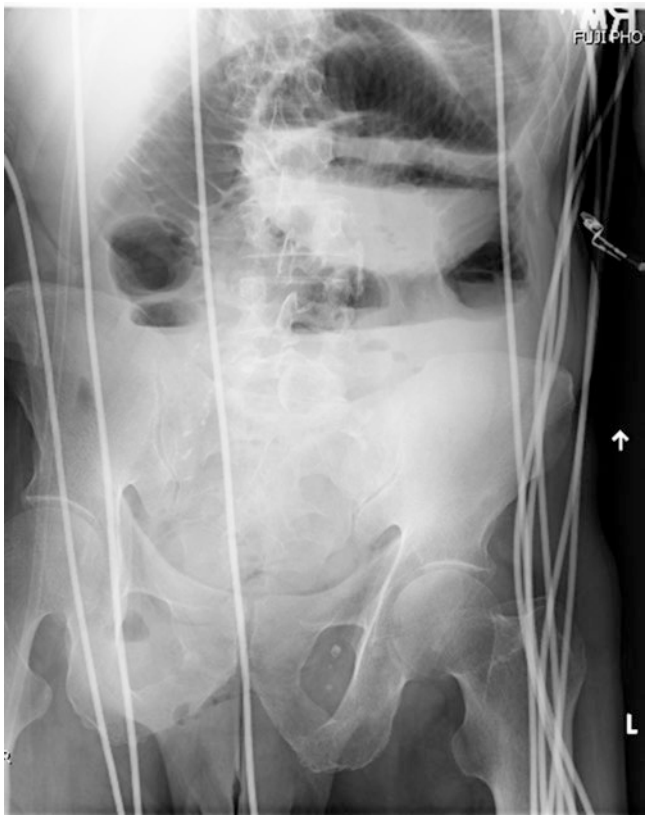

Fig. 22.1 Small bowel obstruction with an incarcerated right inguinal hernia

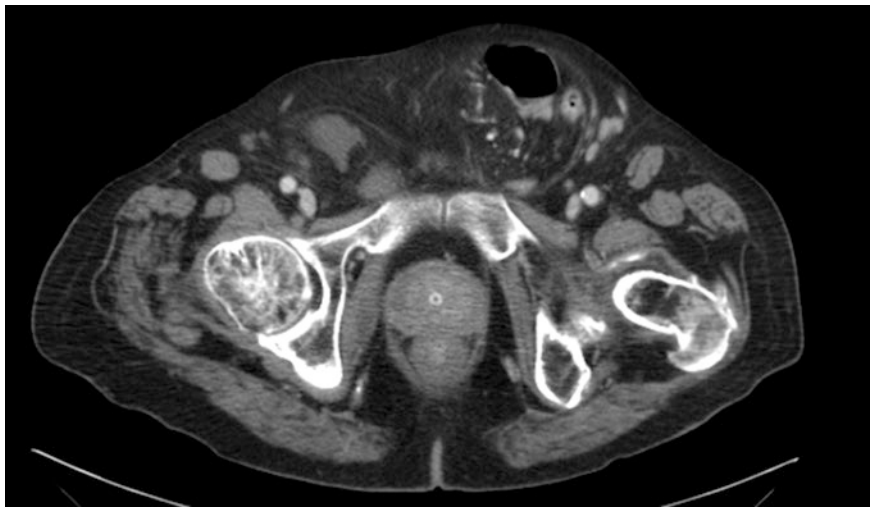

Fig. 22.2 Bilateral inguinal hernias

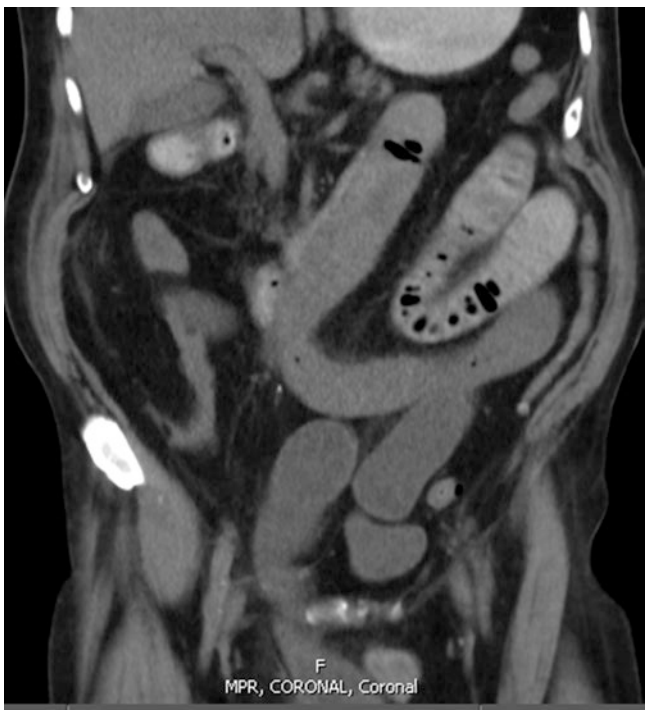

Fig. 22.3 Incarcerated right inguinal hernia with cecum

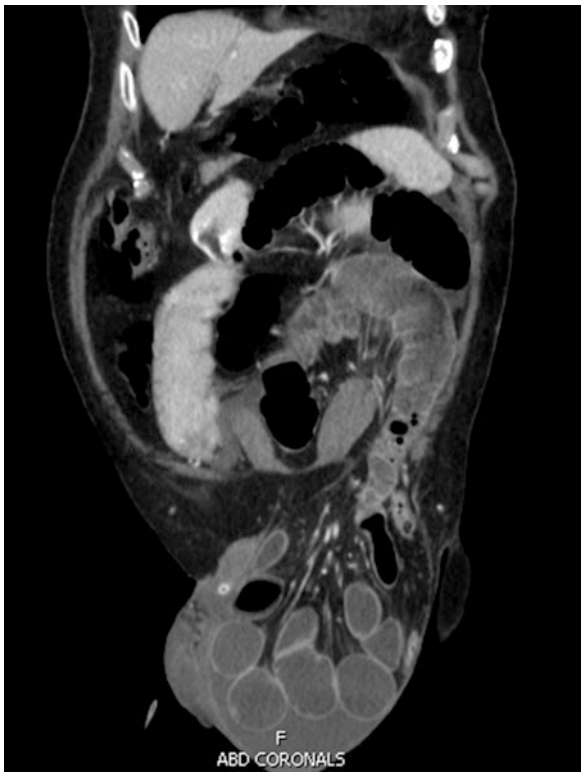

Fig. 22.4 Incarcerated left inguinal hernia

22.5 Repair

22.5.1 Open Repair

In their retrospective review, Hernandez-Irrizary et al. [4] found that 60 % of emergency inguinal hernia repairs utilized the open, non-mesh technique. There was a statistically significant higher number of non-mesh repairs for incarcerated versus elective inguinal hernia repairs (OR 1.8, $p=0.008$). This high proportion of open non-mesh repairs for acute inguinal hernia is in line with traditional teaching, which discourages the use of mesh in "the contaminated field." Open repair provides the option of potentially avoiding general anesthesia in a fragile patient and tends to be an approach that many surgeons are more comfortable with in an urgent situation. Techniques of open tissue repair are discussed in Chap. 13. With the high recurrence rates of tissue repair now being recognized in the literature, the safety of mesh hernior-

rhaphy even in cases where there are necrotic hernia contents, and the utility of laparoscopic techniques for acute hernia repair may be slowly altering traditional practice patterns. Retrospective studies comparing the practice patterns of 15–30 years ago with those of the past 15 years would be useful to precisely delineate this change. The next sections of this chapter will present some of the data that exists regarding mesh repair and laparoscopic repair for incarcerated inguinal hernia.

22.5.2 Role of Mesh Repair

Mesh repair of acutely incarcerated hernias has long been under scrutiny due to the theoretical risk of a contaminated field increasing mesh infection rates [14]. There has been a recent effort in the literature to provide evidence-based guidance for the surgeon who finds his or her patient in this scenario. The randomized-controlled trials have, thus far, been small in sample size and lacking in long-term follow-up; however, the trend in data favors mesh repair as a safe and durable option for incarcerated hernia repair, even in cases requiring bowel resection. In 2005, Papaziogas et al. [15] published a prospective observational study of strangulated inguinal hernia repairs comparing the use of the modified Bassini (Andrews) technique with a tension-free repair with polypropylene mesh. Data was collected over a 15 year period (1990–2004), during which time 33 mesh repairs and 42 Bassini repairs were carried out on strangulated inguinal hernias. The choice of repair technique was based on surgeon preference and, interestingly, a majority of the mesh repairs were performed in the later years of the study. Of note, four (12.1 %) of the mesh repair group underwent bowel resection compared with ten (23.8 %) of the tissue repair group. There was no significant difference in wound infections between the two groups, and no mesh required explantation; the authors concluded that strangulated hernias may be safely repaired with mesh. Another prospective observational study [14] followed 95 patients who underwent open mesh repair with heavyweight polypropylene mesh for an acutely incarcerated inguinal or femoral hernia with a median follow-up of 47 months. Two groups of patients were compared: those who required bowel resection to those who did not. Operative time and length of hospital stay were increased in the bowel resection group, but there was no difference in wound infection rates, morbidity, or mortality between the two groups. Bessa et al. [16] recently published a larger 10-year prospective study on the topic of mesh repair for acutely incarcerated inguinal and femoral hernias, with 234 patients included and a mean follow-up of 62.5 months. Comparison was made between patients with viable hernia contents versus nonviable contents. There was no statistically significant difference in postoperative wound infections, and the only case of mesh infection occurred in a patient who did not undergo resection for nonviable hernia contents. There is one randomized controlled trial of mesh repair in acute inguinal hernias. The trial enrolled 54 patients and followed them for a mean of 22 months [17]. They were randomized to Lichtenstein mesh repair or Bassini tissue repair. In this study, patients requiring bowel resection for ischemia or necrosis of hernia contents were excluded. There was a statistically significant reduction in operative time, hospital stay, and recurrence for patients who underwent tension-free mesh repair. Hentati et al. [18] conducted a systematic review and meta-analysis of this topic. The data favored mesh herniorrhaphy for the outcome of hernia recurrence, and with a trend toward decreased wound infection. The authors were unable to recommend for or against the use of mesh in cases where bowel resection was necessary. The above studies suggest that the use of mesh for incarcerated inguinal hernia repair without bowel resection is likely safe, and although there are no high-quality randomized controlled studies, prospective and retrospective studies utilizing polypropylene mesh in instances with acutely incarcerated inguinal and femoral hernia repair involving bowel resection also appears to be safe. It is also important to note that none of the above studies included patients with perforated bowel or frank peritonitis. Biologic mesh has been suggested as an option in this type of a situation though there is little information regarding the long-term outcomes. Early outcomes for biologic mesh appear to be acceptable in elective open inguinal hernia repair [19], though unknown from the standpoint of recurrence and chronic pain.

22.5.3 Role of Laparoscopic Repair

Watson et al. [20] reported the first case of laparoscopic repair for acutely incarcerated groin hernia in the United States in 1993. This was the case of a femoral hernia repair with small bowel resection. In the years since this case report, there has been debate with regard to the laparoscopic approach best suited for incarcerated hernia repair. Leibl et al. [21] reported a prospective study of 194 transabdominal preperitoneal (TAPP) repairs for incarcerated inguinal hernias. They compared mortality with that of elective TAPP repairs and found no significant difference. Felix et al. [22] also concluded that TAPP was the laparoscopic procedure of choice for incarcerated inguinal hernias. These sources and others have commented on the utility of TAPP in particular for easy examination of incarcerated bowel for signs of necrosis, and the relative simplicity of bowel resection should this be necessary.

Ferzli et al. [23] reported their experience with totally extraperitoneal repair (TEP) for acutely incarcerated hernias. This study only included 11 cases, 3 of which required conversion to open. Follow-up varied widely from 9 to 69 months, and no recurrences were noted. As this space allows limited mobility for reduction of hernia contents, it has been recommended, when necessary, to place an additional trocar, create a medial tissue release for incarcerated direct hernias, medial tissue release with ligation of the epigastrics for indirect hernias, and release of the iliopubic tract for femoral hernias. The incarcerated contents must be examined by opening the sac. Alternatively, initial view and reduction of contents may be performed in a transabdominal fashion, and the peritoneum may be then closed and the procedure then proceeds with a standard TEP approach.

Given the relative paucity of high-quality data supporting the use of laparoscopy for acutely incarcerated inguinal hernias, the European Association for Endoscopic Surgery put forth a guarded consensus statement in 2006 stating that laparoscopic surgery could be used in "carefully selected patients" by "surgeons with maximum expertise in laparoscopic hernia surgery" ([24], p. 20). In 2009, Deeba et al. [25] attempted to pool the available data in a systematic review of seven articles from which 328 total cases were reported with the use of laparoscopy for incarcerated inguinal hernias. Six of these cases were converted to open, and bowel resection was reported in 17. TAPP predominated in four studies, but TEP was the procedure of choice in the other 3. From their data, the authors concluded that a laparoscopic approach is feasible for incarcerated inguinal hernia repair, and bowel resection if needed. Larger studies directly comparing laparoscopy to the traditional open approach are beginning to surface. In 2012, Yang et al. [26] published prospective data comparing 57 laparoscopic repairs to 131 open repairs for acute strangulated groin hernias. There was a similar mean operative time, fewer laparotomies, and fewer wound infections (p values <0.05) in the laparoscopic group, with no difference in hospital length of stay or hernia recurrence. Ultimately, there is a need for larger and higher powered studies evaluating the use of laparoscopic techniques for hernia repair in the acute situation.

22.5.4 Hernioscopy

Romain et al. [6] analyzed the prognostic factors affecting postoperative morbidity after incarcerated groin hernia repair. Statistical analysis demonstrated that midline laparotomy was the only independent prognostic factor for medical or surgical complications. If this is the case, it is important to explore operative techniques that allow for limited use of midline laparotomy while also allowing for safe assessment of the hernia contents during incarcerated hernia repair. Incarcerated inguinal hernias will self-reduce during induction of general anesthesia in approximately 1 % of cases [27], making it difficult to evaluate viability of the previously incarcerated hernia contents. How can excess morbidity be avoided in this circumstance? Hernioscopy (laparoscopy via an inguinal hernia sac) is a well-established technique in pediatric surgery for surveillance of the contralateral side during repair of a known congenital inguinal hernia. Sajid et al. [28] performed a systematic review of the literature on the use of hernioscopy for evaluating the bowel in adult patients with inguinal hernia, and found relatively little evidence (mostly case reports) for this technique in adult practice. Piccolo et al. reported their small case series of hernioscopy use in 2014 [27], and concluded that hernioscopy is useful for evaluating the bowel while avoiding laparoscopy or laparotomy. More evidence of higher quality is needed to determine which patients would benefit from hernioscopy as a method for evaluating incarcerated inguinal hernia contents.

22.6 Summary

Inguinal and femoral hernias carry a low risk of acute incarceration with rates of 5–6 % for inguinal hernias and sixfold that rate for femoral hernias with a female preponderance for femoral hernias. Diagnosis can usually be made clinically but be aided by CT scan when necessary. Treatment is based on surgeon experience, but multiple studies suggest that both the usage of macroporous mesh and laparoscopic techniques are feasible in the acute situation when perforated bowel and frank peritonitis are absent. Based on the available data, we propose an algorithm for treatment of the patient in Fig. 22.5.

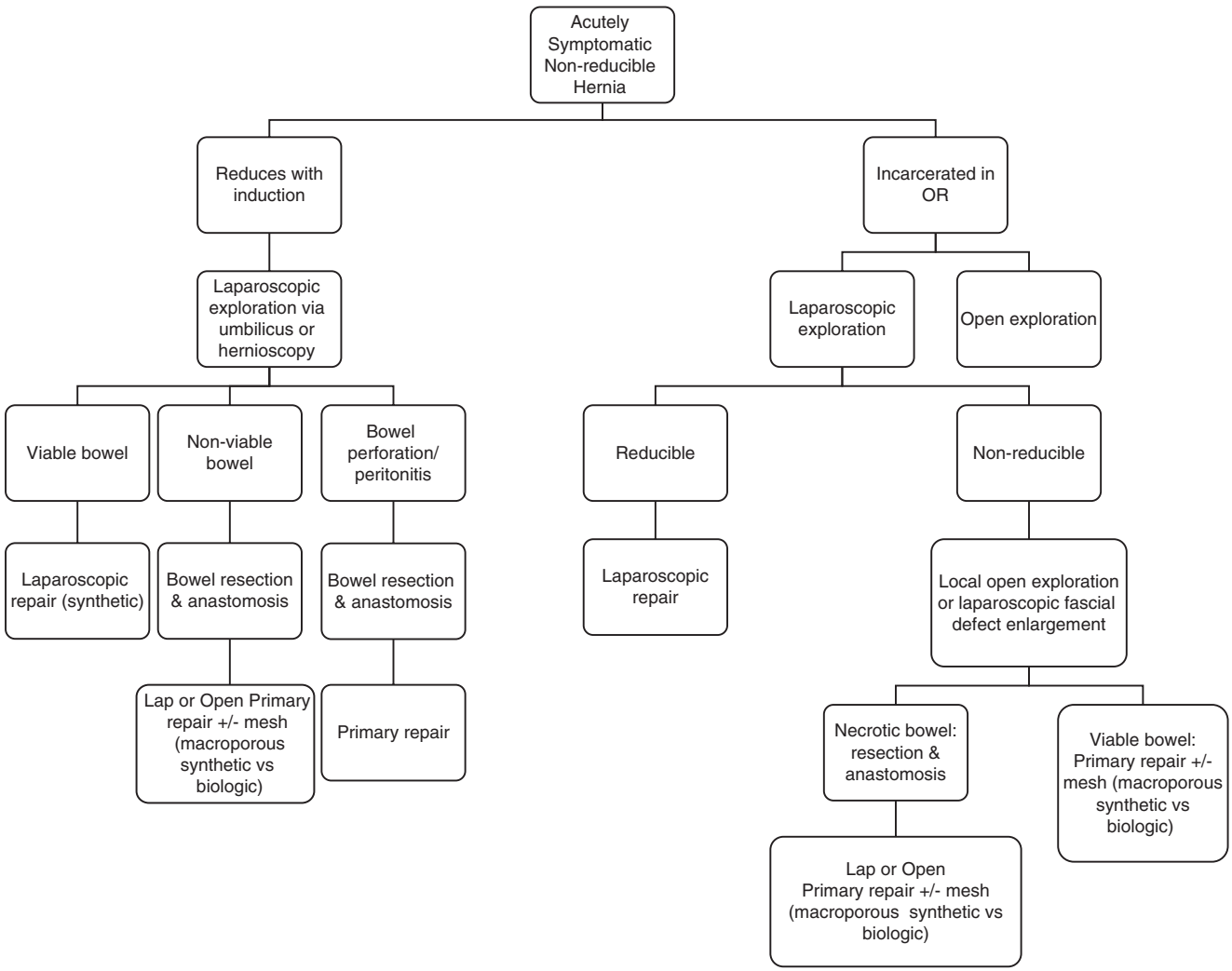

Fig. 22.5 Algorithm for treatment of the patient with an incarcerated inguinal hernia

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Introduction and Epidemiology of Incisional Hernias and the Argument for Mesh in Incisional Hernia Repair

23

Diya I. Alaedeen

23.1 Historical Brief

The Roman doctor Aulus Cornelius Celsus of the first century A.D. was among the first to document the closure of laparotomy. Celsus described the closure of the abdominal wall in his text, *De Medicina*, and termed it "gastrorrhaphy"; he also provided a detailed description of the pre- and postoperative care of the patient [1]. Another prominent Roman-Greek physician, Galen of Pergamon, provided a detailed description of the mass closure of the abdominal wall a century later. Galen was the first to describe the details of a para-median incision in order to prevent incisional hernias [2].

The surgeons of the middle ages (A.D. 500–1500) provided little to the science of hernia repair. It was during the age of enlightenment (A.D. 1750–1850) when the no-longer forbidden cadaveric dissection edified surgeons on the accurate anatomy of the abdominal wall, the pillar of herniology. Based on this knowledge, in 1836, a French surgeon, Pierre Nicholas Gerdy, was the first to document an incisional hernia repair through large closure of the abdominal wall. Gerdy injected ammonia into the hernia sac, to induce dense adhesions, presumably to avoid hernia recurrence [2].

As the field of surgery advanced towards the end of the nineteenth century, with the advent of anesthesia and antisepsis, laparotomy became more common. Along with laparotomy came the iatrogenic consequence of incisional hernia, as we know it today.

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23.2 Prevalence and Cost

Currently, even with the widespread use of laparoscopy and minimally invasive surgical methods, it is estimated that over two million laparotomies are still performed in the United States on an annual basis. Studies reveal an estimate incisional hernia occurrence rate of 25 % of all laparotomies. This leads one to conclude an estimate occurrence of 500,000 incisional hernias per annum in the United States alone. This conservative estimate may be higher with longer follow-up, and when including laparotomies performed for repair of hernia recurrences [3–5].

In 2012, Poulose et al. conducted a study identifying adult patients discharged after ventral hernia repair from two data sources: the 2001–2006 Healthcare Cost and Utilization Project Nationwide Inpatient Sample, and the 2006 Center for Disease Control National Survey of Ambulatory Surgery. The study revealed that an estimate of 348,000 ventral hernia operations are performed annually, as of 2006, in the USA alone. The estimate excludes patients undergoing procedures at military facilities or in the Department of Veterans Affairs. In addition, the study highlighted the total estimated procedural costs for ventral hernia repair at $3.2 billion in 2006 alone [6]. This financial burden of a ventral hernia repair is expected to continue to increase when one takes into account the overall cost of the hospitalization and loss of productivity.

The staggering cost of treating the disease of incisional hernia is a global problem. In Europe, the most recent French data revealed that the total cost for "an average incisional hernia" repair in an "average patient" in 2011 was an estimate of 6451€ [7]. Even in a smaller country like Sweden, data shows an estimated incisional hernia repair cost north of 9000€ per patient [8].

These values do not consider treating any complications that may arise as the result of incisional hernia repair, such as mesh infection. Recently presented data from the Carolinas Hernia Center revealed that the cost of a mesh infection after ventral hernia repair could reach six figures per patient.

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_23

Within a year of recognizing a mesh infection, inpatient hospital charges reach an average of $44,000 plus an additional $63,400 in follow-up costs; with total expenses associated with a mesh infection can reach as high as $107,000 [9].

23.3 Risk Factors for Incisional Hernia

The population most at risk of developing an incisional hernia is all patients who undergo any abdominal incision that violates the integrity of the abdominal wall regardless of location and type of incision. Essentially, the at-risk population are all surgical patients regardless of gender, ethnic, or socioeconomic background. The highest reported occurrence of incisional hernias is with midline incisions that violate the linea alba [10].

Several studies revealed that transverse or oblique incisions are more protective of incisional hernia formation than vertical midline incisions. In 2013, Bickenbach et al. conducted a systematic review and meta-analysis exploring the effect of incision type on hernia formation. They found that midline incisions resulted in higher hernia rates when compared with transverse (relative risk (RR) of 1.77 with 95 % confidence interval (CI) 1.09–2.87) and paramedian incisions (RR of 3.41 and 95 % CI 1.02–11.45) [11].

Any perioperative wound issue such as infection, ischemia, seroma formation, or dehiscence, grouped as surgical site occurrence (SSO), would increase the risk of hernia occurrence by at least threefold [12]. Surgical site infection (SSI) has been shown to be one of the most common contributor to the occurrence of hernia after laparotomy [10, 13].

Several modifiable risk factors have been shown to play a major role in not only hernia occurrence, but also postoperative complications and increased morbidity. Smoking, obesity, malnourishment, poor diabetic control, and wound contamination have been all shown as risk factors.

Smoking "suffocates" the wound by decreasing blood flow and tissue oxygen tension as well as the healthy deposition of collagen in the surgical wound [14]. It has been shown in clinical studies to be a major risk factor for the development of infection, and hence increases hernia occurrence after laparotomy. A Danish cohort study found that smoking has a fourfold increased risk of incisional hernia occurrence after midline laparotomy [15]. The same group, in a well-constructed randomized controlled trail, revealed that abstinence from smoking 30 days preoperatively, with or without the use of nicotine patch, reduces the adverse effects of smoking on wound healing significantly [16]. An expert panel of hernia surgeons stressed their position on the issue of smoking cessation before embarking on any elective abdominal wall reconstruction, and made a courageous stand in refusing to operate on noncompliant patients [17]. This highlights the significance of this issue, and the clear risk of smoking on adverse outcomes that haunt the patient, and the surgeon who has to deal with these costly and time-consuming complications.

Obesity is a well-recognized risk factor for incisional hernia after laparotomy and for hernia recurrence after initial repair. Previous studies have identified it as an independent risk factor for incisional hernia formation [18, 19]. Obesity is perhaps one of the most difficult modifiable risk factors to correct. Without surgical or endoscopic bariatric interventions, most patients are unable to lose the excess weight, or even keep the excess pounds off once some have been lost. In one study, obesity was found to play a more critical role in incisional hernia occurrence than the immunosuppression caused by steroids [20].

Malnourishment, on the other hand, has also been shown to increase the risk of postoperative wound infection, and ultimately hernia formation. A landmark study by the United States Department of Veterans Affairs in 1997 revealed that the single most significant predictor of poor surgical outcome and increased morbidity was a serum albumin level of less than 3 g/dL [21]. Aside from postoperative complications and poor outcomes, there is an increased risk of early occurrence of incisional hernia in malnourished patients [22]. Although the impact of preoperative nutritional support has not been clinically shown to decrease incisional hernia occurrence or recurrence per se, it has been validated in decreasing postoperative complication rate and length of hospital stay [23].

Adequate glycemic control in the perioperative period can lead to a decrease in SSI. The data reveals that when HbA1c is less than 7 % the rate of SSI can be significantly reduced [24]. Furthermore, diabetic patients are at a twofold increased risk of surgical site infection than nondiabetics, even after controlling for hyperglycemia [25]. In the perioperative period, collaborative efforts by the surgeon and the primary care provider should aim to accomplish strict glycemic control for all surgical patients, especially those undergoing laparotomy for any reason.

The routine use of prophylactic antibiotics in patients undergoing laparotomy for gastrointestinal surgery, or hernia repair, is now recommended by the guidelines developed jointly by the American Society of Health-System Pharmacists, the Infectious Diseases Society of America, the Surgical Infection Society, and the Society for Healthcare Epidemiology of America [26]. The guidelines are based on the most current available clinical evidence and data. Wound contamination and infection delay the activation of the repair pathways needed for optimal wound healing after laparotomy as previously discussed in Chap. 1 of this book.

23.4 The Argument for Mesh

Ventral hernia repair was initially carried out with suture alone, and a few surgeons documented the use of metallic meshes. The recurrence rate of hernia repair with suture

alone was frustratingly high, up to 60 %. In 1944, a French surgeon, Acquaviva, documented the first use of plastic in hernia repair, but it was Dr. Francis Usher who popularized and introduced plastic (polypropylene) in the late 1950s with validity. Polypropylene solved many problems that were encountered with the metallic meshes such as with extreme stiffness, fragility, migration, corrosion, and toxicity. But plastics in general remain far from ideal. Today, the large three categories of synthetic prosthetics used in hernia repair are polypropylene, polyester, and expanded polytetrafluorethylene (ePTFE).

As discussed in Chap. 1, hernias are the result of a biomechanical failure of the acute wound. Suture repair alone may lead to excessive tension on the fascial closure, and subsequent wound dehiscence and hernia formation. Aside from the intra-abdominal forces generated during normal activity of breathing, coughing, or physical activity, the oblique muscles tend to flex laterally pulling the median fascial repair apart. The argument for mesh is that the tension is now countered by the strength of the incorporated mesh. Dr. Lichtenstein was the first to coin the concept of mesh "tension-free repair" in 1986 [27].

The use of plastics became common after Usher's work became public. Subsequently, there were many reports and studies documenting the techniques of hernia repair with some favoring the use of sutures alone, while others favoring the use of mesh. In 1993, Hesselink et al., in a retrospective study of 298 patients, revealed a high rate of hernia recurrence, especially when mesh was not used and the hernia defect was larger than 4 cm [28]. But none of the earlier studies were either controlled or randomized. It was not until the year 2000 when the first randomized, multicenter study of patients with midline abdominal incisional hernias confirmed the mesh repair to be superior to suture repair [29].

In their study, Luijendijk et al. randomized 181 patients, with fascial defects less than 6 cm, to suture repair or mesh repair, using the underlay method of mesh placement. At 3-year follow-up the cumulative recurrence of hernias in the suture repair was double that of mesh repair with statistical significance (46 % vs. 23 %) [29]. In 2004, the same group published their follow-up study for the same patient population with almost 70 % participation rate, and determined a cumulative 10-year recurrence rate for the suture repair to be a disappointing 63 % versus 32 % recurrence in the mesh group [30].

Although the use of mesh in a tension-free fashion was revealed to be superior to primary repair, the recurrence rate remained unacceptably high. It is now recognized that the technique for placement and fixation of the mesh is the more critical factor in determining the outcome of the repair. In 1989, Drs. Stoppa and Rives introduced the technique of mesh placement in the preperitoneal and retromuscular position with a wide overlap of at least 5 cm over the normal fascia in all directions [31, 32]. By placing the mesh below the fascia, the technique applies Pascal's law, which states that any pressure exerted on an enclosed fluid is transmitted equally in all directions. Therefore the intra-abdominal pressure is distributed equally across the mesh. This method decreased the recurrence rates to as low as 3–5 %, making it the ideal technique for open repair of ventral hernias by the Americas Hernia Society [33].

Mesh use in hernia repair is now the standard, but there have been tens, if not hundreds, of techniques described in the literature for the repair of incisional hernias. The subsequent chapters will discuss many of the most common techniques used today for the repair of this iatrogenic disease. We, as surgeons, are responsible not only for the repair of this challenging disease, but also at preventing its occurrence in the first place. It is only through collaboration and sharing data that we can find the ultimate cure, and best methods of treatment and prevention.

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Abdominal Wall Anatomy

24

James G. Bittner IV

24.1 Clinical Anatomy

24.1.1 Overview

With the growing number of techniques for ventral and inguinal hernia repair as well as complex reconstruction of the abdominal wall, it is imperative that hernia surgeons maintain a comprehensive and modern understanding of abdominal wall anatomy. This chapter details relevant abdominal wall anatomy, physiology, and dysfunction leading to hernia.

24.1.2 Layers of the Abdominal Wall

24.1.2.1 Fascia

The most superficial layer of the abdominal wall is made up of skin—epidermis and dermis—which overlies Camper's fascia. The blood supply and nerve innervation of the skin and abdominal wall will be detailed in a subsequent section. The two superficial layers of fascia within the subcutaneous fat include the more superficial Camper's fascia, a soft fatty layer, and the deeper Scarpa's fascia, a membranous tissue layer. Above the level of the umbilicus, Camper's fascia is fused to the deeper Scarpa's fascia. Below the level of the umbilicus, Camper's fascia is a thickened layer of subcutaneous fat. Camper's fascia is contiguous with the lateral thigh, specifically the superficial fascia of the thigh. It is also congruous with the superficial fascia of the scrotum in men and labia major in women. This layer is not always easily identified during dissection of the abdominal wall.

Scarpa's fascia above the level of the umbilicus is fused to Camper's fascia. Below the level of the umbilicus, Scarpa's fascia is identified as a membranous layer within the deeper subcutaneous fat. This fascia extends inferiorly and contributes to the fascia lata of the thigh as well the perineum, where it is termed Colles' fascia. While not always possible or desirable, it is the opinion of the author as well as others that Scarpa's fascia be reapproximated using rapidly absorbable sutures to help alleviate tension on the skin closure and achieve optimum cosmesis [1].

The deep fascial layers include the linea alba as well as the investing fasciae of the abdominal wall muscles. The linea alba of the midline results from the fusion of the anterior and posterior rectus sheaths and extends from the xyphoid process to the pubic symphysis. The anatomy of the linea alba is important when considering the etiology of ventral and incisional hernia, as well as for repair of abdominal wall defects. For example, care must be taken to preserve the linea alba when performing a posterior separation of components (release of the posterior rectus sheath from the overlying rectus abdominis muscle).

The anterior and posterior rectus sheaths vary cephalad and caudad to the arcuate line, which is a horizontal line midway between the umbilicus and the pubic symphysis. The arcuate line represents the transition where the rectus sheaths comprise different components. The anterior rectus sheath comprises the external oblique aponeurosis and investing fascia; however, the remaining components of the anterior rectus sheath vary cephalad and caudad to the arcuate line. Above the arcuate line the anterior rectus sheath also includes the aponeurosis and anterior investing fasciae of the internal oblique muscle. The inferior investing fascia of the internal oblique muscle contributes to the posterior rectus sheath above the arcuate line. Below the arcuate line the anterior rectus sheath is made up of external oblique and internal oblique aponeuroses and investing fasciae [1].

Components of the posterior rectus sheath above the arcuate line include the posterior investing fascia of the internal oblique muscle and the transversalis fascia. The fascia of posterior surface of the transversus abdominis muscle serves as epimysium and is known as the transversalis fascia, which represents a thin aponeurosis sandwiched

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_24

between the transversus abdominis muscle anteriorly and the peritoneum posteriorly [2]. Below the arcuate line the posterior rectus sheath includes only transversalis fascia, making this layer very thin and tenuous during hernia repair. The linea semilunaris is a vertical curvilinear line that extends from the ninth rib cephalad to the pubic tubercle caudad along the lateral border of each rectus abdominis muscle. The linea semilunaris not only defines the lateral border of the rectus sheath, but also aids in localizing the neurovascular bundles that supply the anterior abdominal wall musculature. The linea semilunaris represents the merging of the anterior and posterior rectus sheaths. This is an important landmark for multiple reasons when performing posterior separation of components, in particular the transversus abdominis release [3].

24.1.2.2 Musculature

The function of the anterior abdominal wall depends on multiple muscle groups working in conjunction to achieve flexion, extension, bend, and torque. The rectus abdominis muscles provide the majority of abdominal wall flexion and stabilization during ambulation. Besides their musculoskeletal function, they also serve to increase intraperitoneal pressure for forced expiration and Valsalva maneuver and protect the intraperitoneal viscera. The muscle itself begins on the pubic symphysis and inserts on the anterior aspects of the fifth, sixth, and seventh costal cartilages and the xyphoid process. The rectus abdominis muscle fibers are interrupted by inscriptions of the anterior rectus sheath at multiple levels, giving the appearance of multiple muscle bellies in physically fit people.

In addition to its functional importance, the rectus abdominis muscle is critical for various hernia repair techniques and pedicle and free myofascial advancement flaps. A complete description of these procedures is beyond the scope of this chapter; however, it is important to note the negative sequelae that occur following removal or transposition of the rectus abdominis muscle. Unilateral, and to a greater extend bilateral harvesting of the rectus abdominis muscle can result in significant abdominal wall morbidity, specifically a loss of trunk flexion, diastasis recti, ventral incisional hernia, and impaired quality of life.

The external oblique muscle is the thickest lateral muscle of the anterior abdominal wall and plays a significant role in bend, torque, and stability. Unlike the rectus abdominis muscle, which originates inferiorly and inserts superiorly, the external oblique muscle originates on the anterior aspect of the lower ribs (5–12), courses in the inferomedial direction, and inserts on the iliac crest. The external oblique aponeurosis contributes to the anterior rectus sheath as described above, but also folds back on itself between the anterior superior iliac spine and pubic tubercle giving rise to the inguinal (Poupart's) ligament.

The internal oblique muscle, which lies between the external oblique and transversus abdominis muscles, is not as thick as the external oblique muscle but serves an important role in abdominal wall physiology and function. The aponeurosis of the muscle splits to contribute fibers to both the anterior and posterior rectus sheaths at the level of the arcuate line. The internal oblique muscle originates more posteriorly than the external oblique muscle. The fibers begin at the thoracolumbar fascia and anterior aspect of the iliac crest, run in a superomedial direction, and insert on the posterior aspect of the ninth through twelfth ribs as well as contributing fascia to the conjoint tendon. The internal oblique muscle should remain intact when performing either an anterior or posterior separation of components to aid in maintaining stability of the abdominal wall following these procedures.

The conjoint tendon is formed by the lower tendinous fibers of the internal oblique muscle and the lower aponeurosis of the transversus abdominis muscle. It is attached to the pubic crest and pectineal line (a ridge on the superior ramus of the pubic bone), lies immediately posterior to the superficial inguinal ring, and forms the medial portion of the inguinal floor. The conjoint tendon is of clinical significance because it serves to reinforce what would otherwise be an innate area of abdominal wall weakness.

The transversus abdominis muscle lies posterior to the internal oblique muscle, originates from the anterior aspect of the iliac crest, lateral aspect of the inguinal ligament, and lower six costal cartilages, travels in a horizontal direction, and inserts via the wide transversalis fascia. Again, the transversalis fascia contributes to the linea alba and posterior rectus sheath medially as well as the conjoint tendon inferiomedially. The transversus abdominis muscle is of significant clinical importance when considering a posterior separation of components, particularly a transversus abdominis release.

An abdominal wall muscle with minimal clinical significance is the pyramidalis, a small triangular muscle situated at the inferior most aspect of the rectus abdominis muscle. The pyramidalis originates from the pubic crest and inserts into the linea alba inferior to the arcuate line.

24.1.3 Neurovascular Anatomy

24.1.3.1 Nerves

The abdominal wall is innervated by a large number of nerves that serve sensory and motor functions. A complete understanding of the neural anatomy of the abdominal wall is critical before undertaking hernia repair, myofascial advancement flaps, and other tissue rearrangement. It's also necessary to diagnose and appropriately manage complications of hernia repair such as postoperative chronic groin pain. Local injections for perioperative analgesia as well as chronic pain syndromes require appreciation of abdominal wall neural anatomy.

The innervation of the abdominal wall derives from intercostal, subcostal, and thoracolumbar nerves. Sensation is derived from the anterior branches of the intercostal and subcostal nerves (T7–L1). After exiting the spinal canal, these nerve branches travel between the internal oblique and transversus abdominis muscles. The dermatomes involved include skin superior to the umbilicus (T7–T9), periumbilical (T10), skin inferior to the umbilicus (T11–L1), and skin of the lateral abdominal wall and flank (lateral cutaneous branches).

Motor innervation, which is derived from the seventh through twelfth intercostal nerves, ilioinguinal, and iliohypogastric nerves, is of functional importance when operating on the abdominal wall. The rectus abdominis muscle, innervated by segmental branches of intercostal nerves from the ventral rami (T2–T11), may be inadvertently injured or weakened during certain types of hernia repair such as transversus abdominis release. Special care is taken to avoid injury to the segmental branches of these intercostal nerves when dividing the transversus abdominis muscle and transversalis fascia by making the vertical incision medial to the nerves. Other muscles of the abdominal wall—external oblique, internal oblique, and transversus abdominis—are innervated by intercostal and thoracolumbar branches. The external oblique muscle receives its motor innervation from thoracolumbar branches, the internal oblique muscle from intercostal nerves (T6–T12), and the transversus abdominis muscle from intercostal nerves (T7–T12). Both the internal oblique and transversus abdominis muscles receive motor input from the ilioinguinal and iliohypogastric nerves.

The neural anatomy of the groin is of particular importance because of the potential for nerve injury, entrapment, or transection during groin hernia repair. Additional issues such as neuroma or neuroganglioma may occur and understanding the course of nerves and the sites to access them plays a role in selection of operation. It is worth considering the neural anatomy of the lower abdomen and groin during other procedures besides abdominal wall hernia repair such as appendectomy, laparoscopic trocar placement, and vascular procedures. As for nerve injury during groin hernia repair, the operating surgeon must be aware of the ilioinguinal and iliohypogastric nerves that are at risk during both laparoscopic and open approaches. In addition, the lateral femoral cutaneous nerve of the thigh may be at risk during laparoscopic inguinal hernia repair, especially if tack fixation is employed along the lateral abdominal wall.

24.1.3.2 Vessels

Before detailing the clinically relevant blood vessels and lymphatic drainage, one must appreciate the blood supply of the abdominal wall, which is divided into three zones. Zone I extends from the xyphoid process superiorly to the arcuate line inferiorly and to each linea semicircularis laterally. This zone receives its blood supply from branches of the deep superior and inferior epigastric arteries. The venous drainage of Zone I ultimately follows the arteries first as venae comitantes and subsequently as veins that parallel the deep superior and inferior epigastric arteries. These vein tributaries within Zone I ultimately drain into the azygous vein superiorly and internal iliac veins inferolaterally. Zone II covers an area from the arcuate line and anterior superior iliac spines superiorly to the pubic bone inferiorly and the inguinal ligaments inferolaterally. This zone receives its blood supply primarily from branches of the inferior epigastric arteries as well as the superficial pudendal and lateral circumflex arteries. The venous drainage follows the arterial supply. Zone III of the abdominal wall comprises the flank regions (lateral walls), which are supplied primarily by the intercostal, subcostal, and lumbar arteries. Veins accompany these arteries and provide for blood outflow.

It is critical to have a solid working knowledge of these zones and their respective blood supply when operating on the abdominal wall. These zones are particularly relevant for operations involving trauma, hernia repair, free and pedicle flaps, as well as skin and soft tissue transpositions. Previous incisions that comprise blood flow to these zones must be considered when planning an incision. Studies highlight the risk for surgical site occurrence and donor site complications in patients with preexisting abdominal wall incisions that resulted in compromised vascular supply.

The major arteries that feed the abdominal wall include the superior and inferior epigastric arteries. The superior epigastric artery and deep inferior epigastric artery lie in the posterior aspect of the rectus abdominis muscle. These main arteries supply the rectus abdominis muscles as well as the overlying fascia, subcutaneous tissue, and skin via perforator vessels. When necessary, the epigastric vessels and perforator vessels can be localized by computed tomography with intravenous contrast. Notably, the superior epigastric vessels run a slight inferolateral course from a location approximately 4 cm from the midline to a spot 5–6 cm lateral to the umbilicus. The inferior epigastric vessels run a superomedial course from a location approximately 7 cm lateral to the pubic symphysis to a point about 5 cm from the midline around the level of the arcuate line. The watershed area of the superior and inferior epigastric vessels is located within the rectus abdominis muscle at an area between the xyphoid process and the umbilicus.

Specifically, the inferior epigastric artery arises from the external iliac artery approximately 1 cm cephalad to the inguinal ligament. It courses from its origin superomedially along the posterior aspect of the transversalis fascia toward the rectus abdominis muscle. At the lateral border of the rectus abdominis muscle, the inferior epigastric artery penetrates the rectus sheath near the level of the arcuate line. A more superficial inferior epigastric artery, which arises from the

external iliac artery, courses superiorly between Camper's and Scarpa's fascia. It represents an alternative blood supply to the abdominal wall in situations where the inferior epigastric vessels are sacrificed or harvested for pedicle flaps. The superior epigastric artery takes off near the bifurcation of the internal mammary artery around the region of the sixth intercostal cartilage. The superior epigastric artery takes an inferomedial course toward the lateral border of the rectus abdominis muscle until it pierces the posterior rectus sheath. The remaining course of the artery lies within the posterior aspect of the rectus abdominis muscle. Ultimately, branches of the superior epigastric artery anastomose with branches of the inferior epigastric artery in a watershed area located between the xyphoid process and the umbilicus within the rectus abdominis muscle.

The lumbar arteries serve as the primary blood supply of the lateral abdominal wall (flank). In addition, the musculophrenic artery feeds muscles and soft tissue of the flank and may be clinically significant in the setting of pedicle flaps when a more substantial vessel like the inferior epigastric artery is not available or an appropriate conduit. The lumbar arteries feeding the lateral aspect of the abdominal wall travel between the internal oblique and transversus abdominis muscles.

24.1.4 Layers of the Groin

24.1.4.1 Fascia

As described in the section on fascia of the abdominal wall, the groin (inguinal) region comprises multiple fascial layers from muscles of the abdominal wall. The boundaries of the inguinal canal are formed by transversalis fascia posteriorly, the external oblique aponeurosis anteriorly, the internal oblique muscle superiorly, and Cooper's ligament and inguinal ligament medially and inferiorly, respectively. The inguinal canal stretches between the internal and external inguinal rings.

The external inguinal ring is medial to the inferior epigastric vessels but cephalad to the inguinal ligament. It is not usually visible from a posterior (laparoscopic) view except in patients with direct inguinal defects. The internal inguinal ring is located lateral to the inferior epigastric vessels and is easily visualized with a laparoscopic approach; however, the internal ring is more difficult to visualize during open inguinal hernia repair.

24.1.4.2 Contents

The contents of the inguinal canal in males include the spermatic cord (vas deferens), spermatic vessels, genital branch of the genitofemoral nerve, and the ilioinguinal nerve. In females, the inguinal canal contains the round ligament, genital branch of the genitofemoral nerve, and ilioinguinal nerve. The spermatic cord is covered in three layers that include the internal spermatic fascia, derived from the transversalis fascia, the cremasteric fascia, derived from the internal oblique fascia, and external spermatic fascia, derived from the external oblique aponeurosis.

24.1.4.3 Neurovascular

The genital branch of the genitofemoral nerve, which is derived from the spinal nerve roots of L1–L2, provides motor innervation to the cremaster muscle fibers as well as sensory innervation to the scrotum in males and the labia in females. The genitofemoral nerve lies on the psoas muscle laterally as it enters the myopectineal orifice [4]. The ilioinguinal nerve provides sensation to the upper and medial thigh as well as anterior perineum. In males, that represents the areas of the anterior scrotum and base of penis while in females it corresponds to sensation in the area of the mons pubis and labia majora. Given the clinical relevance of these nerves to sensory and motor functions of the groin and perineum, it is the opinion of the author that they should be identified and/or protected during open and laparoscopic inguinal hernia repair in an effort to prevent hyper- or hypoesthesia of the innervated area as well as chronic postoperative groin pain. Given the location of the iliohypogastric and ilioinguinal nerves on the anterior surface of the quadratus lumborum muscle, these nerves can be identified successfully and avoided to minimize the risk of chronic postoperative inguinal pain [4]. The vascular supply of the spermatic cord includes the artery of the vas deferens, testicular artery, and small cremasteric arterial branches. The venous drainage of the spermatic cord is made up of the pampiniform plexus and ductus deferens.

24.1.4.4 Anatomic Regions

Hesselbach's triangle (Fig. 24.1) is an anatomic region of the groin defined by the lateral border or the rectus abdominis muscle medially, the inferior epigastric vessels laterally and superiorly, and the inguinal ligament inferiorly. The posterior wall of Hesselbach's triangle is made up of peritoneum while the anterior wall comprises the transversalis fascia. Weakness of the muscle and fascia in this region may result in a direct inguinal hernia. Just inferior to Hesselbach's triangle and the inguinal ligament is the location of a femoral hernia. Complete dissection of Hesselbach's triangle is an important part of the critical view, which is necessary to evaluate for direct inguinal and femoral hernias during laparoscopic groin hernia repair.

Another region of the groin is the so-called triangle of pain (Fig. 24.2). This term, used most frequently when discussing the anatomy of the groin viewed from a preperitoneal position (laparoscopic inguinal hernia repair), is so named because of the important nerves that traverse the area. Although a relative triangle, this region with its apex at the internal inguinal ring is bordered by the iliopubic tract

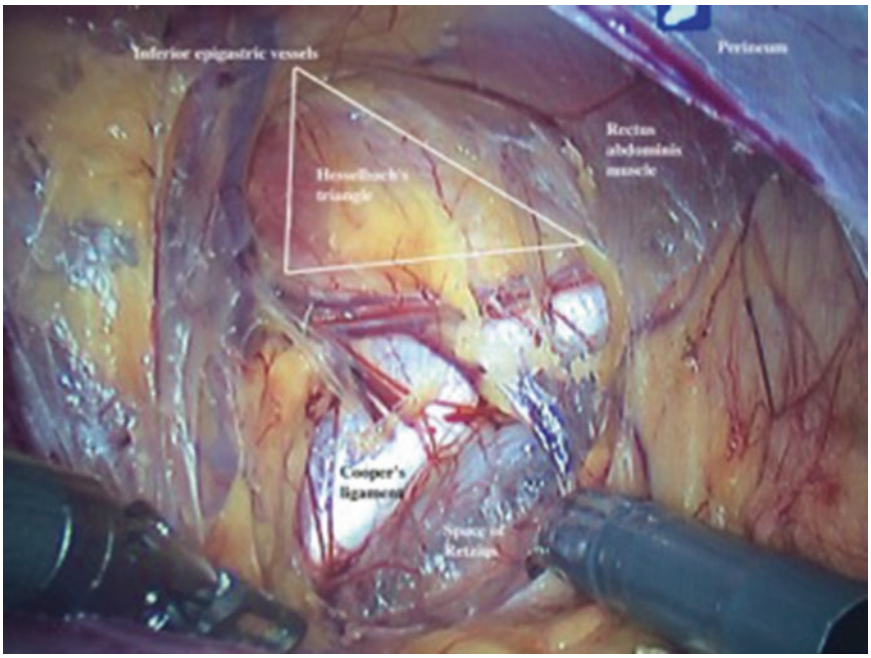

Fig 24.1 The medial aspect of the myopectineal orifice as seen during robot-assisted laparoscopic transabdominal preperitoneal inguinal hernia repair is shown. Hesselbach's triangle is highlighted

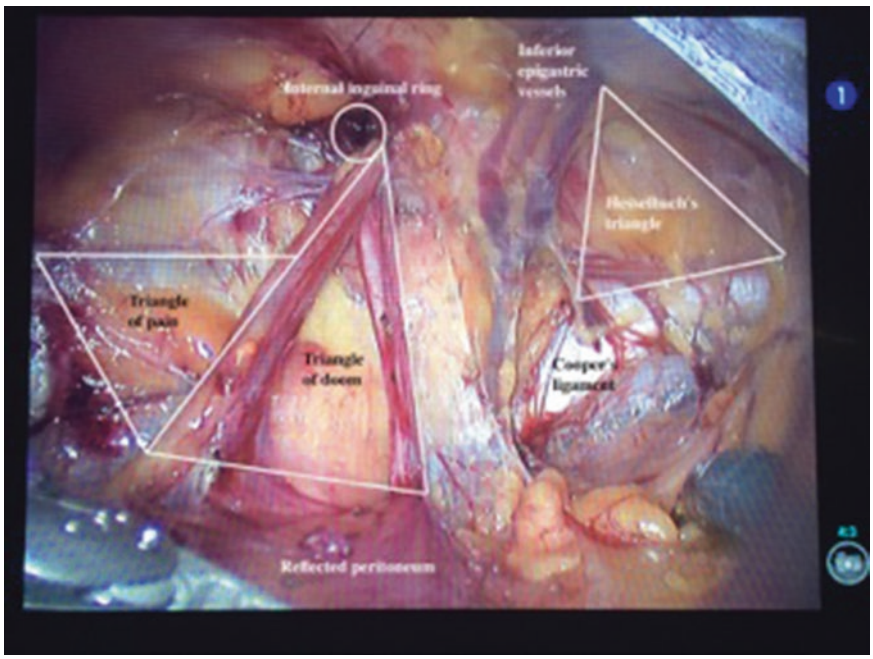

Fig 24.2 The myopectineal orifice is demonstrated highlighting Hesselbach's triangle as well as the triangle of pain and the triangle of doom, which represent important regions to consider during minimally invasive inguinal hernia repair

inferolaterally, spermatic vessels superomedially, and reflected peritoneum laterally. Important anatomy of this region includes the femoral nerve, femoral branch of the genitofemoral nerve, and anterior and lateral femoral cutaneous nerves. Most commonly, the lateral femoral cutaneous nerve exits as a single branch approximately 2 cm medial to the anterior superior iliac spine [5]. The use of tacks or other forms of penetrating fixation for mesh in this region should be avoided so as to minimize the risk of nerve injury or entrapment and resultant postoperative pain.

The triangle of doom is so named because of the major vascular structures that traverse the area (Fig. 24.2). The apex of the triangle is the internal inguinal ring, with borders that include the ductus deferens medially, spermatic vessels laterally, and posterior reflection posteriorly [6]. The contents of the triangle of doom include the iliac artery and vein as well as the genital branch of the genitofemoral nerve. The clinical implication of this area is to avoid unnecessary dissection or fixation that may result in vascular injury of major vessels.

24.2 Physiology of the Abdominal Wall

24.2.1 Overview

The abdominal wall facilities physiologic movement of the torso and limits the movements of the intraabdominal contents. In addition, the abdominal wall helps define the intraabdominal pressure physiology that allow for mobility and respiration. Besides a roll in restriction of contents, the abdominal wall also serves to allow for variation in peritoneal volume and shape. This distensibility is especially notable in patients who are morbidly obese or pregnant. The physiology of the abdominal wall depends on distensibility as well as integrity of the structures such as the abdominal wall muscles, fascia, and linea alba. Disruption of these structures can result in significant pathology and a goal of any abdominal operation should be to repair and restore abdominal wall integrity and function whenever possible [7].

24.2.2 Normal Function

24.2.2.1 Dynamic Function

The musculature of the abdominal wall works to protect the peritoneal contents, and generate intraabdominal pressure to aid in physiologic functions such as respiratory function. Not only does it assist with expiratory effort, the increased intraabdominal pressure generated by the activated abdominal wall muscles assists with bowel function, urination, and childbirth. The dynamic function of the abdominal wall when activated serves to flex the torso and vertebral column. It also stabilizes the upper body during activity to allow coordinated movement and resistance to gravity. When the rectus abdominis muscle is harvested or absent for some reason, the result is decreased abdominal wall dynamic function with various sequelae depending on the extent of resection.

24.2.2.2 Respiratory Function

The abdominal wall plays a role in respiratory function, which must be considered around the time of major abdominal wall reconstruction as this can significantly impact postoperative management. While the diaphragm contributes a constant positive pressure within the peritoneal cavity, changes to the abdominal wall can contribute to that positive pressure due to normal physiologic dispensability or pathology.

During normal respiration, the positive peritoneal pressure can be increased with activation of the transversus abdominis, internal oblique, and external oblique muscles at times of physiologic stress. When these muscles contract it increases the intraabdominal pressure, resulting in cephalad displacement of the diaphragm and greater expiration of air from the lungs. During inspiration, the abdominal wall also plays a role by providing structural support and resistance that allows for a pressure differential between the thoracic and peritoneal cavities. The amount of contribution to respiration by the abdominal wall varies depending on the position of the person. When standing, the negative pressure within the thoracic cavity is lowered due to gravity and the amount of peritoneal contents. However, when supine, the peritoneal contents are pulled posteriorly rather than inferiorly by gravity, so the pressure differential between the thoracic and peritoneal cavities is not as great. The result is a decreased functional capacity. The rise in intraabdominal pressure after ventral hernia repair as measured by bladder pressure monitoring is accompanied by changes in $PaCO_2$ and PaO_2/FiO_2 ratio [8].

24.2.3 Anatomic Abnormalities

24.2.3.1 Diastasis Recti

A diastasis recti is a separation of the rectus abdominis muscles along the linea alba. The inter-recti distance, which is defined as the distance from the medial edges of each rectus abdominis muscle, is increased during pregnancy that extends into the postpartum period. When not related to pregnancy, the inter-recti distance is normally less than 3 cm. Diastasis recti may also occur with increasing frequency in people with underlying connective tissue disorders such as abdominal aortic aneurysm, human immunodeficiency virus, and congenital conditions [9, 10].

24.2.3.2 Ventral Hernia

Ventral hernia remains a significant problem worldwide and most commonly occurs after a midline incision of the abdominal wall. However, primary hernias occur as well, most commonly as umbilical or other hernias of the linea alba as well as groin hernias, which can be direct and/or indirect inguinal, femoral, or obturator in location. Spigelian and lumbar hernias are less common primary ventral hernias. Of note, a true Spigelian hernia is a congenital defect that forms within the fascia at the junction of the linea semicircularis and arcuate line, a natural area of weakness in the abdominal wall [11].

Risk factors that may predispose to developing ventral or incisional hernia include a previous abdominal wall incision, obesity, tobacco dependence, aneurysmal disease, malnutrition, chronic kidney disease, insulin dependence, and malignancy [12–15]. Symptoms of ventral hernia are numerous, but most commonly abdominal pain. Complications including incarceration and strangulation occur and often require operative intervention.

Options for ventral hernia repair vary significantly and include open and minimally invasive approaches. Choice of technique for ventral hernia repair may be determined by both patient and hernia factors, mesh choice, and surgeon experience, among other potential factors. Regardless of the

operative approach, preoperative risk modification (smoking cessation, weight loss) and medical optimization (nutrition assessment, pulmonary and/or physical therapy) of patients with ventral hernia is important [14]. Likewise, a complete understanding of abdominal wall anatomy and meticulous surgical technique, taking care to dissect and realign the correct layers of the abdominal wall to minimize tension, allow for the best possible outcome.

The anatomy of ventral hernia can be complex, and impacted by previous operations and/or attempts at hernia repair. Mechanical failure of the abdominal wall results from a combination of fibrosis, disuse atrophy, and muscle cell alterations plus abnormal muscle loading. Abdominal wall compliance is then impaired over time with lateral retraction and stiffening of the oblique muscles [1]. Knowledge of abdominal wall anatomy and physiology are paramount before undertaking repair of any ventral hernia.

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Hernia Prevention and the Importance of Laparotomy Closure

25

Leonard Frederik Kroese, Johan Frederik Lange, and Johannes Jeekel

25.1 Introduction

Incisional hernia is an important complication of abdominal surgery with an incidence of 10–23 %, after midline laparotomy increasing up to 38 % in specific risk groups [1–8]. In the USA approximately four to five million laparotomies are performed annually, leading to a calculated potential of 400,000–500,000 incisional hernias to occur every year. Incisional hernia can lead to pain, discomfort and cosmetic complaints, resulting in a decreased quality of life [9]. Moreover, incisional hernia can cause incarceration and strangulation of abdominal contents, requiring emergency surgery, with associated morbidity and mortality [10, 11]. About 348,000 operations for incisional hernia are done every year in the USA with US$ 3.2 billion in annual associated costs [12]. Because of the above-mentioned, prevention of incisional hernia occurrence is of vital importance.

In the past decades, abdominal surgery has moved from midline laparotomies to laparoscopic or other minimally invasive techniques. This shift however, has resulted in a higher risk population of patients that still undergo midline laparotomies.

Given the morbidity and costs associated with incisional hernia occurrence and repair, focus should be on treatment as well as prevention. Therefore, this chapter will focus on different closure techniques and other considerations that may prevent the development of incisional hernia.

After discussing different risk factors, different suture techniques and materials will be outlined. The recent development of prophylactic mesh placement will also be addressed. Finally, some future perspectives will be mentioned.

25.2 Risk Factors

Several risk factors for the occurrence of incisional hernia have been identified. They include patient factors and operative factors.

25.2.1 Patient-Related Risk Factors

Known patient factors are overweight, male sex, abdominal distension, postoperative respiratory failure and previous wound infection [13–16]. Also, reoperations through the same laparotomy scar increase the risk of incisional hernia [17, 18]. A well-known risk factor is smoking [19]. Apart from these, older age, diabetes mellitus, malignancy, malnutrition, history of chemotherapy, jaundice and glucocorticosteroid use are also associated with higher incisional hernia rates [13–15, 17, 20, 21]. Patients operated for abdominal aortic aneurysm (AAA) have an increased risk of incisional hernia [22, 23]. In patients with AAA it is thought that the connective tissue with its collagen metabolism, and the ratio between mature and immature collagen in particular, is compromised [24, 25]. This compromised collagen plays an important role in aortic distention leading to AAA. It is thought that this is also of key importance in the formation of

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_25

incisional hernia after laparotomy [26, 27]. An important feature of collagen is the ratio of collagen type I and type III. Collagen type I is larger in diameter than collagen type III and is responsible for maintaining tensile strength. Collagen type III is an immature collagen and is found in early wound healing. A reduced type I/III collagen ratio is an indication of reduced mechanical stability of connective tissue, and it is associated with impaired wound healing. This impaired wound healing leads to higher incisional hernia incidence.

In obese patients, increased intra-abdominal pressure is thought to increase stress on the suture line, promoting incisional hernia formation. This is not the only contributing factor of obesity. Obesity is associated with complicated wound healing, caused by decreased vascularity of adipose tissue. This can lead to local hypoxia. Hypoxic wound can have impaired mature collagen synthesis, causing weaker connective tissue and deficient overall wound healing [8, 14].

25.2.2 Operative Factors

The type of laparotomy incision has often been debated. In several studies, reviewed in two meta-analyses [28, 29], midline laparotomy has a higher risk of incisional hernia than transverse laparotomy. Paramedian incision leads to considerable lower incisional hernia rates. It is therefore advised to use non-midline incisions whenever possible [30].

Too much tension on the sutures can weaken the wound, impairing collagen synthesis and increasing risk of wound infection and incisional hernia [31–33].

To estimate individual patient risk, a risk model was developed by Van Ramshorst et al. in 2010 [34]. This model combines several risk factors such as age, gender, pulmonary disease, ascites, jaundice, anaemia, coughing, type of surgery and wound infection. This model ranges from low scores resulting in almost 0 % risk of abdominal wound dehiscence, to high scores resulting in >60 % risk. The importance of these risk factors has recently been acknowledged by Fischer et al. [21] by constructing a risk model which combines all these risk factors. By making a combined score of all risk factors, they stratified patients in four risk groups, resulting in 0.5 % (low risk), 2.6 % (moderate risk), 8.9 % (high risk) and 20.6 % (extreme risk) incisional hernia after almost 3 years.

25.3 Methods of Closure

25.3.1 Continuous or Interrupted Sutures

When closing the abdominal wall after laparotomy, suturing can be performed using continuous or interrupted sutures. Continuous sutures are found to result in lower incisional hernia rates [3, 11, 35], but this finding is not confirmed by other studies [36, 37]. Apart from this, continuous suturing provides a more time-saving way and might therefore be preferred.

25.3.2 Suture Length to Wound Length Ratio

First described in 1976 [38], the suture length to wound length ratio (SL/WL ratio) is calculated by dividing the length of the used suture thread by the length of the incision, reflecting the relation between the size of the stitches used and the distance between two stitches [39]. Different SW/WL ratios are displayed in Fig. 25.1. Research has shown a beneficial effect of a SL/WL ratio ≥4 [40–42]. A SL/WL ratio <4 can triple the risk of incisional hernia occurrence [39]. Since there is a limited number of RCTs on this topic, no strong recommendations can be made [30]. The limitation of studies describing the SL/WL ratio is that it is often not mentioned in detail how the ratio is determined. Differences can occur when including or excluding knots or when only the remaining suture length is determined.

25.3.3 Layered Closure or Mass Closure

The laparotomy can be closed with a layered closure or a mass closure (Fig. 25.2). Several studies have compared layered closure (closure of the incision with more than one separate layer of fascial closure) with mass closure (closure of the incision with a suture bite that includes all layers of the abdominal wall except the skin). Meta-analyses on this topic showed a favourable result when using mass closure [43, 44].

25.3.4 Stitch Size

In the past, closing laparotomy wounds with larger tissue bites was considered to be the most effective in terms of incisional hernia incidence [38, 45]. Since 2009 however, new evidence, both experimental and clinical, has shown that smaller bite size (being 5 mm bites every 5 mm) increases the laparotomy closure strength and decreases the incisional hernia incidence rate [39, 46]. This has been recently confirmed in a large multicentre randomized controlled trial: the STITCH trial [47]. The smaller bite size reduces incisional hernia incidence after 1 year from 21 to 13 %. The difference in bite size is shown in Fig. 25.1.

25.3.5 Suture Material

Suture materials have two main variables: duration of absorption (rapidly absorbable, slowly absorbable, non-absorbable) and fabric type (monofilament, multifilament).

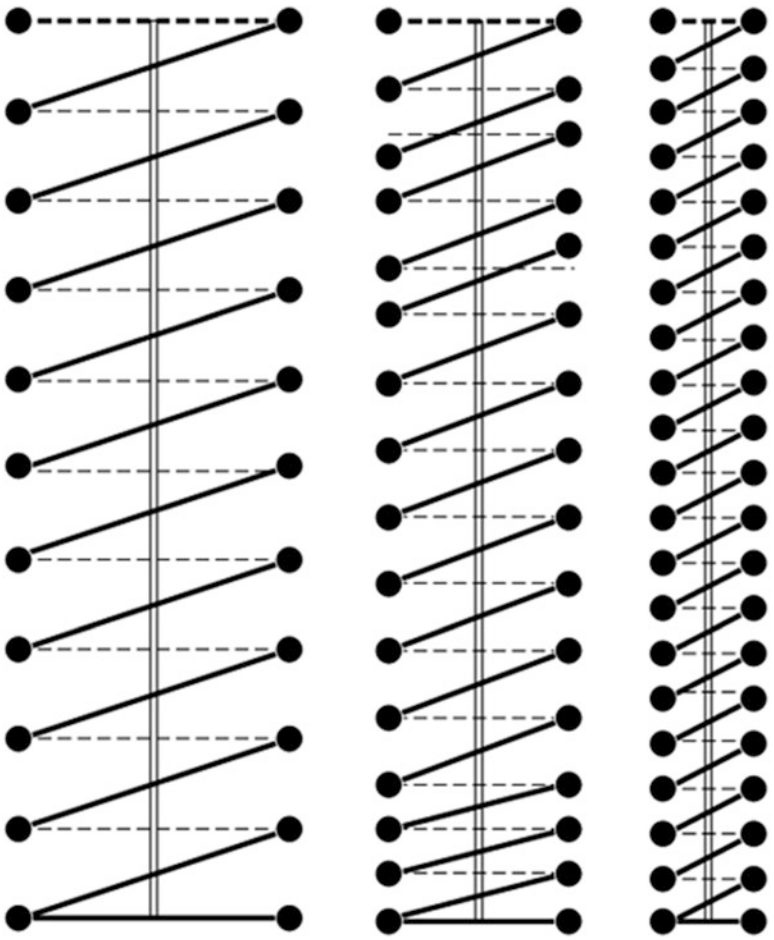

Fig. 25.1 To maintain a suture length to wound length ratio of >4, the number of stitches should increase when they are placed closer to the wound edges

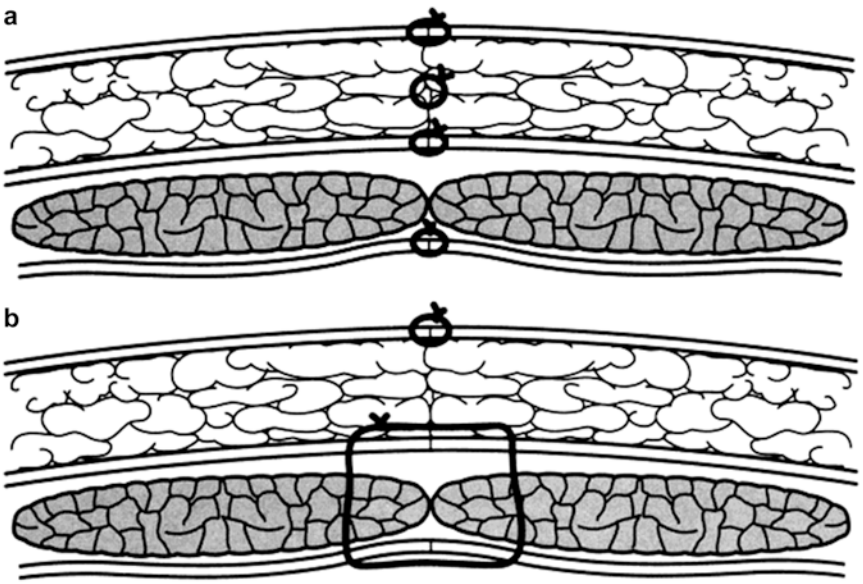

Fig. 25.2 Layered closure versus mass closure. Adapted from: DeLancey, J, Hartman, R, *Glob. libr. women's med.*, (*ISSN*: *1756-2228*) 2008; DOI 10.3843/GLOWM.10038. (**a)** Layered closure: all layers are sutured separately. (**b**) Mass closure: all layers of the abdominal wall except the skin are sutured in one bite

Rapidly absorbable sutures have been found to lead to more incisional hernia compared to slow or non-absorbable sutures [3, 11]; the use of rapidly absorbable sutures is therefore not advised.

No difference was found in incisional hernia rate between slowly absorbable and non-absorbable sutures [11]. However, prolonged wound pain and suture sinus formation incidence are increased when using non-absorbable sutures [11, 48]. Therefore, the use of slowly absorbable sutures is suggested.

Monofilament sutures are associated with lower surgical site infection rates [49]. However, no clear evidence for the use in laparotomy closure has been found. Nevertheless, with all slowly absorbable suture materials currently being monofilament, this is no actual topic of discussion.

No studies have been conducted to compare different suture thicknesses. Although recent studies [39, 47] investigating bite size use a USP 2-0 suture for small bites closure, no evidence exists on which suture should be chosen.

25.3.6 Prophylactic Mesh Augmentation

Mesh placement is well known for incisional hernia repair, reducing recurrence rates compared to primary suture closure [50, 51]. Mesh augmentation to prevent incisional hernia was first described in 1995 [52]. The mesh can be placed in different positions: onlay, sublay or preperitoneal (Fig. 25.3). In the onlay position, the mesh is placed ventrally to the anterior rectus fascia. In the sublay position, the mesh is placed dorsally to the rectus muscles and ventrally to the posterior rectus fascia. In the preperitoneal position, the mesh is placed caudally to the semicircular line of Douglas dorsally to the posterior rectus fascia and ventrally to the peritoneum.

Since 1995, multiple studies have been performed, mainly in high-risk patients like patients undergoing AAA surgery of obese patients. Overall data of these studies show a decreased incidence of incisional hernia after prophylactic mesh placement in high-risk patients [53, 54]. Although not always significant, there seems to be a trend showing slightly higher seroma formation rates in mesh groups.

Recent research like the Dutch PRIMA trial has focused on prophylactic mesh augmentation to prevent incisional hernia after midline laparotomy using both onlay and sublay technique [55, 56]. Short-term results after 1 month show that mesh augmentation is a safe procedure without increased complications such as surgical site infection [55]. After 2 years of follow-up, mesh augmentation showed significant lower rates of incisional hernia. Sublay position resulted in

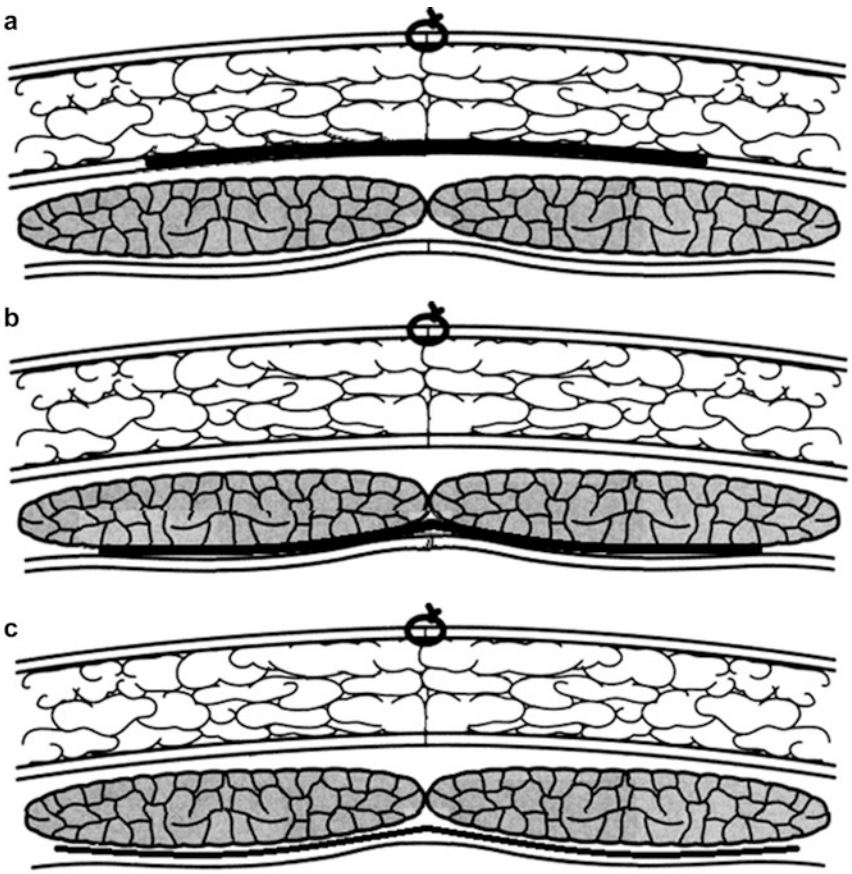

Fig. 25.3 Mesh positions. Adapted from: DeLancey, J, Hartman, R, *Glob. libr. women's med.*, (*ISSN*: *1756-2228*) 2008; DOI 10.3843/GLOWM.10038. (**a**) An Onlay position. (**b**) Sublay position. (**c**) Preperitoneal position

18 % incisional hernia and onlay position resulted in 13 % incisional hernia compared to 30 % in the primary suture group. There was no difference in complication rates between groups. Although not significantly different, onlay position seems to be preferable in terms of incisional hernia rate and applicability.

The recently published Belgium PRIMAAT trial has also focused on prophylactic mesh placement in patients undergoing AAA surgery. This study found 0 % incisional hernia after 2 years of follow-up, compared to 28 % in the suture group [57]. One key feature of this study was that laparotomy closure was always performed by a dedicated abdominal wall surgeon.

Based on these recent studies, an onlay mesh augmentation technique should be used in high-risk patients to prevent incisional hernia.

25.4 Future Directions

Although the number of laparotomies for abdominal surgery is decreasing with laparoscopic surgery being used increasingly, incisional hernia remains a major complication after midline laparotomy. In the future, we expect the population of patients still undergoing midline laparotomy to be higher risk patients. For these patients, the risk of incisional hernia development is even greater. Until now, laparotomies are almost always closed using the big bite suture technique. Recent data provide evidence that the midline laparotomy should be closed with small bite 5 × 5 mm suture technique. The choice of laparotomy closure techniques depends on the patients risk profile [21]. Recent studies show that prophylactic mesh placement significantly lowers the incidence of incisional hernia. Therefore prophylactic mesh placement, enforcing the closed midline, should be applied in high-risk patients.

Finally, with incisional hernia remaining one of the most serious complications of the abdominal surgeon, it might require a dedicated abdominal wall surgeon to perform the laparotomy closure.

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The Use of Prophylactic Mesh in the Prevention of Incisional and Parastomal Hernia Repair

26

Paul Tenzel, Daniel Christian, John Patrick Fischer, and William W. Hope

26.1 Introduction

> An ounce of prevention is worth a pound of cure.
> Ben Franklin

Laparotomy has been an important approach for surgeons to address a myriad of abdominal surgical conditions, and it facilitates good visualization and palpation of abdominal organs and contents. Creation of stomas has also been a mainstay for surgeons in dealing with colorectal and intestinal problems and useful in other surgical specialties such as in the formation of ileal conduits for bladder cancer. Although these techniques can be life-saving, they are not without risk, and the complication of incisional and parastomal hernias has been a perplexing problem despite many advances with surgical technique and suture material.

Incisional hernias remain a common and chronic complication in the twenty-first century with rates ranging from 1 to 20 % [1–4]. Even laparoscopy incisions (>15 mm) carry an incisional hernia risk of 1.5–5.8 % [5, 6]. In the United States, this leads to about 348,000 operations per year and in Europe the number is 400,000 operations per year [7]. The risk of incisional hernia is markedly increased in patient with a BMI >25 kg/m^2, surgical site infection, chronic obstructive pulmonary disease, smoking history, fascial to suture ratio <4.0, malnutrition, diabetes mellitus, immunosuppression, and chemotherapy [8]. The literature has also demonstrated that incision type (laparotomy > hand-assisted > laparoscopy) is clearly a variable in determining the risk of incisional hernia [8]. In addition, the type of operation, likely through correlation of associated patient factors, also predicts the risk of hernia. Operations such as open and minimally invasive bariatric procedures, ostomy and fistula closure, colorectal surgeries, open abdominal aortic aneurysm repair, and emergency operations have the highest risk for the development of incisional hernias [9]. Not only do incisional hernias remain a common and sometimes predictable outcome but also, unfortunately, they impart great morbidity to the patient. Although, the skill and repertoire of the hernia surgeon continues to expand, recurrent rates remain high. Recurrence rates are estimated to range from 20 to 48 % [7, 8, 10]. Indeed, for many patients an incisional hernia becomes a chronic and sometimes lifelong problem. Outside of the clinical effects, the incisional hernia is a financial burden to both patient and the healthcare system as a whole. Approximately 3.2 billion dollars were spent on incisional hernias in the United States in 2006 [7]. The development of an incisional hernia can result in an additional $3875–$98,424 in healthcare costs [8, 9].

It is evident, based on the clinical and economic burden of incisional and parastomal hernias coupled with poor long-term outcomes of incisional hernia repair, that hernia prevention should be a major focus for the surgical community.

Evidence for Prophylactic Mesh Augmentation: Despite the near acceptance in the literature of continuous, slowly absorbable suture done in a 4:1 ratio, the incidence of incisional hernias remain unreasonably high. Within the last two decades, the concept of closing a laparotomy incision with a prophylactic piece of mesh (prophylactic mesh augmentation or PMA) to guard against future hernia formation has gathered interest. Theoretically, PMA increases the biomechanical

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_26

strength of the healing laparotomy incision. This has been demonstrated in animal models with an increase of 43.99–56.96 N ($p<0.05$) with primary suture repair (PSR) vs. PMA at 6 weeks. In fact, this tensile strength is not significantly different from an intact linea alba [11]. Transitioning to human randomized controlled trials, the benefit of PMA has been clearly demonstrated. One small randomized controlled trial by El-Khadrawy et al. studied high-risk patients comparing 20 PSR vs. 20 PMA patients over 20 months and demonstrated a 10% reduction (15% vs. 5%, $p=0.01$) in the incidence of incisional hernias [12]. A meta-analysis by Timmermans et al. using 346 patients demonstrated a significant reduction in incisional hernias (RR 0.25, 95% CI 0.12–0.52, I^2 0%; $p<0.001$) when using PMA vs. PSR [13]. The evidence of significant hernia reduction is mirrored in a larger systemic review by Nachiappan et al. which incorporated approximately 1100 patients pooled from five randomized controlled trials and four comparative studies. The reduction from the randomized controlled trials demonstrated a pooled odds ratio=0.32; 95% CI=0.12–0.83; $P=0.02$ and from the comparative studies a pooled odds ratio=0.11; 95% CI=0.04–0.33; $P=0.001$ [14]. These multiple studies have demonstrated a clear reduction in incisional hernias when PMA is used. The European Hernia Society Guidelines on the Closure of Abdominal Wall Incisions (2015) has most recently given a weak (pending more long-term data) recommendation for the use of PMA in high-risk patients [15]. The following sections discuss different high-risk patient groups for which PMA has demonstrated the most benefit.

Open Abdominal Aortic Aneurysm Repair: Patients who undergo an open repair for abdominal aortic aneurysm are at increased risk for incisional hernia development. Some studies place this risk from 32% to as high 60% [15, 16]. It is believed that the same connective tissue defects which predispose individuals to the formation of aortic aneurysms also predisposes them to incisional hernia formation [15]. Given their preponderance for incisional hernia formation, this population has been one of the best studied for the use of PMA. Several studies have demonstrated a significant reduction in incisional hernia formation when PMA is used as an adjunct in closing the midline incision for open AAA repairs. Rogers et al. used a preperitoneal approach to secure a piece of polypropylene mesh in 27 open AAA patients. Only one incisional hernia was noted at 30 month follow-up [17]. A larger and randomized controlled study by Muysoms et al. using 120 patients demonstrated a 28% incisional hernia rate with primary suture repair vs. 0% incisional hernia rate with PMA at 2 years follow-up ($P<0.0001$) [18]. Although, longer term data are needed, PMA has clearly shown reduction in incisional hernia following open AAA repair.

The Obese Patient: As previously stated, the obese patient is at increased risk of incisional hernia. The incidence is even higher in the morbidly obese with the incidence ranging from 25 to 50% [19, 20]. Theoretically, the increased incidence is believed to be due to increased baseline intra-abdominal pressures. Given that morbidly obese patients have various other common comorbidities including diabetes mellitus and are at increased risk for wound infection, this likely plays a role as well. Several studies have examined the use of PMA in morbidly obese patients undergoing open bariatric surgery. A randomized clinical trial by Strzelcyk et al. compared patients undergoing open Roux-en-Y gastric bypass with conventional closure ($n=38$) vs. retrorectus placement of polypropelene mesh ($n=36$) [21]. Although, the follow-up was short (only 6 months), eight hernias developed in the conventional closure group and none developed in the PMA group (no statistical analysis reported) [21]. Another randomized study by Abo-Ryia et al. of patients undergoing open biliopancreatic diversion compared conventional ($n=50$) vs. retrorectus polypropylene ($n=45$) with longer follow-up [20]. The incidence of incisional hernia in the conventional group was 30%, and the incidence in the patients who underwent PMA was 4.4% ($p<0.05$) at 2 years follow-up [20]. Although open bariatric surgery has fallen out of favor in the United States compared with laparoscopic surgery, the percentage of morbidly obese patients continues to rise. PMA may likely play a role in these patients as well.

Patients Undergoing Colorectal Procedures: Given the high wound infection rates after colorectal procedures, one can understand the trepidation regarding the use of PMA with this patient population. Like other operations that employ midline laparotomies, the incisional hernia rate remains high. However, a study by Garcia-Urena et al. demonstrated that PMA is effective and carries little morbidity [22]. This study included elective and emergent operations, with 54 patients in the control group and 53 patients in the mesh group. Although, approximately 25% of patients in both groups did not complete follow-up at 24 months, there was a significant reduction in incisional hernias in the PMA group (11.3%) compared with the control group (31.5%) [22]. Additionally, no significant difference in morbidity was noted between the control and PMA groups regarding surgical site infection, seroma, mesh rejection, or evisceration [22]. This study further reinforces the utility of PMA in hernia prevention in high-risk patients while also demonstrating its feasibility in even contaminated cases.

26.2 Parastomal Hernia

26.2.1 Introduction

The reported incidence of parastomal hernias is widely variable based on the type of stoma created and the time of follow-up. One literature review reported the incidence to be up

to 78 %, with the majority occurring within the first 2 years after ostomy creation [23]. Most surgical repair is elective with indications based on the extent of symptomatology of the parastomal hernia; this includes pain, increasing size, cosmesis, and failure of conservative management for pouching. Parastomal hernias are rarely inconsequential with reports of up to 76 % of patients having some symptoms, and of these, 56 % were affected to the extent of requiring surgical treatment [24]. There are multiple methods a surgeon can employ to repair a parastomal hernia, but the results are often less than satisfactory with high reported recurrence rates.

With the high incidence of parastomal hernia formation and high recurrence rates following repair, prevention techniques should be a major focus for surgeons performing stomas.

26.2.2 Evidence of the Use of Prophylactic Mesh in Prevention of Parastomal Hernia

One of the first papers to describe the use of a prophylactic mesh was by Bayer et al. in 1986 [25]. The paper was a retrospective review that described the use of prophylactic Marlex mesh in 43 patients. The mean follow-up time varied, but some patients were followed up to 48 months postoperatively. Though there were two complications related to the mesh, a stitch granuloma and a patient with stenosis, there were no identified parastomal hernias in the study group [25]. Since that time, additional studies have trialed this technique of using a prophylactic mesh in stoma creation with overall promising results.

A meta-analysis of three early randomized control trials for prophylactic mesh showed a significant reduction in parastomal hernia rate from 54.7 % in the conventional group to 12.3 % in the prophylactic mesh group [26]. A recent randomized study from Finland showed a significant reduction in clinically significant parastomal hernias but did not show a significant difference in occurrence when evaluated via CT scan [27]. Another recent randomized controlled trial from Norway also determined significant reduction in hernias and indicated the number needed to treat to avoid one parastomal hernia is 2.5 patients [28]. Though there is a wide variability in the reported incidence of parastomal hernias, there are still promising results in many cohort studies that evaluate the use of prophylactic mesh for the prevention of parastomal hernias.

The wide variation in parastomal hernia incidence reported is likely due to the inconsistent length of follow-up, the different types of stoma created, and the multiple classification systems used to define a parastomal hernia [29]. The same variability arises when comparing many cohorts and retrospective studies regarding the use of prophylactic mesh and parastomal incidence. Some studies evaluate for parastomal hernia formation based on clinical exam alone, whereas others use a combination of clinical exam and imaging [30–33]. In addition, a single classification system is needed for better consistency of results. Even with the differences in evaluation, the data are exceedingly in favor of placement of prophylactic mesh.

One topic of consideration in evaluating the need for a prophylactic mesh is the risk of complications of an initial mesh placement versus the risk associated with a reoperation parastomal hernia repair. One meta-analysis of parastomal hernia repairs showed that there was an average complication rate of 24.9 % in patients who underwent mesh parastomal hernia repair [34]. Most of these were common surgical complications (ileus, pneumonia, UTI, etc.) that likely would have been avoided had the patients not required a second operation after the initial stoma creation. In a meta-analysis of prophylactic mesh, there was no significant difference in stoma-related postoperative complications, and no patient had a mesh-related complication [26].

One of the largest randomized controlled trials of prophylactic mesh, with a sample size of 150 patients, evaluated the complications of mesh placement. They used a pre-peritoneal retromuscular mesh in elective open end-colostomy repairs as opposed to end-colostomy alone. They demonstrated no difference in chronic pain, postoperative infection rates, stoma-related complications, or quality of life. They also noted no mesh-related complications in the 72 patients who underwent prophylactic mesh repair [35].

As with most mesh repairs of incisional hernias, different types of mesh and technique are used. At this time, there is no significant research that clearly shows superiority of one mesh type or placement location. Although there is strong evidence to support the use of prophylactic mesh in prevention of parastomal hernias, indications for use, ideal patient populations, techniques of surgery, and mesh choices still require further study.

26.3 Conclusion

Prophylactic mesh augmentation is associated with a significant reduction in the postoperative risk of incisional hernia compared with traditional suture repair for high-risk patients undergoing elective, midline laparotomy closure. This technique appears to be safe and efficacious in the high-risk patient population, with current data showing comparable postoperative complication profiles. Despite strong evidence, a lack of US-based randomized controlled trials and evidence-based guidelines for the use of PMA are significant barriers to widespread adoption. Further reinforcing these challenges to create more widespread adoption is a lack of appropriate coding and reimbursement mechanisms

for PMA, although a recently created Category III CPT code (0437T) will be effective in July 2016 by the American Medical Association for prophylactic mesh augmentation. Future work must focus on demonstrating through well-designed clinical studies the efficacy of PMA, creating the needed evidence-based guidelines to help inform and guide patient selection and to provide the foundation for clinical design support for surgeons and patients alike. Ultimately, work must be focused on the advancement of the coding, tracking, use, and outcomes after PMA.

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Preoperative Optimization and Enhanced Recovery Protocols in Ventral Hernia Repair

27

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27.1 Introduction

Along with recurrence as an important indicator of success following ventral hernia repair (VHR), perioperative wound morbidity greatly influences short- and long-term outcomes in patients. It is well reported that perioperative surgical site occurrences (SSOs), defined as infection, seroma, wound ischemia, and dehiscence, increase the risk of recurrent hernia greatly [1]. Therefore, the surgeon should optimize any and all measures that will promote wound healing, reduce infection, and enhance early postoperative recovery. In the ventral hernia population, the most common complication in the immediate perioperative period is surgical site infection (SSI) [2]. This chapter briefly reviews several pre- and perioperative measures that have been reported to decrease SSOs and shorten length of hospital stay.

Multiple patient factors such as obesity, smoking, uncontrolled diabetes mellitus, malnutrition, and surgical site contamination are all detrimental to wound healing and should be optimized prior to surgery. Wound healing as well as those with a propensity for postoperative infections are the primary targets, both of which increase the incidence of hernia recurrence. Obesity and smoking have been demonstrated to be independent risk factors for increased recurrence of abdominal wall hernias and SSO. Poor glycemic control in the remote preoperative period and perioperative and postoperative periods has repeatedly demonstrated increased risk for superficial and deep tissue infections. Similarly, patients with malnutrition have significant alterations in wound healing and immune function and will consequently have an increased incidence of postoperative SSI as well as hernia recurrence. Unfortunately, many of our patients have several of these detrimental factors at the time of hernia repair. While all these factors influence surgical outcomes and work congruently on morbidity, many can be evaluated and treated as separate entities. Herein, we aim to describe several interventions and evaluate their effectiveness in an effort to maximize outcomes for ventral hernia repair.

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27.2 Preoperative Optimization

27.2.1 Obesity

Perhaps the greatest threat for the development of incisional hernias as well as recurrence following ventral hernia repair is obesity. As BMI increases, so does the recurrence rate [3–5]. The propensity for obese patients to develop incisional hernias was noted early on by surgeons performing bariatric procedures [6]. The incidence of postoperative incisional hernia occurred in up to 40 % of patients following open gastric bypass [7]. In fact, the reduction of postoperative incisional hernias following laparoscopic gastric bypass was one of the major reasons for performing minimally invasive bariatric procedures. We have found that in patients with BMI ≥ 50, the recurrence and wound morbidity rate is prohibitively high; therefore, we no longer perform elective herniorrhaphies in this group of high-risk patients unless they have stigmata of acutely worsening symptomology (e.g., recurrent obstruction, evolving ischemia, strangulation).

Unfortunately, obesity is a very challenging entity to modify, as a lifetime of poor nutrition and/or lack of adequate physical activity are the culprits for many patients. Initial attempts for weight loss include in-office counseling to improve dietary habits and increase physical activity. During the initial evaluation, a reasonable weight loss goal is made between the patient and surgeon (e.g., 15–30 lbs). Having a dietary consult with a nutritionist can provide valuable information for patients, if available. Patients return in 3–6 months after initial consultation; if the patient demonstrates significant weight loss then surgery is typically planned. Conversely,

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_27

if the patient fails to lose sufficient weight, or gains weight in the interim, elective surgery is postponed and other routes of weight loss are advised.

We routinely refer patients to our bariatric surgery colleagues for discussion for surgical weight loss. As many patients with obesity carry an unknown diagnosis or diabetes or prediabetes, checking a hemoglobin A1c can assist with insurance coverage of a bariatric procedure. If we are performing a bariatric procedure in a patient with an incisional hernia, we will attempt to perform the bariatric procedure without repairing the hernia and wait until the patient has lost weight before we attempt definitive hernia repair. If the bariatric procedure is performed open and the hernia is in the epigastric area, the hernia will have to be repaired during the initial operation to close the abdomen. However, the simplest hernia repair is performed at this time (e.g., primary fascial closure +/− mesh reinforcement), saving more complex hernia repairs (e.g., component separation) until after weight loss from their bariatric procedure.

27.2.2 Smoking

Detrimental effects of smoking are well known, with reduction of both blood and tissue oxygen tension, as well as the deposition of collagen in healing wounds [8–10]. These effects adversely influence healing of surgical wounds, including complex wounds seen in some hernia repairs. Numerous animal and human models have studied the deleterious physiological effects of smoking and have compared wound complications in smokers versus nonsmokers. Several authors have examined the effect of smoking on postoperative wound infection and have found wound infection following repair of ventral hernias to be increased in smokers [11–13]. Smoking is also a risk factor for developing an incisional hernia following abdominal surgery [14]. Many of the initial studies involved orthopedics (tendon and fascial healing) and plastic surgery (flap viability) [15, 16]. In a study of 4855 patients undergoing elective open gastrointestinal (GI) surgery, smoking was associated with significantly increased postoperative complications [14]. With VHR frequently requiring a combination of prosthetics, tissue flaps, and GI surgery, these studies reinforce the need for smoking cessation prior to complex abdominal wall reconstruction (AWR).

Because of the harmful effects of continued tobacco use, a great deal of attention has been made on the effect of smoking cessation on reducing postoperative complications. Lindstrom et al. prospectively studied 117 patients undergoing primary hernia repair, hip or knee prosthesis, or laparoscopic cholecystectomy. Half of the patients were treated with smoking cessation therapy and nicotine patches starting 4 weeks prior to surgery, which continued for 4 weeks post-surgery. The control group was allowed to smoke as they were preoperatively. The experimental group with smoking cessation and nicotine therapy had a total postoperative complication rate of 21 % while the smoking group had almost twice the total postoperative complication rate at 41 %. This study clearly demonstrated the adverse effects of smoking; however, the study focused on total complications, and the difference in wound complications did not achieve significance [17]. The other two interesting findings from this study were that this reduction in complications occurred after 4 weeks of tobacco cessation, and a reduction in surgical site occurrence (SSO) was noted in patients using the nicotine patch. This study confirms another landmark study by this group in which volunteers were divided into four groups: smokers, nonsmokers, those who quit smoking for 30 days preoperatively, and those who quit smoking and had a nicotine patch placed. Four full thickness dermal incisions were made on each volunteer for a total of 228 incisions. The nonsmoking group had a wound site occurrence at a rate of 2 % while the smoking group had a 12 % occurrence. The group who quit smoking and those who quit smoking and had the nicotine patch had a wound occurrence rate of 2.3 %. This study indicated that smoking cessation for 30 days allows for the deleterious effects smoking to be alleviated, and the nicotine patch did not alter the beneficial influence of cessation [18]. Thus, 4 weeks may be an effective time of abstinence to reverse the complications associated with smoking. The other interesting and unexpected phenomenon is that nicotine patches did not have a deleterious effect on complications, suggesting that it is not nicotine but something else in the cigarette smoke that is deleterious. In a randomized clinical trial examining the effect of the nicotine patch on wound infection, the patients with placebo patches compared to patients wearing nicotine patches had similar wound infection rates [10]. It is now believed that nicotine in low concentration may actually promote wound healing [18, 19]. Others have observed similar reduction of postoperative complications comparing patients who had quit smoking from 3 to 6 weeks preoperatively from those who continued to smoke [20–22]. A recent meta-analysis and systematic review of the literature nicely reviews the influence of smoking on postoperative complications and the benefits of smoking cessation [23].

Because of well-substantiated association of smoking with wound complications, patients at our institution undergoing elective ventral incisional hernia repair are required to cease all smoking activity for at least 4 weeks before surgery for difficult abdominal wall hernias [11]. We allow the use of nicotine patches whenever the patient asks because there is reasonably good data indicating that nicotine is not a factor in cigarette smoke that causes problems with wound healing. Unfortunately, one cannot accurately test the patient for nicotine levels when the patch is used.

27.2.3 Diabetes

While glycemic control throughout all phases of patient management is important, preoperative reduction in baseline glycosylated hemoglobin (Hgb A1c) is essential for optimal outcomes. Studies have demonstrated reduced wound healing and increased postoperative complications in diabetic patients undergoing a variety of surgical procedures [24–26]. In elective cases, it has been shown that glucose control in the 30–60 days prior to surgery is beneficial in decreasing perioperative complications. Dronge et al. evaluating patients from Veterans Administration hospitals found that SSIs were reduced in patients whose HbA1c was less than 7 % and recommended that HbA1c less than 7 % is a preoperative target to aim for [27]. We routinely postpone elective herniorrhaphy for patients that fail to reach this target and schedule VHR after their diabetes is sufficiently controlled. Postoperative glycemic control is discussed later in this chapter in the Postoperative Optimization section.

27.2.4 Nutrition and Metabolic Control

In an era of evidence-based surgical and medical practice, recommendations for nutrition therapy of the surgical patient are supported by abundant large observational studies, over 40 randomized controlled trials (RCTs), as well as numerous meta-analyses and systematic reviews. Every surgical patient has a highly variable metabolic and immune response to major surgery regardless of preexisting nutritional state. Suboptimal outcomes are clearly associated with malnutrition [28]. This was undoubtedly shown in the large Preoperative Risk Assessment Study done by the U.S. Department of Veterans Affairs. This prospective trial included >87,000 patients from 44 separate medical centers where investigators collected 67 variables on each patient. This study reported the single most valuable predictor of poor outcome and increased morbidity was a serum albumin less than 3.0 g/dL [29]. Kudsk et al. confirmed this observation that that albumin, although not a marker of nutritional status, is a good surrogate marker for poor surgical outcome [30]. However, not all ventral hernia or AWR patients will derive the same benefit from nutrition therapy intervention either preoperatively or postoperatively. Previously well-nourished patients with a relatively minor surgery and those expecting short length of hospital stay derive little benefit from early nutrition therapy. On the other hand, the majority of patients undergoing major AWR with an expected extended length of stay in the hospital as well as intensive care unit stay at moderate to severe nutrition risk will appreciate significant outcome benefits from early attention to nutrition. While this has not been shown definitively in hernia surgery, it has been well demonstrated for major visceral surgical procedures [31]. In patients undergoing emergent or urgent AWR secondary to obstruction or infection who are preoperatively malnourished, these benefits of attention to nutrition are even greater. Several factors influence these benefits, including route and timing of delivery, content of nutrient substrate, and efforts to promote patient mobility. Recent data supports a preoperative assessment and nutritional intervention if the patient meets high-risk criteria [32]. Several nutritional scoring systems have recently been proposed with only one [Nutrition Risk Score 2002 (NRS 2002)] being validated in surgical population [33].

27.2.5 Preoperative Metabolic Preparation for Surgical Intervention

The concept of preoperative preparation of the patient with specific metabolic and immune active nutrients acquired a clinical following after several landmark studies by Gianotti and colleagues [34–36]. These well-done investigations demonstrated benefit in lowering perioperative complications by adding the amino acid arginine and the omega-3 fatty acids, docohexanoic acid (DHA) and eicospentanoic acid (EPA), for 5 days preoperatively. They reported major morbidity could be reduced by approximately 50 % in patients undergoing major foregut surgery, including esophageal, stomach, or pancreas procedures. This benefit was noted in both the well-nourished and malnourished patient populations [36, 37]. The revelation that even well-nourished patients would benefit was a paradigm shift from the notion that correction of malnutrition alone was the only important factor [34, 36]. In these studies, the patients consumed 750 mL to 1 L per day of the metabolic-modulating formula in addition to their regular diet. The formula used by Gianotti and Braga contained additional arginine, [omega]-3 fatty acids, and nucleic acids, and resulted in significant decreases in infectious morbidity, length of hospital stay, and hospital-related expenses [34–36]. In a recent meta-analysis and systematic review of the evidence including 35 articles, Drover et al. reported that these arginine-containing nutritional supplements yielded a significant benefit in lowering infectious complications across the several surgical specialties included. This meta-analysis also reported a signal for a decrease in length of hospital stay [37]. The exact mechanisms of the active ingredients are yet to be completely elucidated. However, it has been shown that fish oils have multiple mechanisms, including attenuating the metabolic response to stress, altering gene expression to minimize the proinflammatory cytokine production, beneficially modifying the Th1 to Th2 lymphocyte population to lower the inflammatory response, increasing production of the anti-inflammatory lipid compounds “resolvins and protectins,” and regulating bowel motility via vagal efferents [38–43]. Arginine has

been reported to have a multitude of potential benefits in the surgical populations. These include improved wound healing, optimizing lymphocyte proliferation, and enhancing blood flow via nitric oxide vasodilation effects [44, 45]. The influence of the Ribonucleic Acid (RNA) found in these preoperative formulas has theoretical benefits that have yet to be well elucidated in mammalian trials [45].

Another area of metabolic manipulation of growing interest is preoperative carbohydrate loading [46]. This metabolic strategy utilizes an isotonic carbohydrate solution given at midnight on the night before surgery, then 3 h preoperatively to maximally load the tissues with glycogen prior to the surgical stress [47]. In most Western surgical settings, the "routine" is for the patient to fast after dinner the night before surgery and remain nothing by mouth (*nil per os*, NPO) after midnight prior to surgery in the am. Essentially following this "routine," glycogen stores are nearly depleted prior to the surgical insult. Soop et al. [48], Fearon et al. [49], and more recently Awad [50, 51] have demonstrated the beneficial effects of carbo-loading in several animal and clinical studies. Caution with direct cause and effect conclusions here is needed as most large humans studies dealing with carbo-loading were done as part of several preoperative interventions with the experimental groups receiving multimodality treatment, including avoidance of drains, controlled perioperative sodium and fluid administration, epidural anesthesia, and early mobilization in addition to the carbo-loading [46]. These carbohydrate loading studies have consistently reported several metabolic benefits including significantly reduced insulin resistance, decreased postoperative nitrogen loss, and better retention of muscle function [48, 49].

27.3 Peri- and Postoperative Optimization

27.3.1 Surgical Site Infection

Surgical site infections (SSIs) following incisional hernia repair has been reported to be higher than that noted with other cases designated as clean cases. It has also been shown that if the index case from which the hernia developed had a wound infection then subsequent incisional hernia repair will have a higher level of infection than would be expected from a clean case [52]. Virtually all incisional hernias greater than 4–6 cm will require mesh for optimal durable repair. In general, if a permanent synthetic mesh is used and becomes infected, the ability to sterilize the mesh and completely eradicate the infection without removing the mesh is rare. Synthetic mesh clearance rates following mesh-related wound infections are reported between 10 and 70 % and will depend on the type of mesh involved. PTFE-based meshes remain the most difficult and virtually impossible to clear, followed by multi-filament polyester, while macroporous polypropylene yields the best chance of clearance [53, 54]. The clearance rates are dependent on the type of mesh used, location of mesh placement and the extent of contamination, as well as the viability of the tissue and host defenses [1, 53]. In addition, infected mesh is associated with costly morbidities such as prolonged wound management, enterocutaneous fistulae, as well as recurrent hernia. These complications can be quite severe and expose the patient to significant morbidity and even mortality. Treating the complications of infected mesh is also quite expensive [54]; therefore, all reasonable measures should be taken to prevent wound or mesh infection.

27.3.2 Skin Preparation and Decolonization Protocols

The data on choice of skin preps immediately prior to incision is now well sorted out. Two major trials have recently been published; the first from an excellent surgical ID group in Virginia. Swenson et al. reported in a prospective trial in over >3200 patients iodine skin preps were superior to chlorhexidine preps [55]. Soon after the Swenson paper was published, a prospective randomized clinical trial with intention to treat analysis in over 800 patients was published, reporting that chlorhexidine was superior to iodine preps [56]. Swenson went back and analyzed the data from both studies. This analysis revealed the key to lower infections was the alcohol in the preps; Duraprep® and Chloraprep® had equivalent surgical infection risk, and iodine prep without alcohol was most commonly associated with infections [57]. Regarding hair trimming, it has been the standard of care for several years that clippers rather than razor be used to clear the surgical site hair that would interfere with the surgical site [58]. Surgical site barriers and skin sealants have not been studied well in ventral hernia repair. The data on these applications is widely variable with reports from beneficial to detrimental. The data on skin sealants and surgical site barriers are far too inconsistent to make any recommendation to use these in ventral hernia repair or AWR. Also, the use of preoperative showers with antiseptic soaps to decrease SSIs has been inconsistent. Showering with antiseptic agents such as chlorhexidine or Betadine when compared to showering with soap have no proven benefit [59]. Most of these studies are underpowered or were studied in a widely heterogeneous population, which makes consistent results near impossible. Many of the early studies do report a decrease in skin bacterial colonization at time of surgery but have not shown a consistent decrease in SSI. Few of the smaller studies have shown benefit of preoperative chlorhexidine shower in reducing SSI but these are in the minority [60]. This inconsistency in the literature led to the Cochrane analysis in 2012 to conclude preoperative showers with antiseptics have no significant benefit [59, 61].

Preoperative nasal clearance of *Staphylococcus aureus* in the preoperative has gained significant popularity in the last several years following a landmark paper published by Bode et al. in the *New England Journal of Medicine*, 2010 [62]. This paper was closely followed by a second manuscript Kim et al. supporting the concept of *Staphylococcus* clearance preoperatively to decrease post-op wound infections [63]. In the Bode study, 6771 patients were screened for on admission with approximately 1200 being positive for *S. aureus*. They then prospectively randomized, with an intention to treat analysis, the patients carrying *S. aureus* to twice daily mupirocin applied to the nostrils with once daily chlorhexidine shower vs. placebo. They reported a 42% decrease in *S. aureus* postoperative infections in the treated group. The logistics of screening then treating those positive is a bit cumbersome and requires consistency and patient compliance, but when done according to protocol is clearly cost effective. It is our practice to avoid random nasal swab methicillin-resistant *Staphylococcus aureus* (MRSA) screening; instead we treat high-risk patients (previous MRSA infection, cohabitant with MRSA, recently hospitalized within 6 months, living in a nursing facility or prison, currently on broad-spectrum antibiotics, etc.) with mupirocin ointment applied intranasally for 5 days prior to the date of surgery.

27.3.3 Perioperative Antibiotics

According to Guidelines that were developed jointly by the American Society of Health-System Pharmacists (ASHP), the Infectious Diseases Society of America (IDSA), the Surgical Infection Society (SIS), and the Society for Healthcare Epidemiology of America (SHEA), patients undergoing routine ventral hernias repair should be given prophylactic antibiotics using a first generation cephalosporin [64]. The antibiotics should be given with adequate time to allow for levels in the tissue to reach a level above the minimum inhibitory concentration (MIC) for the bacteria for which one is trying to inhibit; usually this is at least 30 min prior to incision [65]. Antibiotics should be redosed, if necessary, during the operation as indicated based on duration of surgery, half-life of antibiotic being used, blood loss, and use of cell saver. Antibiotics are not given postoperatively as several well-done randomized trials have shown no benefit of dosing prophylactic antibiotics after the skin has been closed [64, 66–69]. These outcomes have been similar across several surgical disciplines. Most hospitals now have preoperative protocols, and in large surveys, over 90% of procedures are getting the correct antibiotic for prophylaxis according the published guidelines. The place where the prophylaxis is commonly inadequate is in patients with a body mass index (BMI) of >30. In a recent large survey, only 66% of patients received prophylactic dosing to reach adequate serum levels when BMI was over 30 [70]. According to ASHP guidelines it is recommended that all patients under 120 kg receive 2 g cefazolin, while those at or above 120 kg be given 3 g cefazolin, then redosed every 4 h for extended surgeries. Interestingly, because of shorter half-lives antibiotics such as ampicillin-sulbactam, cefoxitin, and piperacillin-tazobactam are redosed every 2 h when used for intraoperative prophylaxis, according to ASHP recommendations [64].

There are conflicting data regarding the risk of subsequent wound infection in patients with a history of prior infection that has healed, with some studies demonstrating increased rates of wound infection [71, 72] while others show no significant difference [73]. At our institution, we consider a previous wound infection as a definite risk factor for subsequent wound infection. We attempt to use appropriate prophylactic antibiotics when culture results of the initial infection are available. If the patient has had a previous abdominal wall MRSA infection, we will add vancomycin for prophylaxis. In these patients, we also prefer biologic or bioresorbable meshes as our reinforcing prosthetics [4]. This is especially important in patients who have had previous infections with MRSA involving synthetic mesh even when no overt signs of infection have been present for up to 10 years. The foreign body yields the substrate for the biofilm to adhere to and allow bacteria to flourish. Once this occurs, the bacteria have adequate numbers for quorum sensing. Within the bacterial colony, intracellular signals allow some bacterial cells in the colony to change phenotypically with some becoming dormant, some actively dividing, and some becoming planktonic [74]. Several papers have speculated that if previous mesh infection was present, the patient should no longer be treated with prophylaxis but treated empirically with a full course of antibiotics [74]. One must be cautious of overusing vancomycin prophylaxis without adequate indications as data show an increased risk of methicillin-*sensitive S. aureus* (MSSA) wound infection when vancomycin is used over a standard beta-lactam antibiotic [75]. For this reason, we commonly use both cefazolin in addition to vancomycin for prophylaxis in patients with high risk for MRSA infection, which is also discussed in the ASHP therapeutic guidelines [64].

For those patients with ongoing wound infections, infected mesh, active fistulae, etc., our primary goal is removal of all infected elements and foreign bodies. Prior to definitive hernia repair we debride all infected tissue, excise all infected mesh(es), sutures, and other foreign bodies, and perform any necessary gastrointestinal resections with anastomoses, as appropriate. For many cases where the bioburden of bacteria is high, we will stage the repair with a negative pressure dressing and close the abdomen with a Vicryl or biologic mesh and perform a subsequent hernia repair, likely with a biologic or biosynthetic resorbable mesh at some point in the future depending on the patient's condition, nutritional status, and degree of contamination [76].

27.3.4 Postoperative Blood Glucose Management

Thee first 24 h of the postoperative period appears to be especially important for glucose control, as hyperglycemia results in nonfunctional or poorly functional neutrophil activity. Hyperglycemia has been shown to alter chemotaxis, pseudopod formation, phagocytosis, and oxidative burst which can prevent the early killing of bacteria entering the wound during surgery [77].

Postoperative glycemic control was initially shown to be of benefit in preventing complications in a large study of primarily cardiac patients [78]. In the early 2000s, meticulous glucose control (80–110 mg dL) was very popular in surgical ICU patients. This popularity was stimulated by a large randomized control trial showing a significant decrease in mortality when strict glucose control protocols were instituted [78]. However, this has subsequently been shown not to be the case, as the risk of hypoglycemia and its complications outweigh the risk of meticulous glycemic control [79]. Additionally, postoperative hyperglycemia has been shown to be a strong predictor of postoperative SSI. Using a multivariate regression model in a retrospective study of 995 patients Ramos et al. correlated postoperative infections, demonstrating that postoperative hyperglycemia was a strong indicator of the probability of postoperative infection. In this study, every 40-point increase from 110 mg/dL serum glucose increased the risk of infection by 30 % [80]. Ata et al. examined the records of 1561 patients undergoing general or vascular surgery and found that postoperative glucose of greater than 140 mg/dL was the only significant predictor of SSIs [81]. The target blood glucose level in the immediate perioperative period appears optimal in the 120–160 mg/dL range.

27.3.5 Miscellaneous Techniques and Treatments to Reduce Risk

Additional measures reported to decrease post-op infectious complications include antibiotic impregnated suture, wound protectors, perioperative patient warming, intra-operative and postoperative hyper-oxygenation, as well as others. While initial enthusiasm for antibiotic impregnated sutures was high, there had been limited literature supporting its routine use. However, over the last several years, additional data have shown a reduction in SSIs with the use of antimicrobial sutures. A meta-analysis of 15 RCTs demonstrated favorable outcomes with triclosan-coated sutures in the majority of these studies [82]. Decreased SSIs have been seen in a range of procedures utilizing antibiotic sutures including breast, colorectal or other bowel cases, pancreaticobiliary, cardiovascular, as well as other operations [82–87]. Currently, no studies exist for the use of such sutures in patients with complex ventral hernias, which typically include higher rates of wound morbidity including SSIs. While we have not utilized antibacterial sutures in our practice of complex VHR, they do appear safe, and there appears to be sufficient data to proceed with future trials evaluating efficacy in this high-risk group.

Intraoperative wound protectors are designed to protect from desiccation, contamination, and mechanical trauma. They have also been said to decrease wound infections. No data on wound protectors in hernia surgery is available to date. To date, at least six randomized clinical trials have been done for colorectal and other GI surgeries. Four studies reported no benefit in lowering SSIs while two showed benefit. When weighing the quality of the studies and using the Grade system to evaluate studies, the review trends toward no benefit [88, 89].

The concept of patient warming to prevent SSI has received significant attention in the past 10 years, and now most operating rooms have patient warming as part of the protocol to minimize SSI. Several observational studies reported a significant correlation between hypothermia and SSI. The theoretical belief is that euthermia helps maintain better perfusion to skin, and better oxygen tension at the skin level will decrease SSI [90]. Hypothermia has also been associated with adverse influence on the immune function. T-cell mediated antibody production and reduction in both oxidative and non-oxidative killing of bacteria by neutrophils [91]. These concepts were supported by two moderate-sized RCTs, both showing hypothermia is significantly associated with an increase in SSI. A large case-controlled study done using the NSQIP (National Surgery Quality Improvement Program) database appears to not have confirmed these earlier findings [92].

Supplemental Perioperative Oxygenation (Hyperoxia) has been well investigated, but unfortunately not in hernia surgery. The concept that adequate oxygenation is required for neutrophil and macrophage killing of bacteria and the association that surgical wounds have a much lower partial pressure of oxygen than normal tissue makes this an attractive hypothesis for lowering SSI [93]. Two landmark studies in colorectal surgery patients showing benefit in reducing SSI lead to multiple protocols of using supplemental oxygenation [94, 95]. This led to a large study with governmental funding of 1400 patients showing no benefit [96]. A more recent meta-analysis favors supplemental oxygen protocols in the higher risk population such as colorectal surgery patients [97]. Although no direct studies have been done in abdominal wall reconstruction, this population carries risks of SSI very similar to colorectal surgery patients.

Perioperative antibiotic use commonly results in antibiotic associated diarrhea (AAD) in an estimated 20 % of patients, with perioperative use of antibiotics being a major source for AAD and *Clostridium difficile* diarrhea [98, 99]. Numerous recent prospective trials have shown that

Table 27.1 Perioperative interventions for ventral hernia repair

Solid data to support intervention	Awaiting greater confirmation of data
Obesity and weight management	Bowel preparation
• Sufficient weight loss necessary, however, no consensus on target BMI	
Smoking cessation—30+ days pre-op	Patient warming
Diabetes management and perioperative glucose control	Hyper-oxygenation
• Pre-op Hgb A1c <7.0	
• Post-op blood sugar 120–160 mg/dL	
Nutrition and metabolic control	Carbohydrate loading
• Pre- and post-op supplements	
• Consider specific nutrients (arginine, ω-3 fatty acids)	
Alcohol-containing skin prep	Prehabilitation
Antibiotic prophylaxis	Antibiotic-impregnated sutures
• Choice of antibiotic—1st generation cephalosporin for most	
• Vancomycin in high-risk groups	
• Duration—should stop when wound closed and all sutures placed	
• Duration—for redosing, consider $t^{1/2}$ of specific antibiotic; refer to ASHP and/or hospital guidelines	

appropriate selection and supplementation of probiotics (live viable bacteria when given in adequate amounts showing benefit in the host) are safe and can significantly decrease both AAD and *C. difficile* diarrhea [98–100].

It is valuable to mention that several other factors can be addressed in the intraoperative period and postoperative period that can optimize patient outcome and minimize SSO but are beyond the scope of this chapter. One concept that is rapidly gaining traction in major surgery is the idea that preoperative routine scheduled physical activity program, so-called "prehabilitation," can decrease length of stay and decrease total complications associated with major surgery [101].

27.4 Conclusion

There are multiple factors that affect postoperative outcomes following ventral hernia repair. Optimizing the patient preoperatively including smoking cessation, glucose control, and nutritional support can all be achieved over a relatively short time (1–5 weeks). Obesity, however, is a major threat to this high-risk group that takes months for patients to lose significant weight, be it with diet and exercise or even following a bariatric operation. If the surgeon has the luxury of waiting (minimally or asymptomatic hernia), he or she should wait until the patient has lost considerable weight to maximize outcomes. Unfortunately, for those hernias which are highly symptomatic or with threatened bowel, the surgeon may not have the advantage of waiting. Various segments of the patient's surgical journey should be addressed and optimized when possible (Table 27.1). These preoperative and perioperative interventions have been shown to be safe and even cost effective in most cases. The interventions performed in the immediate perioperative period, including appropriate choice and timing of prophylactic antibiotics, metabolic preparation with specific nutrients and/or carbohydrate-loading, choice of alcohol-containing skin preps, and preoperative decolonization of *Staph aureus* from the nostrils and skin, are reasonable interventions which, when implemented, should minimize peri- and postoperative morbidity.

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Overview of Operative Approaches and Staging Systems for Ventral/ Incisional Hernia Repairs

28

David M. Krpata and Michael J. Rosen

28.1 Introduction

With the multitude of operative approaches and variability amongst patients and hernias, defining a single, ideal operative approach is challenging and possibly unrealistic for ventral hernia repair. Additionally, surgeon preference and technical ability probably play the largest roles in determining an appropriate operative approach for patients undergoing ventral hernia repair. Some surgeons have been trained in minimally invasive surgery and prefer laparoscopic ventral hernia repairs over open ventral hernia repair, while others are more comfortable with open approaches. Further complicating decision making is identifying the location for mesh placement as a sublay, onlay, underlay, or bridge? It remains controversial as to whether a component separation should be performed and if fascial releases are contemplated the reconstructive surgeon has a multitude of layers of the abdominal wall to release. While previous chapters in this text focused on important concepts in ventral hernia repair, such as anatomy and preoperative optimization, and subsequent chapters will focus on specific techniques for the various approaches to ventral hernia repair, this chapter tries and defines the decision making behind choosing the ideal/appropriate operative technique based on the hernia and patient characteristics. In order to facilitate that conversation, we also think it is important to provide the structure of a classification system to enable all surgeons to appropriately classify hernias to help guide the technical discussions.

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28.2 Classification Systems for Ventral Hernias

In a field where standardization of techniques and operative approaches is sparse, the need for a classification system is only more greatly highlighted. Classification systems have many benefits, but most importantly they provide a common language which allows for comparison of surgical techniques and approaches within the literature and between surgeons on a case-by-case basis. If you search the term "ventral hernia" on pubmed.gov over 9000 articles describing studies regarding ventral hernias appear. It can safely be assumed that there is no standard method for characterizing ventral hernia defects throughout these 9000 manuscripts. This makes it difficult to compare studies and can at times only confuse the literature. Further complicating the creation of a ventral hernia staging system is identifying the most appropriate outcome measure to stratify risk. In the authors' opinion the two most relevant hernia outcome measures include surgical site infection and hernia recurrence rate. It is important to understand the historical efforts to define a hernia classification system and their advantages and disadvantages.

In 2000, the earliest attempts at unifying discussions of ventral hernia repair and creating ventral hernia classification systems were made. Schumpelick and Chevrel, independent of one another, each proposed systems in which characteristics such as hernia defect location, size, and primary vs. recurrent nature were considered [1, 2]. Additional classifications such as those proposed by Ammaturo and Bassi which adds the ratio between the anterior abdominal wall surface and wall defect surface as a new parameter [3] and Dietz et al. who describes a classification system in which patient body type, hernia morphology and risk factors for recurrence are used [4]. While this classification was very complete and detailed in the hernia assessment it proved cumbersome which limited its use for comparative purposes. These early classification systems largely focused on factors that might predict hernia recurrence. Current classification

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_28

systems which are commonly utilized are the European Hernia Society classification system [5], the Ventral Hernia Working Group [6], and the Modified Ventral Hernia Working Group [7].

28.2.1 European Hernia Society Ventral Hernia Classification System

While they were not the first to attempt to classify ventral hernias, the European Hernia Society was the first to collaborate in an effort to standardize a classification system for ventral hernias. This classification of primary and incisional hernias was reported in 2009 [5] (Table 28.1). This group elected to separate primary and incisional hernias. For primary ventral hernias they selected location and size of the hernia as the most important variables to consider. Ultimately, they created a grid format reporting classification with four locations (epigastric, umbilical, spigelian, and lumbar) and three sizes based on diameter (small <2 cm, medium 2–4 cm, and large >4 cm) for primary ventral hernias. This system maintains a simple method for reporting which was a goal of the society.

The classification of incisional or recurrent ventral hernias provided more challenges. The society again utilized size and location as main variables for the classification system; however, for size it was felt that both length and width of the hernia should be reported rather than simply measuring a diameter. Additionally, location was more scrupulously defined and included five medial locations (M1—subxiphoidal, M2—epigastric, M3—umbilical, M4—infraumbilical, and M5—suprapubic) and four lateral locations (L1—subcostal, L2—flank, L3—ilialc, and L4—lumbar) with the lateral boarder of the rectus muscles defining the border between medial and lateral regions. Length was stratified into three categories: W1 (<4 cm), W2 (4–10 cm), and W3 (>10 cm). Interestingly the European Hernia Society also felt, from a reporting standpoint, it was important to document the actual length and width of the hernia defect, rather than just a range. The final piece to the classification system was the documentation of whether the hernia was a recurrent hernia or not. Unfortunately, because of the multiple variables and a lack of consensus on a size variable, the society did not achieve their goal of creating a grid-like, easy flow format for the classification. Nonetheless, it provided a sensible tool to classify and report ventral hernia characteristics allowing for a more standardized description in future literature.

One very notable point that came from this consensus classification system was a standard method of measuring ventral hernias with multiple defects. Because of the importance the society put on measuring the size of the defect, they clearly defined this in their report: "In the case of multiple hernia defects, the width is measured between the most laterally located margins of the most lateral defect on that side" [5]. Similarly, for multiple defects the length of the hernia is measured by the most cranially and most caudally identified margins of the hernia defects. Of note, the European Hernia Society classification system excludes parastomal hernias. In fact, they put out a separate classification system for parastomal hernias in 2014 [8]. The lack of inclusion of these challenging potentially contaminated and contaminated cases in their original guidelines certainly led some to question the importance of contamination in a classification system.

Table 28.1 European Hernia Society classification for incisional abdominal wall hernias

European Hernia Society			
Midline	Subxiphoidal	M1	
	Epigastric	M2	
	Umbilical	M3	
	Infraumbilical	M4	
	Suprapubic	M5	
Lateral	Subcostal	L1	
	Flank	L2	
	Iliac	L3	
	Lumbar	L4	
Length	cm	Width	cm
Width	<4 cm	W1	
	4–10 cm	W2	
	>10 cm	W3	
Recurrent hernia?		Yes	No

Adapted from: Muysoms F et al. Classification of primary and incisional abdominal wall hernias. Hernia. 2009;13:407–414

28.2.2 Ventral Hernia Working Group

In 2008, a group of eight general and plastic surgeons were brought together to create recommendations regarding the grading and technique for repair of ventral hernias which were later published in 2010 [6]. While the initial intention of this group was not to create a classification system, but rather to guide decision making about ventral hernia repair techniques and technology, they nonetheless created a grading system that is heavily reported in current literature and presentations. The Ventral Hernia Working Group (VHWG) grading system consists of four grades based on risk of surgical site occurrence (Table 28.2). Surgical site occurrence was defined as the presence of a surgical site infection, seroma, wound dehiscence, or development of an enterocutaneous fistula. Grade 1 patients are those who are generally healthy without a history of wound infection and are considered to have a low risk of surgical site occurrence. Grade 2 patients are those who have multiple comorbidities which are believed

Table 28.2 Ventral Hernia Working Group classification

Grade 1	Low risk	– Generally healthy patients
		– No history of wound infection
Grade 2	Comorbid	– Active smokers
		– Obese
		– Diabetes mellitus
		– Immunosuppressed
		– COPD
Grade 3	Potentially contaminated	– History of previous wound infection irrespective of other comorbidities
		– Presence of a stoma
		– Any violation of the gastrointestinal tract
Grade 4	Infected	– Infected mesh
		– Septic dehiscence

Adapted from: Breuing K et al. Incisional ventral hernias: Review of the literature and recommendations regarding the grading and technique of repair. Surgery. 2010; 148(3):544–558

to put the patient at a higher risk of a surgical site occurrence. These comorbidities included smoking, obesity, diabetes mellitus, immunosuppression, and chronic obstructive pulmonary disease. Grade 3 patients are those who have potentially contaminated surgical fields. This includes a history of a surgical site infection, the presence of a nearby stoma, or violation of the gastrointestinal tract. Grade 3 patients are considered to be at a high risk of surgical site occurrence; however, the highest risk was Grade 4 patients. Grade 4 patients are those who have active infection such as infected mesh or a septic dehiscence.

Based on the VHWG grading system, the VHWG made recommendations for each grade. As one reads these recommendations it should be noted that the VHWG was supported and brought together by a biologic mesh company. The recommendations are summarized as follows: Grade 1 patients should have a hernia repair based on surgeon preference and patient factors, Grade 2 patients based on their increased risk of SSO are at additive risk of permanent synthetic mesh repair and there is a potential benefit to biologic mesh in these patients, Grade 3 patients should not have synthetic mesh placed in them and there may be an advantage to biologic repair material, and Grade 4 patients should not have permanent synthetic repair material and biologic material should be considered. These recommendations are currently being challenged in today's literature and may no longer be relevant.

While this is an interesting characterization of ventral hernias, it's important to recognize that the VHWG failed to include characteristics of the hernia defects such as size and location. Some would argue that this leaves the VHWG grading system somewhat incomplete. Despite this, the VHWG grading system is probably the most widely reported grading system in the literature for comparison of ventral hernias at this time.

28.2.3 Modified Ventral Hernia Working Group

Another significant concern of the VHWG grading system is that it has never been validated. Kanters et al. utilized a prospective database of 299 ventral hernia repairs to try and validate the VHWG grading system [7]. There were three important conclusions from their work. The first was that patients with a history of surgical site infections were misclassified. It turns out that the risk of surgical site occurrence for patients with a history of wound infection was similar to patients who had comorbidities that were considered VHWG Grade 2 patients. Secondly, patients with potentially contaminated fields from the presence of a stoma or violation of the gastrointestinal tract had similar surgical site occurrence rates when compared to patients in the VHWG Grade 4 group who had active infection from an infected mesh or septic dehiscence. As a result of these two findings, the modified VHWG grading system was created which included only three grades (Table 28.3). In the modified VHWG grading system Grade 1 patients remain the same as the original VHWG system; however, Grade 2 now includes patients with comorbidities and patients with a history of wound infections. Grade 3 then combines patients from VHWG Grade 3 and 4 essentially making the modified VHWG Grade 3 patients all CDC wound class 2 (clean-contaminated), 3 (contaminated), and 4 (dirty) cases.

The third important finding from the modified VHWG study was that it actually provided SSO risks for each grade. Having this important information allows surgeons to have informed discussions with their patients about the risk of surgical site occurrence based on the patients modified ventral hernia grade. In the modified VHWG grading system, the risk of SSO for Grade 1 is 14 %, Grade 2 is 27 %, and Grade 3 is 46 %. The modified VHGW grading system provides information the VHWG originally neglected and is validated;

Table 28.3 Modified Ventral Working Group classification

	Description	Rate of SSO (%)
Grade 1	– Generally healthy patients	14
	– No history of wound infection	
Grade 2	– Smoker	27
	– Obese	
	– COPD	
	– DM	
	– History of wound infection	
Grade 3	– Clean-contaminated case	46
	– Contaminated case	
	– Dirty case	

however, its major limitation is that fact that it is based on the VHWG grading system. So just like the VHWG, the modified VHWG grading system fails to take into consideration hernia characteristics like size and location. Additionally, these grading scales fail to address one very important outcome of ventral hernia repair, hernia recurrence.

28.3 Ventral Hernia Staging System

The importance of a common language for surgeons repairing ventral hernias cannot be emphasized enough. The creation of staging systems in oncology has allowed physicians to standardize approaches to each type of cancer. This standardization has improved outcomes, unified surgical approaches, and established a language for communication among all physicians that enhances the multidisciplinary approach. Maybe most importantly, the staging system provides a straightforward language for patients to understand their options and prognosis. Hernias may be a different disease process than cancer, but their impact on the healthcare system is still great as it is one of the most common operations performed by surgeons and a staging system can ultimately help tailor operative approaches for ventral hernias and likely improve outcomes for patients.

The ventral hernia staging system was first reported by Petro et al. in 2015 [9]. It emphasizes features of the European Hernia Society but also includes aspects of the VHWG and establishes a staging system based on hernia width and level of surgical field contamination. Interestingly, the ventral hernia staging system did not initially set out to only include these two main factors; however, after complex modeling including multiple patient variables, hernia characteristics, and levels of wound contamination the two variables that were significant enough to be part of a staging system were hernia width and level of wound contamination. It should be recognized that just because other variables are not in the staging system it does not mean they have no impact on surgical site occurrence and hernia recurrence rates. For example, diabetes mellitus, despite that it is not in the staging system still has a significant influence on ventral hernia outcomes, but that influence is not significant enough to be considered part of a global ventral hernia staging system. The ventral hernia staging system also tries to overcome a weakness of previous classification systems by including both surgical site occurrence and hernia recurrence as outcome measures.

Table 28.4 Ventral hernia staging system

	Risk	Description
Stage I	Low	<10 cm, clean
Stage II	Intermediate	10–20 cm, clean
		<10 cm, contaminated
Stage III	High	>10 cm, contaminated
		Any >20 cm

The ventral hernia staging system has three stages (Table 28.4). Stage I includes ventral hernias that are less than 10 cm in width and are a CDC clean wound class. This stage generally has a low risk of surgical site occurrence and hernia recurrence quoted at around 10 % for both. Stage II includes hernias that are either 10–20 cm wide and a clean wound class or less than 10 cm wide and a contaminated wound class. A contaminated wound class in this staging system is any none clean wound class regardless of whether it is CDC wound class 2, 3, or 4. Stage II hernias have an intermediate risk of surgical site occurrence (20 %) and hernia recurrence (15 %). Finally, Stage III includes hernias that have a hernia width greater than 20 cm and are clean surgical fields or any contaminated hernia with a hernia width greater than 10 cm. These hernias have high risks of surgical site occurrence and recurrence, 42 % and 26 %, respectively. This staging system is easy to follow and can be anticipated preoperatively based on clinical scenarios which ultimately should inform discussions with patients and allow surgeons to optimize their operative approach.

28.4 Operative Approach Based on Ventral Hernia Stage

One of the most significant challenges in hernia repair is not the operation itself but rather surgical judgment on selecting the most appropriate approach for each patient. This concept of tailoring ones operative approach based on each individual clinical scenario is gaining traction; however, it currently has limited data to help surgeons make decisions in each scenario. Deciding on an operative approach takes into account surgeon preference, patient preference, and patient and hernia characteristics. Some would argue that currently the greatest influence on operative decision making is surgeon preference and comfort with the technique. Utilizing a

staging system to decide on operative approaches should not ignore a surgeon's clinical experience but rather act as a general guideline. In the chapters that follow, many techniques including laparoscopy, various component separations and even robotics will be discussed. These guidelines are not meant to define techniques.

Management of Stage I ventral hernias provide the most versatility with regards to the various techniques available. As a general concept, Stage I hernias should have closure of the midline fascia and synthetic mesh reinforcement with limited exceptions. Exceptions to the use of mesh include primary umbilical hernias less than 2 cm, patients of child bearing age who anticipate further child bearing, and patient preference to avoid mesh. Biologic or absorbable synthetic mesh should not be used in Stage I ventral hernia repairs. The VHWG raised concerns over the use of synthetic mesh in VHWG Grade II patients because their comorbidities put them at increased risk of surgical site occurrence which led to a fear of mesh infection. For patients who are at felt to be at increased risk of surgical site occurrence, however, are Stage I ventral hernias, it is recommended that they have macroporous, lightweight, monofilament synthetic mesh placed in a sublay (retromuscular) position. This approach utilizes a synthetic mesh with properties that are most resistant to bacterial contamination [10] and places mesh in a position with complete tissue apposition while keeping it away from the bowel but below the fascia and protected from superficial surgical site infections. Stage I hernias in patients without the comorbidities or obesity and smoking can also be approached as an open onlay technique. This approach can be combined with an anterior component separation to achieve midline fascial closure for larger defects. However, the wound morbidity associated with skin flap creation should limit the utilization of this approach for any patient at high risk for wound complications. In those patients we recommend a retromuscular approach with a posterior component separation if necessary.

Alternatively, minimally invasive ventral hernia repair, with laparoscopy or robotic assistance, is an option for Stage I ventral hernias while maintaining the concept of midline closure and mesh reinforcement. We typically reserve a minimally invasive approach for those patients with hernia defects less than 6 cm in maximal width and without hostile abdomens or excessive scars that need revision. Methods of minimally invasive hernia defect closure have been described including the "shoelace" technique with multiple Table of eight sutures or continuous closure with laparoscopic or robotic assistance. For minimally invasive techniques, there should be a minimum of 4–5 cm of mesh overlap relative to the size of the defect prior to closure. Although we recommend defect closure for laparoscopically approached Stage I ventral hernias, this concept is still being debated in the literature. Deciding on an open approach or minimally invasive approach remains in part surgeon preference. The authors preferred approach for any ventral hernia in which the hernia defect should be closed is an open operation with retromuscular mesh placement. This preference reserves a minimally invasive approach for patients who are morbidly obese and minimally functional who only need to eliminate the risk of bowel incarceration rather than need a functional repair.

Stage II ventral hernias are larger than Stage I hernias and can involve the presence of contamination and as such have higher rates of surgical site occurrence and hernia recurrence. Multiple factors should be considered when determining ones approach to repair of these hernias. These hernias are almost always best approached with an open rather than a minimally invasive approach for two reasons. First, tissue separating mesh with its anti-adhesive barrier should not be used in contaminated fields. As a result, defects that would have been amenable to laparoscopy because they are less than 10 cm are no longer candidates because of mesh selection. Importantly, it's not that synthetic mesh with appropriate mesh properties cannot be used in contaminated cases but rather that tissue separating barriers on synthetic meshes may provide a favorable environment for bacterial colonization and mesh infection. Secondly, large defects (>10 cm) are likely to require components separation to achieve medialization of the rectus muscles and recreation of the line alba. There have been recent descriptions of minimally invasive components separation such as the endoscopic and robotic transversus abdominis releases with closure of midline defects; however, few of these have been in hernias greater than 10 cm and long-term results are lacking. As a result, currently these patients should be approached with an open operation unless one has advanced training in abdominal wall reconstruction and minimally invasive surgery.

One significant difference between Stage I and II ventral hernias is mesh selection. While Stage I hernias should be limited to synthetic mesh, Stage II hernias provide a different clinical scenario with contaminated cases which includes CDC wound classes 2,3, and 4. As such, appropriate mesh selection is important and meshes with favorable properties in contamination should be considered. These meshes include macroporous, lightweight, monofilament synthetic mesh, biologic mesh, and bioabsorbable or absorbable synthetic mesh. The greatest advantage to synthetic mesh over biologic and absorbable synthetic mesh is durability; however, a mesh infection may require reoperation and partial or complete mesh removal. Alternatively, if biologic mesh becomes infected it may get broken down by bacterial collagenase and avoid mesh sepsis. From a technique perspective, any of these meshes when placed in a retromuscular fashion are likely to perform well; however, absorbable synthetic meshes are designed to breakdown over 6–18 months and as such their long-term durability for a ventral hernia repair remains in question.

Our approach to Stage II hernias can be summarized based on the defect size and presence of contamination. For those defects less than 10 cm and contaminated we think it is very reasonable to remove the source of infection and then close the patient primarily and allow them to have a high hernia recurrence rate. This hernia can then be fixed in an elective fashion in the future in a clean field. If the defect cannot be safely repaired primarily due to fear of evisceration or wound dehiscence, then we will perform a single staged repair. This can involve a posterior component separation with macroporous synthetic, absorbable synthetic, or biologic mesh. There are no randomized controlled trials guiding the superiority of any of these meshes in the setting of contamination. For clean defects that are 10–20 cm the surgeon can consider the most appropriate myofascial release possible. For defects less than 15 cm often a standard retromuscular Stoppa type repair is sufficient. If necessary, a posterior component separation can be utilized for larger defects.

Stage III ventral hernias present very complex surgical problems, large defects (>10 cm) with contamination, and even larger defects (>20 cm) in clean cases, resulting in surgical site occurrence rates of approximately 40 % and hernia recurrence rates of approximately 25 %. The operative approach to this stage of hernia should be very calculated. First, determining the benefit to risk ratio for these patients is not always easy but is necessary. Repair of hernia defects greater than 20 cm in patients with multiple comorbidities could place patients at greater risk of morbidity and mortality than is acceptable. To appropriately counsel these patients on the risk of surgery a thorough understanding of their quality of life limitations should be obtained. Hernia defects greater than 20 cm rarely have incarceration or strangulation from the hernia defect itself and as such repair of these hernias is a quality of life issue.

Secondly, these hernias should always be approached with an open operation. Regardless of minimally invasive surgical skill, massive hernias with or without contamination are best approached with an open operation. Many times these patients will require removal of some degree of excess or thinned out skin and almost always will require components separation for defect closure. Importantly, for massive ventral hernias, midline defect closure may not always be attainable. In these cases, it is acceptable to perform a bridged repair with synthetic mesh for clean cases of massive ventral hernia. In this instance a heavy weight synthetic mesh should be utilized. As a result, it is imperative that the soft tissue coverage over the heavy weight synthetic mesh is healthy and at low risk of devascularization and ischemia. For cases where the soft tissue coverage over the heavy weight synthetic mesh is questionable, free flaps with latissimus or anterolateral thigh may provide a suitable alternative. A bridging repair with biologic or absorbable synthetic mesh is not recommended.

Given the size of these defects, a components separation is usually required. While a traditional anterior components separation, as described by Ramirez [11], and a posterior components separation with transversus abdominis release provide equal myofascial advancement [12], it is the author's preference to perform a posterior components separation for three reasons. First, it avoids large skins flaps which could disturb blood flow to the abdominal wall soft tissue ultimately placing patients at increased risk of wound complications. Secondly, a posterior component separation provides a retromuscular and pre-peritoneal pocket for mesh placement that keeps the mesh extraperitoneally away from the bowel with vascularized tissue on both sides of the mesh for optimal integration. Lastly, a posterior components separation allows for wide mesh overlap, wrapping the entire extraperitoneal surface from psoas muscle to psoas muscle. This degree of mesh overlap may not be necessary for all ventral hernias; however, for massive ventral hernias this approach most likely provides the best opportunity for a durable repair. As described in other chapters, the posterior component separation technique is technically demanding and should not be attempted in these very large hernias without significant surgeon experience.

Mesh selection in Stage III hernias can be broken down into two paths. In general, for massive ventral hernias in clean fields heavy weight synthetic mesh is utilized to provide the best chance of avoiding hernia recurrence in the future; however, for large hernias with contamination heavy weight synthetic mesh should be avoided as the mesh properties are not favorable in contaminated fields. As a result, for contaminated fields options include light weight, macroporous, monofilament synthetic mesh, absorbable synthetic mesh, or biologic mesh. It should be pointed out that using any of these meshes in contaminated fields would be considered off label use regardless of whether it is synthetic, absorbable synthetic, or biologic mesh. As previously mentioned, there are advantages and disadvantages to each of these options in a contaminated field and further investigation is needed to make a definitive statement about which mesh is best in this scenario.

28.5 Outcomes

Deciding on an operative approach for ventral hernia repair has to balance what surgeons and patients believe is a good outcome. Unfortunately, it is currently accepted that outcomes of surgery are measured in a binary fashion; there is a recurrence or there is no recurrence. Is a small, asymptomatic recurrence after massive ventral hernia repair really a failure? The answer to this is likely to be different between surgeons, patients, and between individual case scenarios. As such, it's important that surgeons know more than their surgical site occurrence and hernia recurrence rates. Instead, surgeons need to work collectively to accumulate data on each individual stage, measuring not only surgical site occurrence and hernia recurrence, but also patient quality of life both before and after surgery to make sure we provide patients the best operative approach.

Fortunately, societies like the Americas Hernia Society with their Americas Hernia Society Quality Collaborative (AHSCQ.org) and European Hernia Society provide registries for surgeons to maximize patient care by following these outcomes in a risk adjusted fashion. Ultimately, these registries will help to shape classification and staging of ventral hernias allowing surgeons to optimize and tailor operative approaches and provide the best possible care for their patients.

28.6 Summary

Ventral hernia repair is one of the most common operations performed today, yet its increasing complexity is presenting more challenging cases and clinical scenarios. Currently available classification systems, such as the European Hernia Society, the Ventral Hernia Working Group, and Modified Ventral Hernia Working Group, are important because they establish a system with a common language amongst surgeons to discuss and improve upon current techniques and approaches to ventral hernia repair. The Ventral Hernia Staging System takes the best of all these systems, including patient and hernia characteristic, and provides not only a simple straightforward common language, but also expected outcomes which inform discussions with patients about expectations. This staging system can also aid surgeons in decision making about operative approaches, including technique and prosthetic mesh selection.

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Onlay Ventral Hernia Repair

29

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29.1 Introduction

A recent review of the American Hernia Society Quality Collaborative database has dispelled former myths about onlay ventral hernia repair regarding surgical site occurrences (SSO) and seroma. Comparing onlay repairs with adhesive fixation to sublay repairs in 262 patients (171 sublay and 91 onlay), results showed that there was no statistical significance regarding SSO and seroma between the groups. Being able to move past the concept of placing mesh directly under a layer of subcutaneous tissue and, furthermore, placing drains on top of the mesh has been an obstacle for American surgeons, thereby limiting the use of the onlay technique for ventral/incisional (V/I) hernia repair. In order to fully understand these biases, we need to look at the history and evolution of ventral hernia repair.

In the 1970s, two techniques of ventral hernia repair surfaced in Europe. Chevrel described a technique of recreating the linea alba with sutured onlay mesh reinforcement that included the use of fibrin glue for fixation of mesh over the midline closure. Also around this time, Rives described the retrorectus mesh repair of V/I hernias which included closure of the posterior sheath and sublay mesh placement fixated with transfascial sutures. While these techniques ran parallel courses in Europe, the Rives repair gained almost exclusive popularity in the United States due to Dr. George Wantz, a New York surgeon who travelled to France to learn the technique directly from Rives. Dr. Wantz brought the repair to the United States including teaching the technique at our institution to our faculty and residents in the 1980s.

As we began teaching our suture-based laparoscopic repair of V/I hernias it became apparent the Rives repair was something we could use in teaching the technique of our laparoscopic repair. As we held courses and exposed American surgeons to the Rives sublay repair, it became well known as the years went by and became the standard open repair in many academic institutions, centers for hernia repair, and for many surgeons in private practice. The onlay repair never achieved this level of attention and on the contrary developed a bad reputation due to poor patient selection, improper technique, and limited mesh options, which led to a high incidence of complications and morbidity. We were part of this bias until we began using adhesives for TEP inguinal hernia repair in 2003, and started to appreciate the ease of use, strength of repair, and the excellent results. We then began to relook at the onlay repair and believe that maybe Chevrel was on to something that had been underappreciated. Our repair differed from Chevrel's in that we developed a sutureless repair using fibrin glue as our method of mesh fixation instead of sutures.

29.2 Principles and Biomechanics of Onlay Ventral Hernia Repair

Chevrel's original onlay technique was not the result of an arbitrary decision to place mesh on top of the repaired defect. It was based on thoughtful scientific endeavors to understand the biomechanics of the abdominal wall. He performed a series of cadaver studies in order to understand the relative strengths of the various parts of the abdominal wall. He found that the strongest part of the abdominal wall was the

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_29

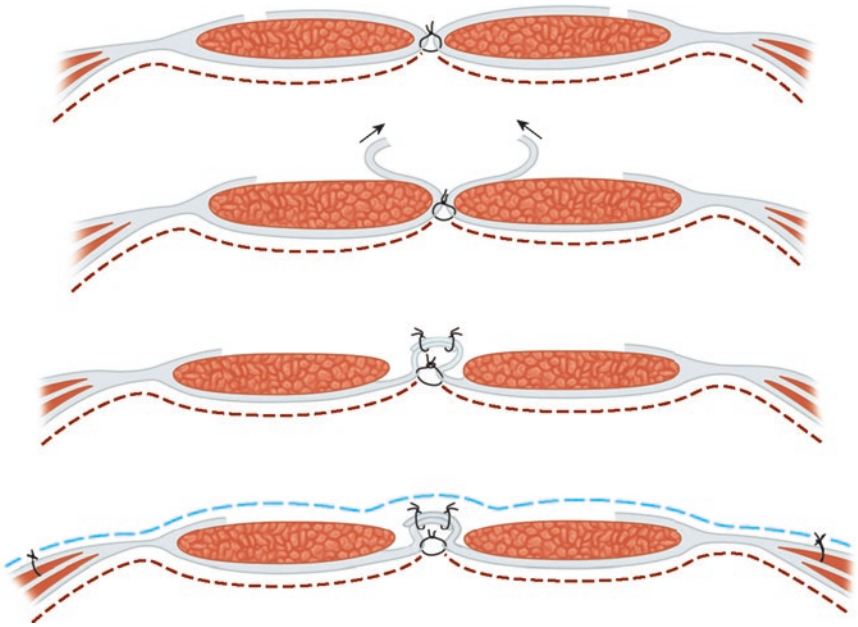

Fig. 29.1 Chevrel's original technique recreating the linea alba

suprarcuate anterior rectus sheath, and that the anterior sheath in general was the most comparable in strength to the linea alba. He also found that the posterior sheath was much weaker than the anterior sheath and the linea alba (1, 2). Since the only two meshes available at the time for V/I hernia repair were uncoated polyester and polypropylene, he was concerned the weak posterior sheath, which first sustained any increase in intraabdominal pressure, would rupture and tear exposing the viscera to the mesh with all of the resultant potentially devastating complications. This is why he favored the onlay placement of mesh.

These findings supported and likely helped form his technique which is based on recreation of the strongest part of the abdominal wall: the linea alba. Chevrel's original technique predictably involved using the anterior rectus sheath as a substitute for the linea alba (Fig. 29.1). After mobilizing the fascia with subcutaneous flaps, he would close the midline, thereby re-approximating the rectus muscle. He would then incise the anterior rectus sheaths, medialized them, and then suture them together as a second midline closure. Finally, he placed an onlay prosthesis that was sutured throughout and fixated over the midline closure with fibrin glue. Subcutaneous drains were placed and they were left in until there was no drainage for 48 h. Patients wore an abdominal binder for 2 months after the surgery (3).

29.3 Clinical Data

In Chevrel's original series he compiled other techniques of V/I hernia repair with his specific onlay method and in total he treated 426 incisional hernias from 1979 to 1998. He used the fibrin glue onlay technique in 143 repairs and they followed up 93 % of them for up to 20 years. His recurrence rate was 4.9 % (compared to Flament's Rives repairs of 6.5 %) and his seroma rate was variable based on how much fibrin glue he used. He found that more glue resulted in more seroma. One significant advantage he noted was that no mesh was lost due to surgical site infection. This is something we have replicated, especially with macroporous mesh. The mesh can almost always be salvaged if wound issues develop as opposed when the mesh is placed in a deeper plane (3).

Kingsnorth published a series of ventral hernia repairs using mesh onlay, Ramirez type components separation, suturing of the mesh at the periphery, and fibrin glue for skin flap treatment (not specifically for mesh fixation). There were 116 patients with a median follow-up of 15.2 months. Seroma rate was 9.5 % and skin infection rate was 8.6 %. There were no mesh infections. Recurrence rate was 3.4 % over the follow-up period (4).

Stoikes, Voeller et al. published their initial series of 50 patients of an onlay technique using fibrin glue alone for mesh fixation. The mesh prosthesis was positioned initially with skin staples as a place holder and then fixated to the entire anterior fascia with fibrin glue alone. Chevrel's original principle of recreation of the midline was done with a tension-free primary closure by selectively using myofascial advancement consistent with Ramirez' principles. Mean follow-up was 19.5 months with no known recurrences identified. The seroma rate was 16 % and skin infection rate was 6 %. There were no mesh infections (5).

An update to the data was recently published in Surgical Endoscopy. It included 97 patients with mean defect size of 150 cm^2 and mean BMI of 32. Overall skin infection rate was 4 and 7 % developed skin necrosis. Nine percent of patients required reoperation for skin-related morbidity with 100 %

salvage of mesh in cases of infection or skin ischemia. BMI was found to be the only risk factor linked to infection and reoperation. This series included the use of the technique in clean-contaminated and contaminated scenarios, with no association between level of contamination and infectious complications or reoperations. We have found now, with experience, that the skin flap complications can be avoided if one adheres to the principals elucidated below (6).

29.4 Contemporary Onlay Ventral Hernia Repair with Fibrin Glue Fixation

Patient selection is a key component of the onlay ventral hernia repair. Patients with known vascular compromise (prior aortobifemoral bypass, AAA repairs) are not good candidates because of the need for large skin flaps. These patients have compromised collateral blood flow to the skin of the abdominal wall and should be avoided if large skin flaps are required. Other considerations include those patients at risk for wound morbidity such as diabetes, prior smoking, or morbid obesity. In general patients with morbid obesity or an active smoking history are not candidates for elective ventral hernia repair in our practice. With that being said, we have shown that even in the most dire situations mesh has been salvaged 100 % of the time in cases with wound morbidity.

After lysis of adhesions and reduction of the hernia, bilateral subcutaneous flaps are raised to allow a minimum of 8 cm mesh overlap of the midline closure (Fig. 29.2). The fascial edges are then debrided of hernia sac and devitalized tissue. Tension is then assessed as the fascia is approximated with atraumatic clamps. The goal should be for the fascia to overlap itself approximately 1–2 cm when brought together. If tension exists when the midline is approximated then selective myofascial advancement is then done to relieve this tension. We utilize a classic, stepwise components release for myofascial advancement, as described by Ramirez (7). We start with a posterior rectus sheath incision unilaterally and reassess the tension at the midline (Fig. 29.3). If tension still exists, we incise the posterior sheath on the opposite side

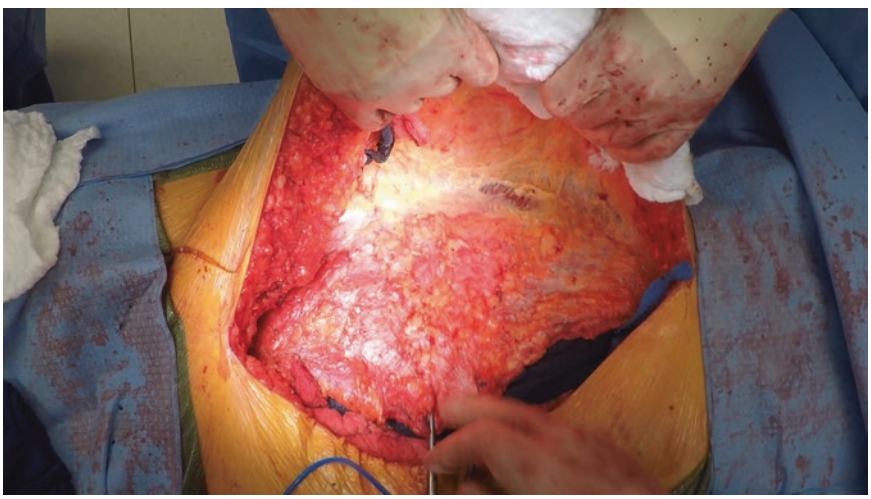

Fig. 29.2 Creation of subcutaneous skin flap

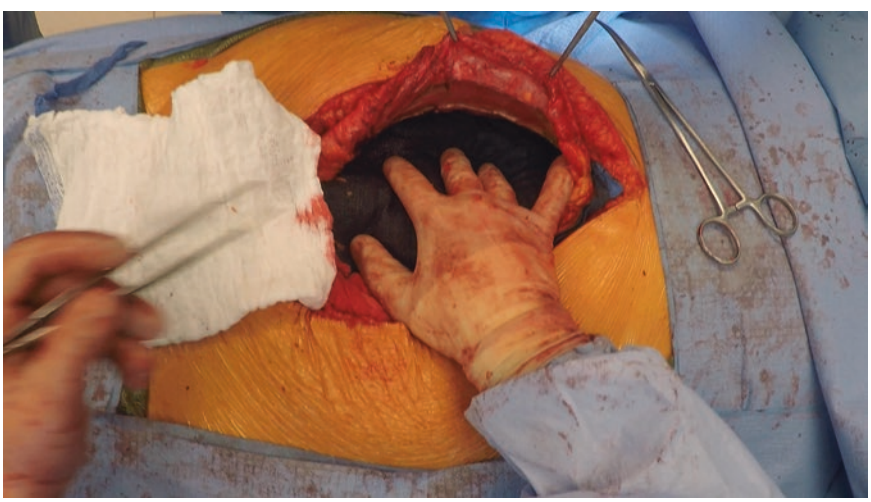

Fig. 29.3 Posterior fascial release

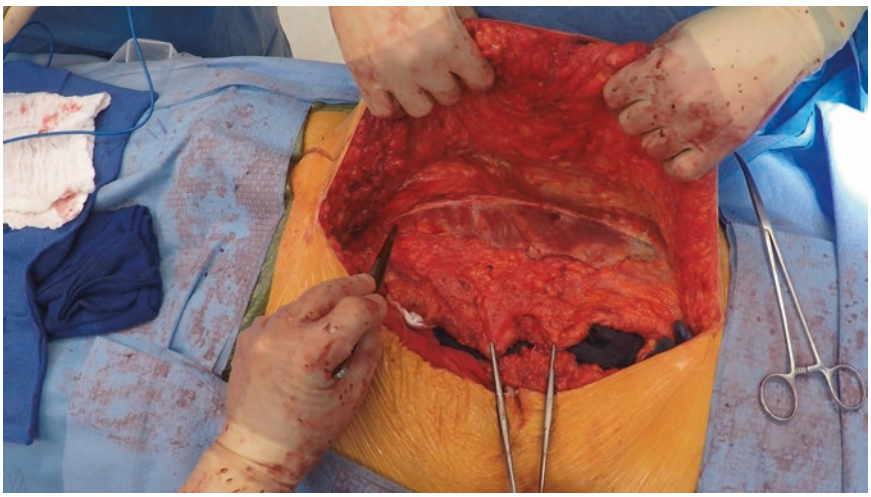

Fig. 29.4 External oblique fascial release

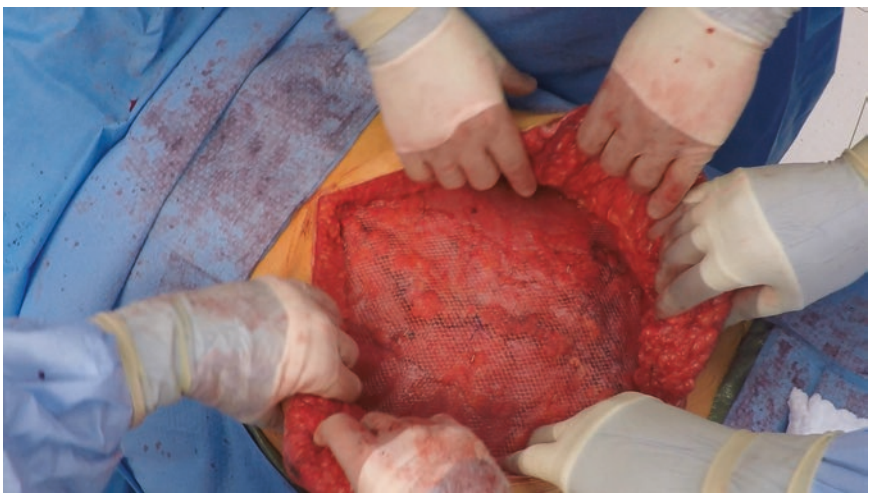

Fig. 29.5 Positioning of onlay mesh with skin staples

and again assess the midline. Posterior rectus releases are performed by incising the posterior rectus sheath fascia along the length of the abdominal wall with cautery. It is critical to evaluate the amount of tension at the midline after each step. If bilateral posterior sheath releases are done and tension is still present, we proceed to a unilateral external oblique release on 1–2 cm lateral to the semilunar line along the length of the abdominal wall (Fig. 29.4). Again, we only release the external obliques bilaterally if tension is still present after unilateral release. The defect is then closed at the midline with a running permanent monofilament suture or interrupted polyester sutures. A second layer of running, slowly absorbable monofilament suture is used over the closure to imbricate the midline if tension allows, thereby utilizing Chevrel's technique of recreation of the linea alba. A large mid-weight, macroporous polypropylene mesh is then placed over the abdominal wall including coverage of all lateral releases. Several skin staples are used to position the mesh over the entire involved area of repair (Fig. 29.5). Fibrin glue is then massaged over the mesh to mold it into place fixating the entire surface area of the mesh to the anterior abdominal wall (Fig. 29.6). It is important to note that fibrin glue has two constituents that are typically mixed in a common catheter tip during application. We *do not* use the mixing catheter tip, but apply the constituents unmixed onto the mesh, which are then mixed by hand directly on the surface of the mesh. Spray application can be utilized but requires setting up more equipment and is not as readily directed. We found in our basic science studies in the lab that both Evicel and Tisseel brands of fibrin glue have similar strength and that either spray or the "dollop" method we use have similar results. We have preferred the Tisseel brand of fibrin sealant due to its better immediate appearance of fixation. The glue is allowed to fix, and then two to four large closed-suction drains are placed in the subcutaneous space, and the skin is closed in two layers. Patients wear an abdominal binder at all times for 2–3 months, and drains are managed in the clinic. We routinely continue the drains until

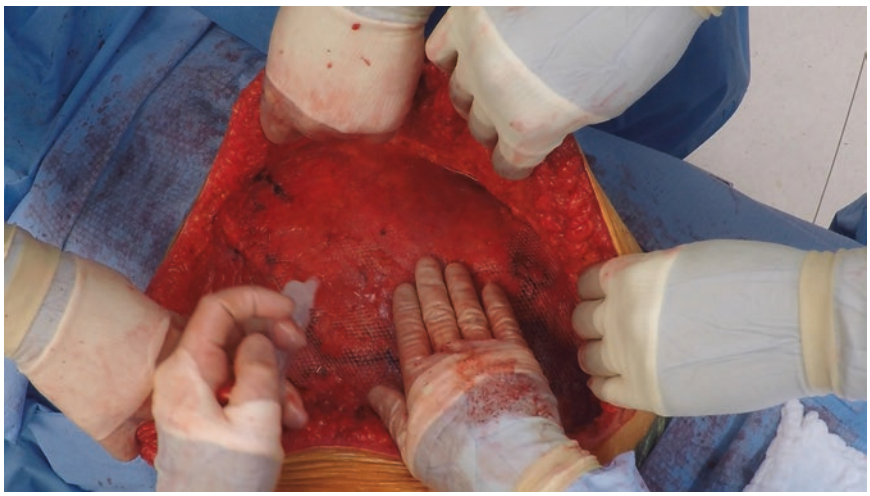

Fig. 29.6 Fixation of mesh with fibrin glue

there is only scant drainage and have had no complications with drain site infections. We place BioPatch around each drain and keep patients on minocycline while the drains are in to suppress skin flora.

29.5 Discussion

Routine use of fibrin glue for mesh fixation has enhanced the onlay ventral hernia repair technique. The biomechanics support the advantages of having immediate fixation of the entire surface area of the mesh, thereby theoretically immediately taking tension off of the midline closure. Furthermore, the modality of adhesive fixation functions in a fundamentally different way from mechanical fixation methods, which is important in the hernia-forming patient. As a principle, mechanical fixation relies on the strength of the fascia, suture or tack and the mesh whereas adhesive fixation only relies on surface area.

Historically the works of Schwab, Kes, and Katkhouda first established fibrin glue as a superior fixation method for laparoscopic inguinal hernia repair (8, 9). It prevented dislocation of the mesh the best, gave the highest stress resistance across the abdominal wall and the best stability of the mesh when compared to mechanical fixation. Our original animal study in 2013 proved the feasibility of fibrin glue fixation of mesh for onlay ventral hernia repair. In a pig model fibrin glue was compared to suture fixation of mesh. Time points included 24 h, 7 days, and 14 days. Shear strengths were evaluated and it was found that the suture group was significantly stronger at 24 h but at 7 and 14 days the mesh in both groups were so integrated that there was no significant difference between the groups. Histology at all time points also showed similar fixation properties between groups. Another interesting and potentially important finding was that the glued mesh had less contraction than the sutured group (10).

The next step in understanding adhesive fixation is to evaluate the different fibrin sealants and how they are applied. In a similar pig model we have preliminarily (pending publication) compared Tisseel vs. Evicel at 24 h and 4 day time points. Application methods including spray application and droplet application with hand massaging of the glue to cover the mesh were also compared. At both time points the two products had similar shear strengths regardless of application method, though Tisseel trended to be stronger at 24 h.

Future studies of onlay ventral hernia repair include both basic science and clinical research. Anecdotally, we have observed decreased postoperative pain in these patients compared to the Rives and laparoscopic repairs, and no development of chronic abdominal pain. Clinical trials examining quality of life and pain scores are a necessary next step. Regarding basic science, further understanding of adhesives is needed. Specifically, optimizing the amounts of glue applied during a repair may translate to improved outcomes for patients while reducing procedural costs. We are also studying new adhesive technologies in our lab that show promise of an exciting future in the field of mesh fixation.

Clinically the outcomes of onlay ventral hernia repair appear to be comparable to other methods of abdominal wall reconstruction based on AHSQC data previously mentioned. However, current sublay techniques such as the Rives retrorectus repair or the TAR (transversus abdominis release) can be technically demanding and difficult to teach. The relative simplicity of the onlay technique may translate to wider use in view of the recent results. There is no one repair for all patients and hopefully the AHSQC will allow us to determine who will benefit the most from each repair. The onlay repair is not for every patient, but we believe Chevrel was correct in believing that the onlay repair, when done properly in the right patient, is another arrow in the hernia surgeon's quiver.

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Retrorectus Hernia Repair and Transversus Abdominis Release

30

Arnab Majumder and Yuri William Novitsky

30.1 Introduction

Modern hernia surgery has placed great emphasis on functional reconstruction of the abdominal wall, relying on the foundations of tissue-based, tension-free repair along with the latest technologies in mesh reinforcement. Retromuscular hernia repair, as originally described by Rives and Stoppa, has gained significant traction in the recent surgical era [1–3]. Coupled with the principles of giant prosthetic reinforcement of the visceral sac from Wantz [4], the retrorectus, Rives–Stoppa–Wantz, technique was declared the gold standard for midline incisional hernia repair by the American Hernia Society in 2004. Despite the benefits offered, there are two major shortcomings of retrorectus-only repair, namely limited myofascial advancement and a limited area for sublay mesh placement, specifically within the confines of linea semilunaris. To address these limitations, a number of modifications have been developed in an effort to further improve the technique. Anterior component separation (ACS), as described originally by Ramirez [5], has been widely utilized to gain myofascial advancement, however the subcutaneous flaps raised to perform the external oblique release remains associated with significant wound morbidity [6]. Further techniques including perforator sparing ACS, endoscopic component separation, and pure preperitoneal repair have attempted to address such issues with variable adoption by surgeons. Importantly however, these techniques have significant disadvantages including limited myofascial advancement, injury/sacrifice of neurovascular structures, and/or non-sublay mesh placement.

Among the various options in the surgical armamentarium, posterior component separation via transversus abdominis release (TAR) [7] continues to gain popularity worldwide since its introduction by Novitsky et al. in 2009 at the World Hernia Congress [8]. The technique offers major benefits for complex hernia patients while addressing the limitations of retrorectus-only hernia repair. TAR allows not only significant myofascial advancement, but also creation of a large retromuscular sublay space for mesh implantation avoiding contact with peritoneal contents and subcutaneous tissue. These two principles are central in the Rives–Stoppa repair, however, expanded to fit an ever-challenging populace with large complex hernias.

30.2 Indications

Patient selection remains an integral component to success for any surgical procedure. The variability in hernia and patient characteristics demands a tailored approach to repair, rather than a "one size fits all" mentality. Two major branch points arise when determining the appropriate use of retrorectus techniques: first is the determination between a minimally invasive approach and open, and second the use component separation techniques versus traditional Rives–Stoppa repair.

In addressing the first distinction, laparoscopic hernia repair should be considered to patients with small to medium defects (defined as <7–8 cm wide), without prior intraperitoneal mesh, and/or overlying skin changes, skin grafts, or wounds healed by secondary intention. For patients with larger defects, the use of minimally invasive approaches results in increased difficulty with obtaining adequate mesh overlap and suboptimal cosmesis. Often, despite adequate mesh overlap, the inability to complete defect closure laparoscopically may result in an undesirable bulge following successful repair. With the recent advent of robotic and laparoscopic abdominal wall reconstructions, the above algorithm is evolving [9].

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_30

Once the retrorectus approach is decided upon, the next distinction to be made is whether the hernia requires a traditional retrorectus Rives–Stoppa repair or posterior component separation via TAR. For smaller (about 6–10 cm) defects where adequate mesh overlap can be obtained within the confines of the rectus sheath, laterally delineated by linea semilunaris, a repair without component separation is adequate. For complex patients with larger defects, beyond 10 cm, we believe the TAR approach should be utilized. Importantly, this also includes patients who are not candidates for anterior component separation such as those with subcostal or Chevron incisions, previous ACS, prior appendectomy incisions, or those with a history of abdominoplasty. Additionally, patients with uncommon hernia locations including large subxiphoid, parailiac, and suprapubic hernias may also be best suited for PCS via TAR.

The effectiveness of retromuscular hernia repair has been shown in many patient populations with widely different hernia presentations [10–13]. Only a few scenarios exist where TAR should not be employed; chief among this is a pairing of the technique with ACS during the initial operation. Concomitant anterior and posterior component separations will result in a destabilization of the lateral abdominal wall via a disconnection of the major components of linea semilunaris aside from the internal oblique. Interestingly, in the absence of optimal alternatives, use of the TAR procedure for recurrences after prior ACS can be performed with an understanding and acceptance of potential lateral abdominal wall laxity [14]. Other relative contraindications include previous dissection in the retromuscular plane including preperitoneal and/or retrorectus repairs, need for concurrent panniculectomy/abdominoplasty, and history of severe necrotizing pancreatitis due to scarring in the retroperitoneum.

30.3 Technical Description

As the TAR technique is effectively a modification/continuation of the retrorectus Rives–Stoppa repair, the technical description in this chapter is given in two parts: a description of the "pure" retrorectus-only Rives–Stoppa repair and the TAR technique as a separate continuation after the retrorectus dissection is completed.

30.3.1 Retrorectus Hernia Repair

Patients are placed in supine position and prepped widely from the nipples to mid-thigh and laterally to the posterior axillary lines. Use of Ioban Drape (3M, St. Paul, MN) to minimize the risks of mesh infection is recommended.

Most commonly, the operation begins with a midline laparotomy and adhesiolysis. Modifications such as elliptical incisions to encompass previous scars as well as all attenuated or ulcerated skin should be performed when necessary. Often in the morbidly obese with large midline hernias, excision of the umbilicus is performed to minimize postoperative wound morbidity. Adhesiolysis, especially of those to the lateral abdominal wall, is essential as these can limit myofascial medialization, cause peritoneal/posterior sheath tears during myofascial release/advancement, or increase the risk of injury to adherent bowel during retromuscular dissection. Lysis of inter-loop adhesions can be performed judiciously based on the patient's symptomatology. Complete inter-loop adhesiolysis is often unnecessary and serves only to increase operative time. Once adhesiolysis is completed, a countable white/blue towel is placed on top of the viscera with extension into the paracolic gutters, pelvis, above the liver, and towards the esophageal hiatus. Complete exclusion of the viscera from the immediate operative fields serves to protect the peritoneal contents during the hernia repair itself.

Once the peritoneal contents are isolated, attention is turned to the retrorectus dissection. Incision into the posterior sheath is made approximately 0.5–1 cm from the edge of the rectus muscle. It is important to identify the muscle either visually or by palpating the muscle belly. This step is critical in patients with large defects and associated loss of domain, where the rectus muscles are retracted laterally. Otherwise, the initial incision may be made incorrectly into the hernia sac, which if divided can result in entry into the subcutaneous plane rather than then retromuscular one. To further alleviate this risk, the initial incision should be attempted either above or below the hernia defect (if possible), where the rectus muscles are more near their native position. Once the muscle edge is identified however, the incision is carried deep until the muscle fibers are visualized clearly (Fig. 30.1). It is important to ensure the correct anatomic location prior to carrying the incision along the length of the rectus towards cephalad and caudad extremes.

Once the edge of the posterior rectus sheath is freed from the rectus muscle, constant tension should be utilized to facilitate development of the retrorectus space. This is achieved with a combination of Kocher clamps placed onto the muscle/anterior fascia with constant superior tension and Allis clamps, which are placed on the posterior rectus sheath so that tension may be applied perpendicularly towards the operating surgeon. These clamps should be moved along with the dissection as it progresses to maintain opposing tension. If further superior tension is needed for separation of the posterior sheath, Richardson retractors can be placed along the muscle belly with retraction up and towards the assistant. To develop the retrorectus space, a combination of blunt dissection and electrocautery can be used. Cautery is specifically used to divide the finer areolar tissue and to dissect the small perforating branches of the epigastric arteries, to keep them with the rectus muscle. The retrorectus space is developed towards the linea semilunaris, but importantly, just medial to this boundary as defined by the perforating neurovascular bundles (Fig. 30.2). The neurovascular struc-

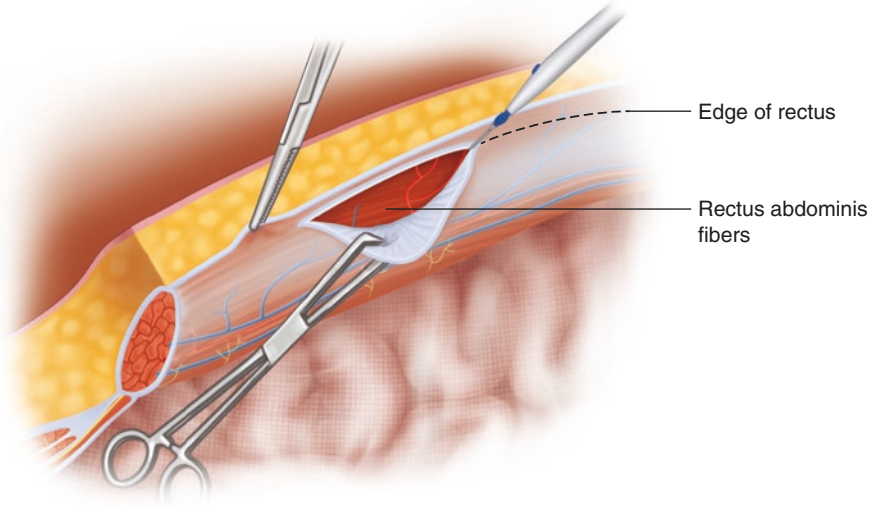

Fig. 30.1 Retrorectus dissection—following laparotomy and adhesiolysis, incision is made into the posterior rectus sheath approximately 0.5–1 cm from the edge of the muscle and carried deep until the muscle fibers are encountered. This incision is carried along the length of the rectus muscle towards cephalad and caudad extremes

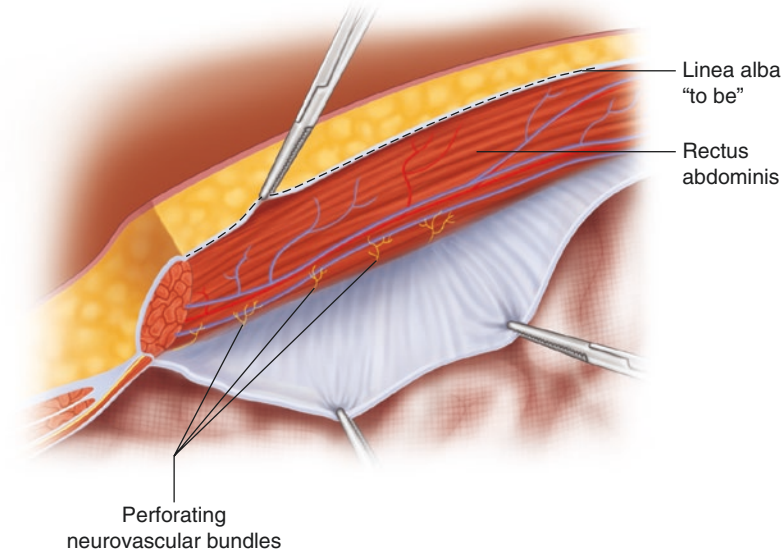

Fig. 30.2 Completed retrorectus dissection—the retrorectus space is developed towards linea semilunaris until just medial to the perforating neurovascular bundles to the rectus abdominis are encountered

tures to the recti emerge from the transversus abdominis plane after piercing the posterior lamina of the internal oblique aponeurosis. The cephalad extent of the dissection is the costal margin and may extend to the xiphoid process in the midline depending on the hernia. The caudal extent is defined by the space of Retzius bilaterally with exposure of the pubic symphysis and Cooper's ligaments (Fig. 30.3).

Once the retrorectus space is developed bilaterally, both leaflets of the posterior sheath can be closed with a running 2-0 braided absorbable suture. At this point, an appropriately sized mesh can be placed as a retromuscular sublay within the confines of both linea semilunaris. Once the mesh is in appropriate position, fixation can be performed with transfascial #1 absorbable monofilament suture using a suture-passer and to Cooper's ligaments bilaterally. The number of sutures used for fixation remains largely based on surgeon preference with some surgeons arguing for multiple points to distribute tension evenly, while others try to optimize the balance between fixation points and potential for pain.

Mesh selection is another point of ongoing discussion, though beyond the scope of this chapter. For clean cases, use of midweight, macroporous polypropylene mesh has been associated with favorable wound outcomes and excellent durability. However, the use of biologic meshes and absorbable synthetics has all been reported in the sublay plane. Once the mesh has been placed, closed suction drains are placed ventral to the mesh and the anterior rectus fascia is re-approximated with a running #1 absorbable monofilament suture. The remaining soft tissue should be closed in layers and any redundant or attenuated skin and soft tissue should be excised to minimize wound complications. If there are large subcutaneous pockets remaining following layered closure, additional subcutaneous drain(s) are utilized. The skin is closed with a running suture or staples.

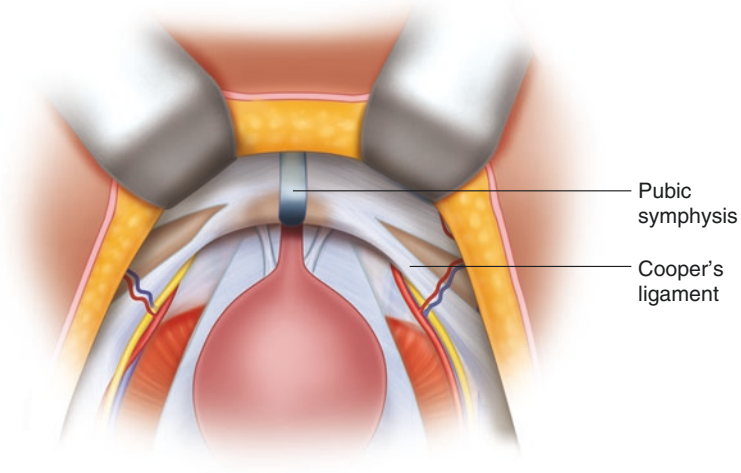

Fig. 30.3 Inferior retromuscular dissection—the space of Retzius is developed inferiorly, exposing the pubic symphysis and Cooper's ligaments bilaterally, which will be used for inferior mesh fixation

30.3.2 The Transversus Abdominis Release Procedure

The TAR procedure is a continuation/modification of the traditional retrorectus-only Rives–Stoppa repair. As such, its steps begin once the retrorectus dissection is completed. The dissection is begun with electrocautery and the ventral surface of the posterior sheath (the posterior lamina of the internal oblique) is scored just medial to the perforating neurovascular bundles along the length to cephalad and caudad extremes. This should expose the underlying transversus abdominis muscle and aponeurosis (Fig. 30.4). If this incision is made too medially, one may not encounter the muscle and instead create a fenestration in the peritoneum. Contrary to many textbooks and diagrams, in the cephalad aspect of the abdominal wall, the muscular component of transversus abdominis occurs medial to the linea semilunaris dorsal to the rectus muscle. To ensure safe entry into the retromuscular plane deep to the transversus abdominis, it is best to begin the dissection in the cephalad aspect of the abdominal wall, where the muscular component can be more easily identified and dissected off the underlying peritoneum and/or transversalis fascia. If this dissection is begun too caudally, it may be more difficult to separate the aponeurotic component of the transversus abdominis from the underlying layers, increasing the risk of inadvertent entry into wrong planes.

Once the muscle is identified in the cephalad region, the fibers are isolated with a right angle clamp and divided with cautery. This should be done carefully to ensure no inadvertent fenestrations are made in the underlying peritoneal layer. The medial edge of the muscle is divided along its length. In the cephalad portion, the costal margins denote the lateral extent of the dissection. The correct retromuscular plane is dorsal to the ribs. As the dissection progresses caudally, the muscle fibers become more and more lateral, giving rise to the aponeurotic component medially. Although this transition is quite variable, commonly at the level of the umbilicus, the muscular portion of the muscle is found lateral to the linea semilunaris. After complete division of the transversus, a right angle clamp is placed onto the lateral cut edge of the muscle to provide retraction and tension. Again, Allis clamps are placed onto the posterior sheath with perpendicular retraction towards the operating surgeon helps provide counter-traction. Then using a Kittner dissector the retromuscular plane is developed bluntly by separating the muscle from the underlying peritoneal layer. This dissection is relatively avascular and any significant bleeding should raise concern that entry into the intramuscular plane has been made. The preperitoneal/pre-transversalis plane can be developed laterally until the lateral edge of the psoas muscle is encountered, although this is not necessary for all cases (Fig. 30.5). The lateral edge of the psoas can be used to help define the space of Retzius and Bogros when moving in a lateral to medial manner. Alternatively, dissection can be done medial to lateral which involves dissection of Cooper's ligaments bilaterally and traveling laterally across the myopectineal orifice. During this dissection, care should be taken to identify neurovascular structures in order to prevent injury. Additionally, in the caudad portion, special attention should be paid to keep the transversalis fascia with the rectus muscle and not with the peritoneum. Staying in the purely preperitoneal plane rather than the pre-transversalis plane will avoid injury to the epigastric vessels. Finally, in female patients the round ligament should be identified and divided. In male patients, the spermatic cord should be isolated and dissected similar to a laparoscopic inguinal hernia repair.

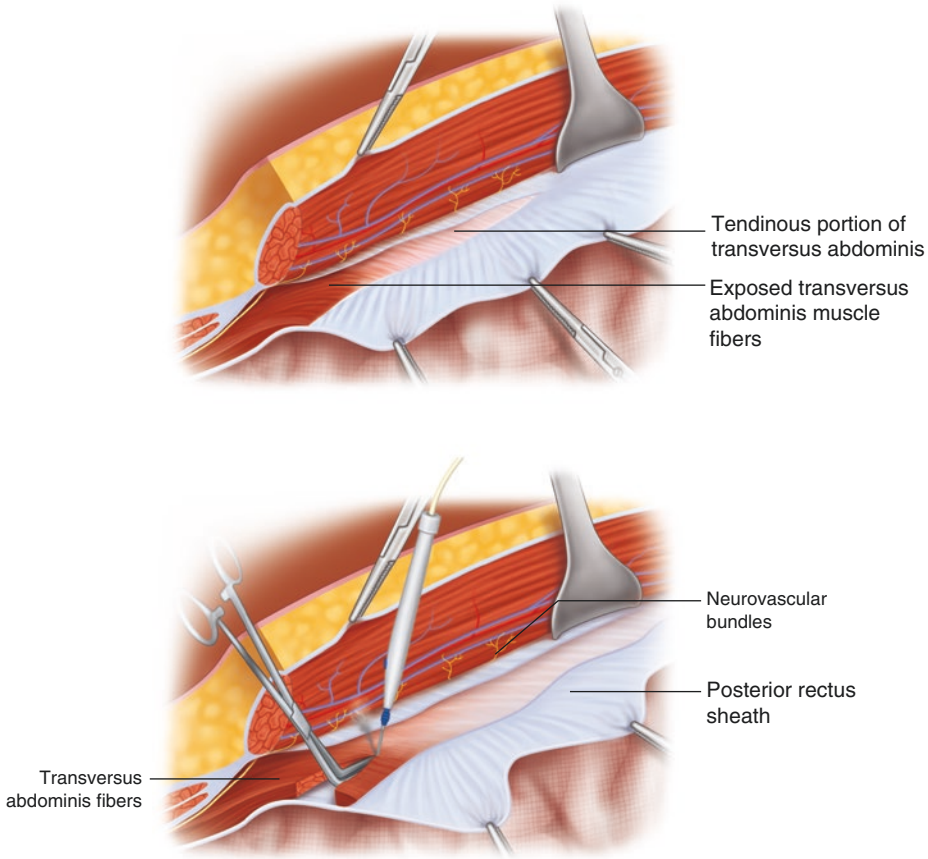

Fig. 30.4 Initiation of transversus abdominis release—incision is made into the ventral aspect of the posterior rectus sheath just medial to the perforating neurovascular bundles following retrorectus plane development. This will expose the transversus abdominis muscle fibers in the cephalad region and the tendinous aponeurotic portion more caudally

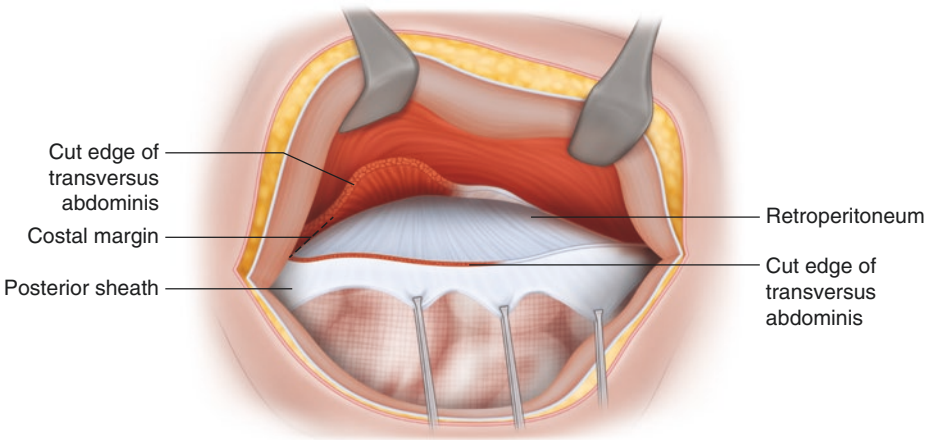

Fig. 30.5 Completed transversus abdominis release—once the transversus is divided along its length and dissected from the underlying transversalis fascia/peritoneum, significant myofascial medialization is obtained along with a large sublay plane for mesh placement

The superior dissection poses some unique challenges based on the extent of the hernia. For hernias with cephalad extension to the epigastric area, dissection must occur in the retrosternal space to ensure adequate mesh overlap. In these cases, the linea alba is divided to the extent of the xiphoid during laparotomy and retrorectus dissection extends into the retrosternal space. It is important to identify the subxiphoid fat pad during this dissection, as it is an indication of the correct plane/depth. In this situation the cephalad continuation of linea alba lies ventral to the dissection plane and the leaflets of the posterior sheath are rejoined to form a retrosternal sublay space (Fig. 30.6). Critically, this dissection involves division of the transversus abdominis in the subcostal plane and extension towards the midline. During this dissection, division of the muscle fibers of the diaphragm is possible as they interdigitate with the transversus abdominis. If care is not taken to spare the diaphragmatic fibers, entry into the thoracic cavity is possible, effectively creating an iatrogenic Morgagni hernia.

Hernias, which extend less cranially (to supra-umbilical area), require connection of the retrorectus planes across the midline below the subxiphoid region. This allows adequate sublay space for mesh placement, thus reducing the risk of recurrences superior to the mesh. To perform this dissection, the contribution of the posterior sheath to the linea alba is incised approximately 0.5–1 cm laterally on each side. The leaflets of the posterior sheath are re-approximated during closure, again with 2-0 braided absorbable suture.

Once component separation is completed superiorly, inferiorly, and laterally any fenestrations in the posterior rectus sheath are closed in a transverse manner, if possible, to alleviate tension, using a 2-0 braided absorbable suture. Closure of the posterior sheath is generally begun at

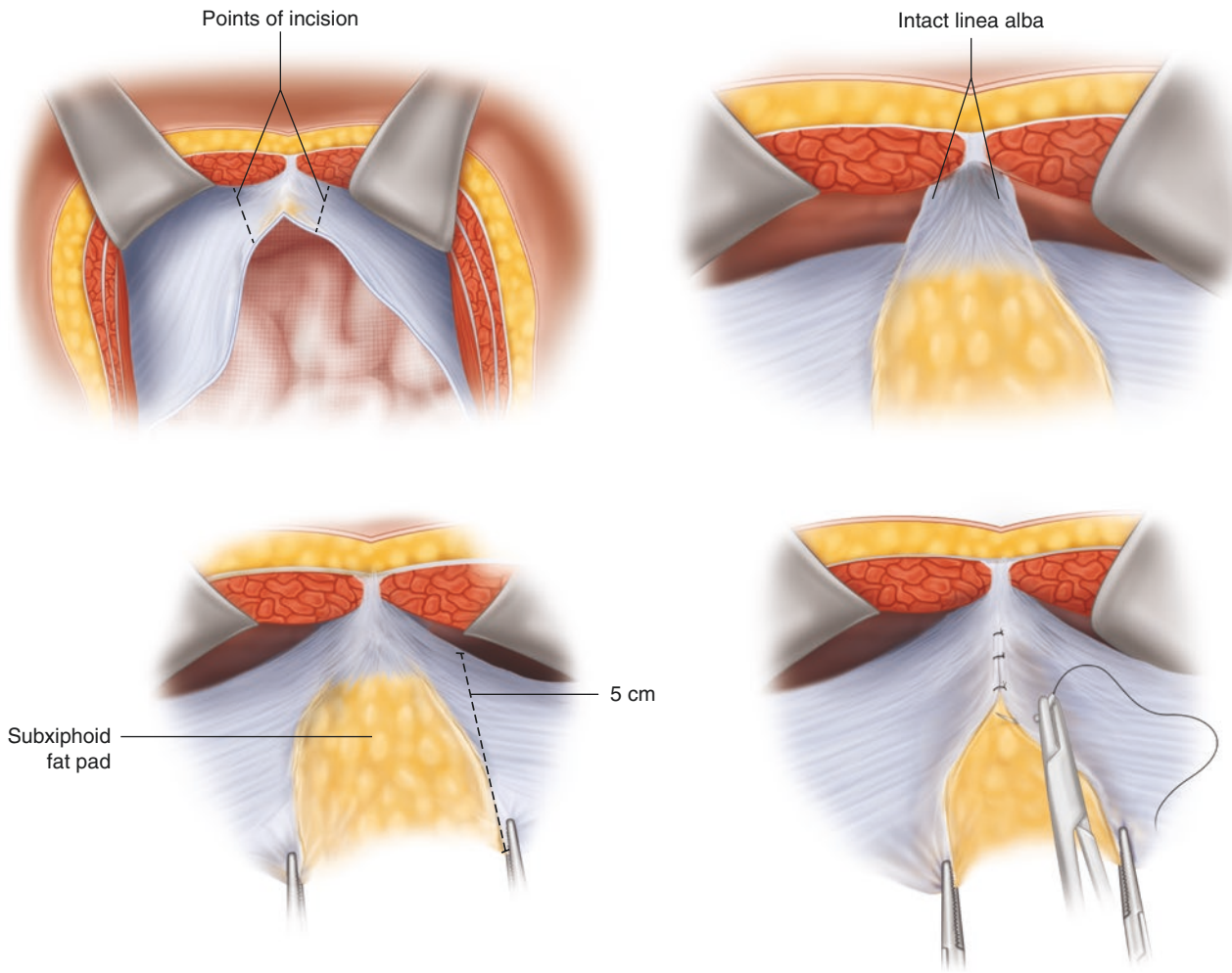

Fig. 30.6 Superior subxiphoid dissection—approaching the cephalad portion, the posterior rectus sheath is detached from the linea alba and dissection proceeds into the retrosternal space with identification of the subxiphoid fat pad. The leaflets of the posterior sheath are rejoined to recreate a sublay space in this region

cephalad and caudad ends separately, again using the 2-0 braided absorbable suture in a running fashion towards the middle. The closure is similar to the traditional Rives–Stoppa repair in this regard. In cases where myofascial advancement still fails to restore the posterior sheath, the patient's own native tissue or a bridging absorbable mesh may be utilized to span the gap. Every attempt should be made at complete restoration of the visceral sac as it reduces the risk of intraparietal hernias (between the layers of the abdominal wall) and prevents contact between peritoneal contents and the reinforcing mesh. If there is significant tension in closure of the anterior sheath despite TAR, interrupted figure-of-eight sutures can be used to close the anterior fascia. Similar to the retrorectus-only repair, large closed suction drains are placed above the mesh and the remaining soft tissue is closed in layers. The same principles of skin/soft-tissue excision are utilized following TAR and the skin is closed in a running fashion or with staples.

30.4 Outcomes

A single methodology for ventral hernia repair is not ideal for all patients or hernia presentations. Although the search for the "ideal" technique and mesh is ongoing, retrorectus hernia repair and TAR have proven efficacy in a wide variety of patients. The traditional Rives–Stoppa repair has a long proven record of accomplishment with multiple database studies evidencing recurrence rates between 7.3 and 12.1 % [15, 16]. Furthermore, the initial series of 42 patients undergoing TAR was published in 2012, with 24 % rate of wound events and only 4.7 % recurrences at a median follow-up of over 2 years [7]. Recently, in the series of 428 patients undergoing TAR with synthetic mesh reinforcement, we demonstrated 9.1 % surgical site infections (including contaminated repairs), and a 3.7 % recurrence rate with a mean follow-up of 31.5 months [10]. Furthermore, the use of TAR has been demonstrated in a variety of complex patient populations including hernias following trauma with open abdomens, kidney transplant patients, and patients requiring repair following previous anterior component separation with favorable results [12, 13, 17]. Retromuscular hernia repair with posterior component separation via TAR provides a safe and durable method for complex hernia repair.

Despite favorable clinical results, however, there is pertinent ongoing discussion on the potential deleterious effects of TAR. As the transversus abdominis is responsible for both maintenance of circumferential abdominal tension and generation of tension in the thoracolumbar fascia, concern about the effects on abdominal wall and spine stability were raised. Further investigation into the physiology of the abdominal wall following TAR demonstrated both rectus muscle hypertrophy and compensatory hypertrophy of the external and internal oblique muscles [18]. A clinical functional study utilizing dynamometry evidenced an improved core functionality following TAR as well [19]. Available data have clearly addressed some of the initial skepticism and concern regarding division of the transversus abdominis muscle.

30.5 Pearls

- Identifying the muscular component of transversus abdominis is easiest in the cephalad portion of the abdomen where it occurs medial to linea semilunaris. It is important to begin the dissection of transversus from here.
- Scoring the ventral aspect of the posterior rectus sheath (posterior lamina of the internal oblique) is important to keep the TAR in-line. Without the guiding mark initially, the temptation will be to extend further and further lateral to follow the muscle fibers.
- If during the division or dissection of transversus abdominis, an inadvertent hole is made in the posterior sheath, attempt should be made to go further lateral and around the defect.
- Although every effort should be made to avoid holes in posterior sheath/visceral sac, they may be already present from previous drain sites, surgery, or stoma sites. These can be repaired with figure-of-eight or running 2-0 braided absorbable suture.
- Once the dissection proceeds to the costal margin, it is important to stay in the subcostal space with confirmation by palpating the ribs above. If the plane ventral to the costal margin is entered, the error should be recognized and corrected.
- Following lateral dissection, the lateral edge of the psoas muscle can be used to facilitate identification and dissection of the space of Retzius and Bogros. Care must be taken to not "cross" the psoas muscle to avoid neurovascular and ureter injuries.

30.6 Conclusion

Retromuscular hernia repair has been widely recognized as a safe and durable method for complex hernia repair for over a decade. The transversus abdominis release technique has gained widespread popularity in the recent era due to its ability to address the limitations of the traditional Rives–Stoppa approach. Primarily, the TAR technique allows for significant medial myofascial advancement of both anterior and posterior fascial components and the rectus muscle complex. This medialization allows surgeons the ability to address very wide defects, including patients with loss of domain, with the ability to recreate the visceral sac and restore linea alba.

Furthermore, the creation of a large sublay space for mesh deployment provides a compartment away from the peritoneal contents as well as protection from the subcutaneous tissues and potentially high wound morbidity. The well-vascularized bilaminar fascial coverage provides a favorable environment for mesh integration allowing rapid ingrowth. Finally, large sublay plane offers the ability to provide wide mesh overlap of the entire visceral sac thus reducing the likelihood of recurrences. Importantly, the TAR technique can be employed to address many scenarios parastomal, flank, and subxiphoid defects. Both the retrorectus-only repair and the TAR technique are based on a tension-free tissue-based repair, combined with the ability to place a large sublay prosthetic. These factors in concert provide a reliable and versatile repair method for surgeons for use in even the most demanding scenarios.

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Anterior Component Separation Techniques

31

Kyle Stigall and John Scott Roth

31.1 Introduction

Incisional hernias are the most frequent complication occurring after abdominal surgery, occurring in up to 20 % of patients with predisposing factors including obesity, advanced age, pulmonary disease, steroid use, wound infection, and malnutrition [1, 2]. Albeit unusual, unrepaired hernias run the risk of incarceration, obstruction, or strangulation. As a result, more than 300,000 ventral hernia repairs are performed annually in the United States, representing one of the most common surgical procedures [3]. A multitude of techniques for hernia repair have been described involving both sutured closure and prosthetic mesh materials. In general, a goal of most repairs is to obtain fascial opposition; however, in circumstances with limited tissue elasticity or large fascial defects, primary closure may not be feasible and advanced surgical procedures, such as component separation, are required [4].

Principles of ventral hernia repair include patient optimization, judicious tissue dissection, and fascial defect closure with the use of prosthetic materials for reinforcement [5]. Incisional hernia repair without mesh has unacceptable results with recurrences in more than 50 % of patients while the use of mesh may reduce recurrence rates by nearly 50 % [6]. While a mesh herniorrhaphy alone is appropriate in the majority, patients with complex hernias often require local tissue advancement to augment and restore the abdominal wall successfully. This requires reestablishment of physiologic abdominal wall tension and dynamics, allowing improved wound healing and decreased ischemic complications [1–3, 5]. The component separation technique is a surgical procedure capable of restoring these characteristics [7]. Component separation technique allows for closure of the ventral abdominal wall while maintaining physiological tension, innervation, and vascularization [3]. The procedure results in a repair best mimicking physiological abdominal wall dynamics [5].

Component separation technique, also known as separation of parts, relies on physical characteristics of the abdominal wall to increase mobility. The abdominal wall is composed of overlapping muscle layers able to be separated while maintaining vascularization and innervation. By dissecting out muscle layers, the mobilization of individual units becomes greater than the mobilization of the unit as a whole [8]. This allows for greater advancement of the abdominal wall and improved approximation of each side [3, 8]. The relatively avascular plane located between the external and internal oblique makes this separation possible, and a total of 10 cm of advancement on each side can be obtained. However, the internal oblique and transversus abdominis muscle should not be separated due to the segmental neurovascular bundles of the rectus muscles and the sensory branches of the middle and lower abdomen, groin, and scrotum located in that plane [8].

Ideally, mobilization and approximation of the rectus-internal oblique-transversus abdominis flap will allow for primary facial closure. In giant ventral hernias, however, component separation technique can be insufficient to completely close the defect. In such cases, bridging mesh may be required, although this is unusual. While not ideal, component separation with bridging provides more reliable hernia closure than bridged repair alone [5]. The adjunct of the component separation will further minimize the size of the defect and result in a smaller area for the bridging mesh. However, even when primary fascial closure is obtained, mesh reinforcement of the abdominal wall is still advised [3, 5]. The mesh may be positioned to reinforce not only the midline closure but also any potential weaknesses resulting in division of the external oblique muscle [9]. Thus, by advancing the abdominal wall and reinforcing with a prosthetic mesh,

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_31

the abdominal wall radius is decreased and the thickness of the abdominal wall is increased [5]. This aids in limiting recurrence based on the principles of LaPlace's law (abdominal wall tension is proportional to wall radius and inversely proportional to wall thickness) [3].

Since the time of the landmark publication of the component separation technique by Ramirez et al. [8], numerous modifications have been described. The three main component separation techniques in existence today are the open anterior component separation technique, the perforator preserving (or sparing) technique, and the endoscopic technique. In each procedure, the goal is to separate abdominal muscle layers to achieve greater wall mobility. The differences lie in the methods used to achieve that end with associated reduction in wound complications through avoidance of undermining skin flaps. Still, each technique remains relevant, as each technique may be best suited for individualized patient scenarios.

31.2 Open Anterior Components Separation Technique

31.2.1 Overview

Ramirez et al. [8] initially described the dissection of the abdominal wall into components for mobilization of the rectus abdominis complex to allow for closure of complex abdominal wall defects. The procedure was hailed as the solution to high recurrence rates seen in previous procedures. However, the technique quickly fell out of favor due to high rates of surgical site occurrences including seroma, hematoma, and infection [3]. A recent resurgence of the open component separation technique has occurred due to an increasing interest in restoring abdominal wall function, achieving physiological tension, and maintaining abdominal wall dynamics, which are characteristics achieved utilizing component separation techniques [7].

The Ramirez component separation technique is frequently utilized in the repair of complex abdominal wall hernias due to the relatively short learning curve associated with the technique [7]. Reported indications for the Ramirez component separation technique include high-risk elderly populations, patients with a history of multiple prior abdominal surgeries, and large abdominal wall defects where maximal advancement is required [1, 2, 4, 5, 10]. The Ramirez component separation technique has been widely reported and provides for maximal abdominal wall advancement through the creation of large undermining skin flaps, separation of the posterior rectus sheath from the rectus abdominis muscle, and open separation of the external oblique from the underlying internal oblique muscle. Each component of the operation results in increasing advancement of the abdominal wall, and the combination of each of the three elements when performed bilaterally may allow for closure of abdominal wall defects nearly 20 cm in width.

31.2.2 Evolution

Prior to the initial description of the component separation technique, ventral hernias were repaired by advancing the abdominal wall as a solitary unit. When closure was not feasible, options included placement of a prosthetic mesh to bridge the defect, skin closure alone over the defect, or utilization of a graft or flap. Bridging mesh was associated with frequent complications due to mesh extrusion [4]. The use of flaps was associated with additional donor site morbidity. The component separation technique significantly reduced hernia recurrence rates while alleviating the need for remote tissue transfer or bridged mesh implantation [8]. Over the past three decades, the component separation technique has remained relatively unaltered except for the more recent introduction of the use of a prosthetic mesh reinforcement which may be placed as an onlay, sublay, or intraperitoneal underlay [3–5].

31.2.3 Technique

The technique for component separation hernia repair commences in a manner similar to a ventral hernia repair, generally through a midline laparotomy incision, although a transverse abdominal incision may also be employed. The abdominal cavity is entered and the viscera are dissected from the posterior abdominal wall. The first step involves the creation of skin flaps from the anterior abdominal wall musculature (Fig. 31.1). The skin and subcutaneous tissues are dissected from the anterior rectus sheath and the external oblique to the approximate level of the anterior axillary line (Fig. 31.2). Dissection is extended laterally to a distance several centimeters lateral to the linea semilunaris laterally, cranially to a distance at least 5 cm above the costal margin, and inferiorly to the level of the inguinal ligament. The creation of these large undermining skin flaps will result in several centimeters of abdominal wall advancement. Next, the rectus abdominis muscle is separated from the posterior rectus sheath, resulting in elongation of the rectus abdominis muscle. This is achieved by incising the posterior rectus sheath 1 cm medial to its insertion into the linea alba. The use of Kocher clamps on the linea alba is often helpful to provide traction to the abdominal wall musculature. Once the posterior rectus is incised, the rectus abdominis muscle may be identified anterior the posterior rectus sheath. The posterior rectus sheath incision is extended to the level of the costal margin superiorly and inferiorly to the pubic symphysis.

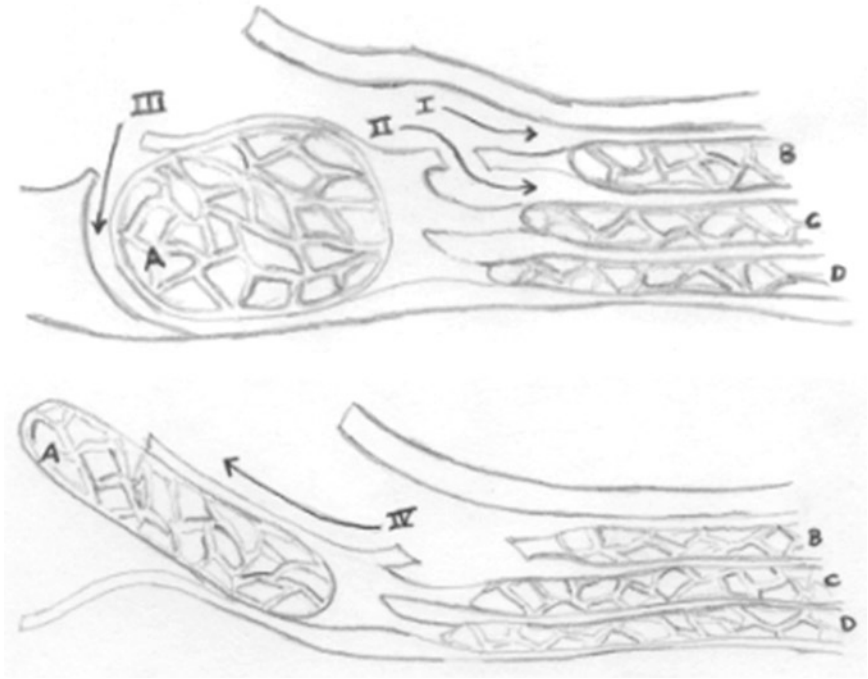

Fig. 31.1 Open component separation technique. *Top*: (*I*) separation of skin and subcutaneous tissue. (*II*) Transection of external oblique aponeurosis and dissection of external oblique from internal oblique. (*III*) Separation posterior sheath from rectus abdominis muscle. (*IV*) Advancement towards midline up to 10 cm. *Bottom*: (*A*) rectus abdominis muscle. (*B*) External oblique. (*C*) Internal oblique. (*D*) Transversus abdominis

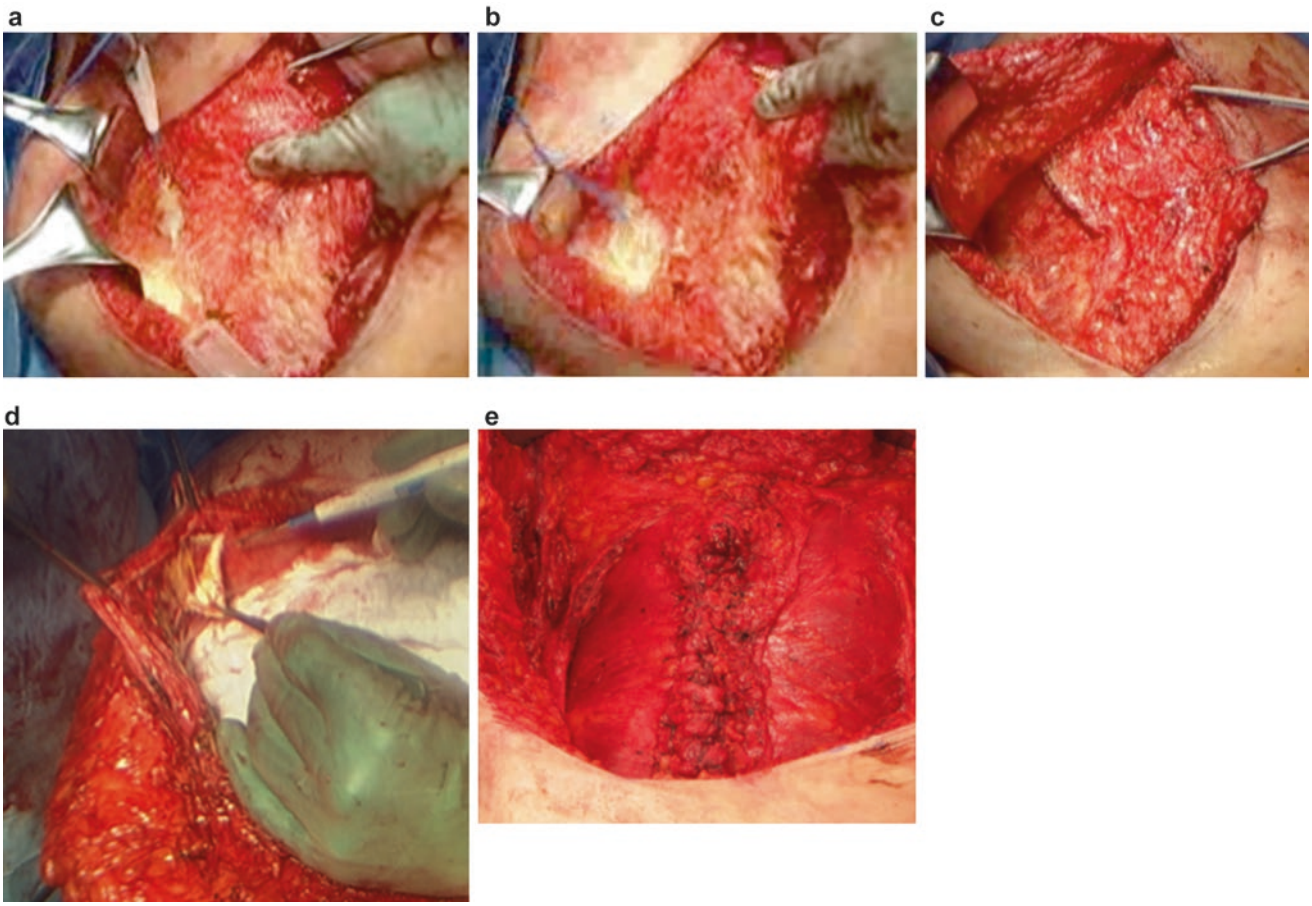

Fig. 31.2 Open component separation. (**a**) Division of the external oblique aponeurosis lateral to the linea semilunaris. (**b**) Internal oblique aponeurosis visualized below divided external oblique. (**c**) Completed external oblique division with advancement of the rectus abdominis complex. (**d**) Dissection of posterior rectus sheath from rectus abdominis complex. (**e**) Abdominal closure

Laterally, the posterior rectus sheath is dissected from the rectus abdominis muscle until the neurovascular bundles innervating the rectus muscle are encountered at the lateral aspect of the compartment. Preservation of these segmental neurovascular bundles is essential to preserve function of the rectus muscle, although occasional sacrifice of a single segmental nerve will not result in significant dysfunction. This posterior rectus sheath dissection may result in significant advancement of the abdominal wall. However, in the event of large defects or excessive tension on the midline following this maneuver, the external oblique aponeurosis may be divided for maximal release. Division of the external oblique aponeurosis is accomplished by dividing the external oblique at least 2 cm lateral to the linea semilunaris. The inferomedially oriented fibers of the external oblique muscle are a helpful landmark to identify the junction of the muscular and aponeurotic portions of the external oblique. Medially, the aponeurosis of the external oblique fuses with the internal oblique aponeurosis and transversus abdominis aponeurosis (below the arcuate line) to form the linea semilunaris. Division of the linea semilunaris may result in significant abdominal wall deformity and should be avoided.

Division of the external oblique aponeurosis is performed at the junction of the muscular and aponeurotic portion of the muscle to prevent injury to the linea semilunaris. The incision is extended inferiorly to the inguinal ligament and superiorly to a distance 5 cm above the costal margin. The space between the external oblique muscle and the underlying internal oblique muscle is widely separated to obtain maximal advancement. This space is devoid of both nerves and vasculature and is readily dissected with blunt dissection. Dissection of this space will result in significantly more abdominal wall advancement than division of the external oblique aponeurosis without this associated dissection. This dissection creates a "sliding myofascial flap" consisting of rectus abdominis muscle, internal oblique muscle, and transversus abdominis muscles.

Cephalad to the costal margin, where the rib cage protects against herniation, the lateral aspect of the rectus muscle is released to allow mobilization from the chest wall. Continuity with pectoralis major muscle is kept intact by preservation of the overlying fascial attachments allowing for continuation of the pectorals with the rectus muscle. This is referred to as the "rectopectoralis flap" and facilitates closure of epigastric defects.

Following dissection and separation of the abdominal wall into its components, the abdominal wall is closed by approximating the left and right rectus-internal oblique-transversus muscle complexes. Typically, a running slowly absorbable suture is utilized, although interrupted closure may be considered for more challenging closures. The lateral edges of the divided external oblique muscles retract laterally. Nonviable skin is resected (which often includes the umbilicus), and subcutaneous closed suction drains are placed in the subcutaneous space followed by skin closure [9].

31.2.4 Outcomes

The outcomes for the open anterior compartment separation technique demonstrate significant improvements over prior ventral hernia repair techniques. Prior outcomes of tensor fascia latae flap translocation and closure resulted in recurrence rates as high as 42 % compared to the 16 % recurrence seen in open component separation. Still, the component separation technique has higher recurrence rates compared to its subsequent evolutionary techniques, the perforating preserving and endoscopic component separation procedures which are discussed later. Furthermore, the component separation technique results in high rates of surgical site occurrences when compared to perforator preserving techniques, endoscopic techniques, and other traditional hernia repair techniques [3, 5, 9]. Surgical site occurrences associated with component separation technique include seroma, abscess, hematoma, cellulitis, surgical site infection, and skin necrosis [5, 9]. Although open component separation technique is often associated with longer hospital stays, operating room times are generally shorter and there is no need for any specialized equipment compared to other techniques, unlike laparoscopic approaches [10].

31.2.5 Challenges and Pitfalls

The open component separation technique requires creation of large lipocutaneous flaps, resulting in division of the epigastric perforating vessels (providing vascularity to the central abdominal wall skin), creation of dead space, and wide undermining of subcutaneous tissue [4, 11]. While this may be well tolerated in select patients, this may be attributed to the surgical site complication rate seen with the technique. The loss of epigastric perforating vessels leave skin flaps vascularized by only the intercostal arteries and branches of the pudendal artery [9]. This co-lateral flow may be insufficient to maintain viability, resulting in skin necrosis. Other challenges to the procedure include the risk of lateral herniation. Caution while dissecting the superficial layer of internal oblique fascia is paramount as deep dissection can damage segmental innervation of the rectus abdominal muscle or injure Spigelian fascia, increasing the risk for incisional complications and lateral hernias [10, 11]. Despite drawbacks, the open component separation technique offers many advantages and allows for a robust abdominal wall closure in appropriately selected patients.

31.3 Perforator Preserving Component Separation Technique

31.3.1 Overview

The perforator preserving open component separation technique evolved as a result of the wound morbidity which occurred in patients undergoing the open anterior approach. During open component separation, subcutaneous tissues are dissected laterally to reach the aponeurosis of the external oblique muscle. This widely dissected lipocutaneous flap extending from costal margin to pubic bone relies on the intercostal arteries for vascularity. Patients with compromised vascularity to the abdominal wall from prior retroperitoneal incisions, obesity, or vascular disease may be more likely to develop postoperative ischemic wound complications from a traditional anterior component separation. The perforating preserving technique improves upon the open method by reducing subcutaneous dead space and avoiding transection of perforator vessels [12]. In the perforating preserving component separation technique, first presented by Maas et al. [13] and modified by Saulis and Dumanian [14] and later Butler and Campbell [12], the epigastric perforator vessels are salvaged by avoiding the 3 cm radius around the umbilicus. The perforating vessels which supply the anterior abdominal wall skin are typically located in the periumbilical region and arising from the deep epigastric vessels. Maintaining these perforating vessels helps preserve vascularity to the lipocutaneous flap. The procedure optimizes pulsatile blood flow to the abdominal wall skin, thus improving wound healing without compromising the benefits of the procedure [14].

31.3.2 Evolution

As first described, the perforator preserving technique was performed through separate transverse incisions placed on the lateral abdominal wall [13]. This incision was made through skin, subcutaneous tissues, and the external oblique fascia to expose the space between the internal and external oblique muscles (Fig. 31.3). A balloon dissector is placed below the external oblique muscle and above the internal oblique muscle to dissect this "inter-oblique" space. Following removal of the balloon, under video-endoscopic control, the external oblique aponeurosis is incised lateral to the linea semilunaris extending from the inguinal ligament to the costal margin. This results in a well-vascularized compound flap that can be advanced to the midline. This technique requires the use of balloon dissectors and video-endoscopic equipment to expose the external oblique muscle and aponeurosis through this 2–4 cm lateral incision.

Numerous other techniques have been developed since Maas' initial description of an endoscopically assisted component separation technique [12, 14]. Many of these procedures involve counter-incisions on the lateral abdominal wall to dissect and expose the semilunar line and lateral abdominal wall. In 2011, Butler and Campbell described minimally invasive component separation with inlay bioprosthetic mesh (MICSIB). This technique involves creation of lateral tunnels on either side of the rectus sheath performed through the midline laparotomy to avoid counter incisions while also allowing implantation of bioprosthetic mesh [12]. This procedure limits incisions into the abdominal wall while increasing the strength of repair with prosthetic mesh placement.

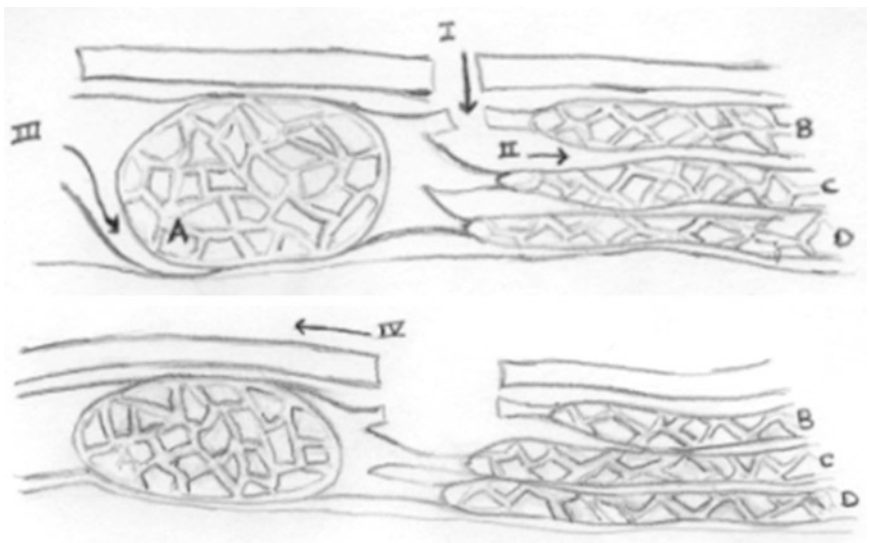

Fig. 31.3 Minimally invasive separation technique. *Top*: (*I*) incision through skin, subcutaneous tissue, and external oblique aponeurosis. (*II*) Dissection of external oblique from internal oblique. (*III*) Separation of posterior sheath from rectus abdominis muscle. (*IV*) Advancement towards midline up to 10 cm. *Bottom*: (*A*) Rectus abdominis muscle. (*B*) External oblique. (*C*) Internal oblique. (*D*) Transversus abdominis

31.3.3 Technique

The technique for a perforator preserving component separation begins similarly to an open component separation by performing a laparotomy and lysing adhesions between the viscera and abdominal wall. The skin and subcutaneous fat are then dissected off the anterior rectus fascia to clearly identify the edge of the rectus muscles at the semilunar line. Just lateral and parallel to the semilunar lines, over the external oblique fascia, a subcutaneous pocket is bluntly created superiorly and inferiorly. A second access to the semilunar line is then created inferior to the periumbilical rectus abdominis perforators, just above the suprapubic area. This is accomplished in the same manner by dissecting subcutaneous fat off the rectus fascia until the linea semilunaris is identified. The inferior access site is then connected with the superior access site by creating a subcutaneous tunnel lateral to the periumbilical rectus abdominis perforator vessels. The external oblique aponeurosis is then incised lateral to the linea semilunaris to access the space between the internal and external oblique muscles. A Yankauer suction is introduced into the inter-oblique space and is utilized to retract the linea semilunaris medially, thus allowing for division of the external oblique aponeurosis laterally. Once isolated, the length of the external oblique muscle and aponeurosis is incised from above the costal margin to the inguinal ligament. The incised lateral external oblique edge is then bluntly separated from the internal oblique to allow maximal medial advancement of the rectus musculature. Following advancement, the fascia is closed. Butler and Campbell [12] described fascial closure with interrupted braided nylon sutures, placement of three closed-suction drains, debridement of redundant or ischemic skin, and skin closure. Alternative closure techniques include slowly resorbable or permanent monofilament sutures placed in an interrupted or running fashion.

31.3.4 Outcomes

There are limited studies comparing the perforator preserving component separation technique to either the open or endoscopic techniques. However, it is clear the perforator preserving technique lowers surgical site occurrences when compared to open component separation. In one study, the perforator preserving method had a 27 % wound complication rate compared to the 52 % wound complication rate associated with the open procedure [15]. This can likely be attributed to successful preservation of the epigastric perforating vessels and the subsequent reduction of skin necrosis. However, the creation of the subcutaneous tunnels may be technically difficult due to the limited exposure and visualization of the external oblique. But the simplicity of the dissection, which requires only a retractor and a Yankauer suction tip to expose and divide the external oblique, adds to the appeal of this approach. The operative time required to perform the dissection may be increased with a perforator preserving component separation relative to an open component separation, but the reduction in postoperative complications more than makes up for the modest increase in intra-operative time [10].

While adverse outcomes for the perforating preserving technique are decreased compared to the open compartment separation technique, the learning curve is steep. Variability in outcomes can be anticipated as surgeons develop experience with the technique [7]. An additional challenge pertains to resection of redundant abdominal wall skin following closure of the rectus muscles in the midline. Prior surgical scars and redundant skin is typically resected, but retention of the periumbilical perforators may be difficult while excising the lipocutaneous tissues of the abdominal wall. However, left unremoved, the redundant abdominal wall skin may result in large subcutaneous seromas within the undermined skin flaps. An assessment of the risk of devascularization of the residual abdominal wall relative to the risk of postoperative seroma should be made when determining the extent of skin resection.

31.3.5 Challenges and Pitfalls

The perforator preserving technique can be challenging to perform. Creating tunnels through the midline requires a generous tunnel to provide adequate visualization of the external oblique aponeurosis. Placement of additional incisions on the lateral abdominal wall may facilitate this exposure in obese patients or in cases with significant retraction of the lateral abdominal wall musculature.

There are typically four or five pairs of perforating vessels that are located in the periumbilical region. Direct dissection and visualization of the perforating vessels should generally be avoided so as to avoid inadvertent injury, traction injury, or thrombosis. It is advisable to avoid dissection of the subcutaneous tissues for several centimeters above and below the umbilicus. While the majority of vessels are located in the periumbilical location, occasionally additional vessels are encountered. Any dominant vessel should be preserved when feasible. The use of perfusion scanning technology may be a useful adjunct to help identify vascularity and ensure a viable skin flap following completion of the dissection.

31.4 Endoscopic Components Separation Technique

31.4.1 Overview

In the 25 years since Ramirez et al. [8] introduced the open component separation technique, the technique has evolved significantly in an effort to reduce wound morbidity while

maintaining the benefits of myofascial advancement for abdominal wall closure. The endoscopic component separation procedure has emerged as an advantageous approach to open component separation for repair of ventral hernias due to the reduced morbidity with comparable hernia recurrence rates. The endoscopic component separation technique is an easily learned form of perforator preserving technique that facilitates division of the external oblique aponeurosis under direct visualization utilizing video-endoscopic equipment.

31.4.2 Evolution

The earliest descriptions of ventral hernia repair by means of an endoscopic component separation date back to 2000 [16]. The first report detailed a technique utilizing a subcutaneous balloon dissector placed in the mid-axillary line which bluntly dissected the external oblique muscle and aponeurosis from the overlying soft tissues (Fig. 31.1). The aponeurosis was then fully divided lateral to the semilunar line with electrocautery from the costal margin to the level of the anterior superior iliac spine. This initial series reported a dramatic reduction in wound infection, seroma rates, and necrosis without impacting hernia recurrence rates. However, the technique was not widely adopted at that time. Building upon the endoscopic component separation technique of Maas et al. [17], refinements in the endoscopic component separation technique were subsequently reported which described the technique in the management of infected abdominal wall hernias [18]. In this description, an incision was made 1 cm below the costal margin with dissection of the abdominal wall to identify the external oblique muscle. Following division of the external oblique fibers, a balloon dissector was utilized to dissect the inter-oblique space (Fig. 31.2). Following removal of the balloon dissectors, additional trocars were placed into the inter-oblique space to accommodate division of the external oblique aponeurosis. This report detailed seven patients that underwent endoscopic component separation with minimal postoperative wound morbidity despite the complexity of the patient population and significantly contributed to the popularization of the procedure.

31.4.3 Technique

The endoscopic component separation technique may be utilized as an adjunct to both open and laparoscopic ventral hernia repair. The myofascial advancement of the rectus abdominis complex facilitates apposition and approximation of the midline fascia with reduced tension. Unlike many advanced laparoscopic operations, the endoscopic component separation technique is easily mastered with a relatively short learning curve.

Patients are positioned in the supine position with the arms tucked to facilitate exposure of the entire abdomen and lower thorax. Positioning is similar with both laparoscopic and open procedures. In open ventral hernia repair, the midline laparotomy and hernia dissection is performed prior to performing the endoscopic component separation. However, when endoscopic component separation is utilized during laparoscopic ventral hernia repair, the endoscopic release is generally performed prior to insufflation of the abdominal cavity as the lateral trocar placement utilized for laparoscopic hernia repair will result in carbon dioxide leaks which can limit distension of the lateral abdominal wall during the endoscopic component separation.

Endoscopic component separation (Figs. 31.4 and 31.5)

1. A 2 cm incision is made approximately 5 cm cephalad to the costal margin lateral to the linea semilunaris. This is typically located between the midclavicular and mid-axillary lines but should be modified based upon the hernia characteristics to ensure the incision overlies the external oblique. Placement of the incision medially may result in dissection of the rectus sheath.
2. Subcutaneous dissection is performed through the subcutaneous and Scarpa's fascia to identify the external oblique musculature. The external oblique is consistently muscular above the costal margin, which facilitates identification of the infero-medially oriented fibers. The external oblique fibers are dissected bluntly to expose the underlying fascia.
3. A balloon dissector is bluntly advanced through the dissected external oblique fibers and advanced parallel to the linea semilunaris toward the inguinal ligament. As the internal oblique muscle fibers insert directly into the four lowest ribs, the balloon dissector will enter the inter-oblique space as it is advanced below the costal margin. Advantages of this technique for initial port placement include the ease of identification of the external oblique muscle due to its muscular appearance and the counter resistance of the thoracic cage when dissecting through the abdominal wall and external oblique fibers.
4. The dissecting balloon is insufflated under direct video-endoscopic visualization. The external oblique fibers are clearly visualized creating the ceiling of the lateral abdominal compartment with the internal oblique muscle comprising the floor. This space dissects easily with minimal bleeding due to a paucity of vessels; the blood supply to these muscles enters laterally.
5. Following removal of the balloon dissector, a balloon tip trocar is inserted at the original incision site and carbon dioxide insufflation of the abdominal wall is performed to 12 mmHg.
6. One additional port is inserted in the lateral abdominal cavity at the anterior axillary line immediately below the costal margin. This port is then utilized for division of the external oblique aponeurosis.

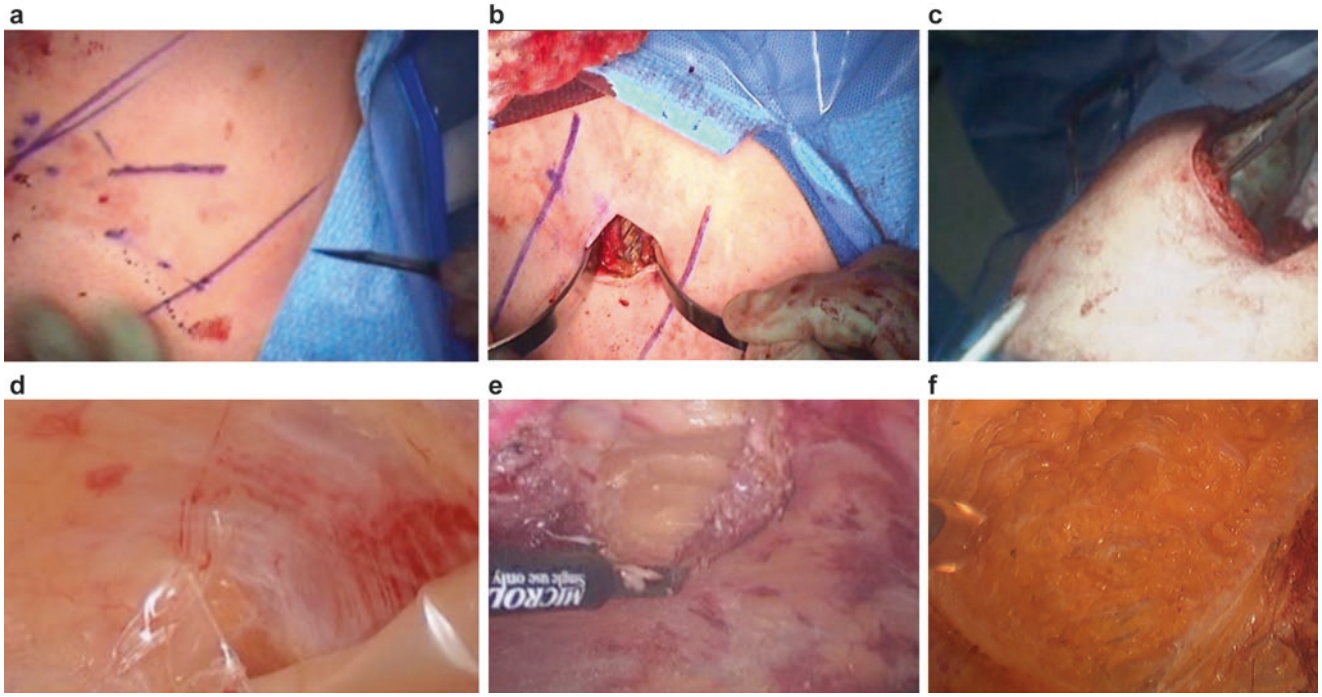

Fig. 31.4 Endoscopic component separation technique. (**a**) Left-side incision located 5 cm cephalad to costal margin lateral to the linea semilunaris. (**b**) Exposure of the external oblique muscular fibers. (**c**) Balloon dissector insertion. (**d**) Balloon dissection completed. (**e**) External oblique division. (**f**) Completed external oblique release

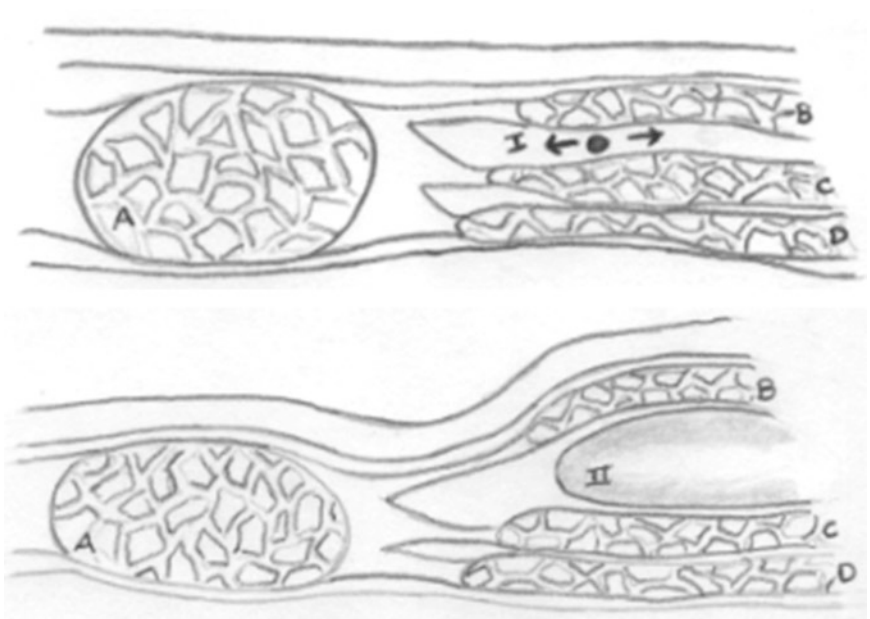

Fig. 31.5 *Top*: (*I*) blunt dissection of external oblique from internal oblique. (*II*) Insertion and insufflation of endoscopic component separation balloon. *Bottom*: (*A*) rectus abdominis muscle. (*B*) External oblique. (*C*) Internal oblique. (*D*) Transversus abdominis

7. The external oblique aponeurosis is divided with scissors or cautery beginning above the costal margin and is extended caudally to the inguinal ligament. Maximal advancement of the abdominal wall is obtained by dividing the overlying subcutaneous tissues and Scarpa's fascia following division of the external oblique aponeurosis.

The placement of two ports in the upper abdomen facilitates the endoscopic component separation by allowing the dissection to be performed unidirectionally, beginning above the costal margin and continuing in a caudal direction toward the pelvis. This port placement will avoid the challenges caused by instruments directed toward the video-endoscope resulting in a "mirror-image." Although additional ports may

be placed to facilitate dissection, in most cases, a two-port approach can be performed. Postoperative drains are generally not required in the lateral abdominal cavity.

31.4.4 Outcomes

Despite the frequency of ventral hernia repair, there is limited evidence regarding the efficacy of the endoscopic component separation technique. A systematic review of the literature by Feretis and Orchard [19] analyzed 33 publications, involving 220 patients, and found that endoscopic component separation has decreased postoperative wound complication rates compared to minimally invasive component separation/open component separation, with an increased risk of hernia recurrence when compared to minimally invasive component separation, although others have found no increased risk of hernia recurrence when comparing endoscopic component separation to open component separation [19]. Postoperative complications including pulmonary, renal, cardiac, and gastrointestinal problems have been reported to occur less commonly among endoscopic component separation procedures [16], and have been reported to improve overall quality of life. In one study, nearly all patients reported improvement in their preoperative scores regarding mental and general health perception, pain, vitality, and physical/social functioning when compared to the general population [20]. Endoscopic component separation has not only been associated with overall patient health benefits such as decreased scarring, preservation of anatomic structures and vascularity, as well as reduced postoperative pain. Endoscopic component separation costs when compared to open component separation are less despite the need for specialized equipment [21].

31.4.5 Challenges and Pitfalls

The endoscopic component separation technique is well suited for the repair of midline abdominal hernias. Although not a contraindication, prior transverse incisions increase the technical difficulty of performing an endoscopic component separation. Following endoscopic component separation, mesh placement is limited to either the retro-rectus space or the intraperitoneal location. Placement of a reinforcing mesh in the retro-rectus space does not reinforce the laterally released external oblique muscles. However, the intact internal oblique and transversus abdominis muscles are generally adequate to prevent lateral hernia bulges and hernias. Intraperitoneal mesh placement may also be performed, although retro-rectus mesh placement is generally associated with lower hernia recurrence rates [22]. We typically utilize endoscopic component separation as an adjunct to a Rives–Stoppa ventral hernia repair. The decision to perform an endoscopic component separation is based upon the degree of tension on the midline incision following dissection of the posterior rectus sheath from the rectus abdominis muscle, similar to initial reports by Ramirez et al. [8] in which the external oblique is divided following dissection of the retro-rectus space. Patients undergoing endoscopic component separation cannot undergo onlay mesh placement as this space has not been dissected whereas patients undergoing open component separation hernia repairs may undergo onlay mesh placement, thus reinforcing the divided external oblique muscles. There are no reports comparing outcomes following component separation hernia repairs specifically analyzing mesh location. Furthermore, patients with hernias located off-midline may be better suited for alternative hernia repair techniques as the endoscopic component separation is most advantageous for advancing the rectus complex toward the midline.

31.5 Conclusion

Ventral hernias are common and challenging for surgeons, frequently resulting in recurrences and complications. Component separation techniques are a useful adjunct to facilitate midline closure and create a dynamic abdominal wall repair at physiologic tension. Anterior component separation techniques have evolved significantly over recent decades with efforts to reduce wound morbidity. Although associated with a higher morbidity, the open component separation technique as initially described has utility in appropriately selected patients to maximally advance abdominal wall musculature. Although utilized less frequently than other techniques, the open component separation technique is useful in patients where skin flaps are not avoidable either as a result of the natural dissection of the hernia sac or in patients undergoing concomitant panniculectomy. Endoscopic and perforator preserving anterior component separation techniques result in similar long-term outcomes, albeit with reduced short-term morbidity. Surgeon experience and training as well as variability in patient populations cannot be overlooked when considering the best approach to hernia repair. Each repair technique requires extensive resources preoperatively, in the operating room, and postoperatively. As a result of the challenges associated with abdominal wall reconstruction, complex hernia repair patients are often managed in high volume centers with a special interest in hernias.

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Endoscopic Component Separation Techniques

32

Jorge Daes and David C. Chen

32.1 Background/Historical Perspective

Complex ventral hernias remain a challenging surgical problem with successful outcomes requiring a combination of techniques and tools, including tissue-based repairs, prosthetic reinforcement, fascial releases, and myofascial advancement flaps. The goal of abdominal wall reconstruction (AWR) is to provide a durable structural, functional, and cosmetic repair.

More recently, primary closure of defects has been considered an essential aspect of AWR because it attempts to recreate the anatomy and physiology of the abdominal wall while reducing dead space and its consequences [1, 2]. Ventral hernias with defects up to three can be repaired by simple primary closure, whereas for larger defects some type of tension-free reconstruction is advised. This can be accomplished using various muscle relaxation techniques, including surgical, pharmacological, and mechanical methods, with component separation (CS) techniques being the most common. Almost invariably, repair is reinforced with a mesh.

Anterior component separation (ACS) of parts was first introduced by Ramirez in 1990 as a method to reestablish the linea alba with autologous fascia [3]. This technique creates a myofascial advancement flap by partitioning one component of the redundant lateral musculature to enlarge and advance the abdominal wall, assisting in the primary closure of defects without undue tension. The external oblique aponeurosis is released lateral to the semilunar line, and the avascular intermuscular plane between the external and internal obliques is developed. If additional advancement is required, the posterior rectus sheath can be vertically divided and advanced. In general, 8–10 cm of unilateral advancement can be achieved enabling medialization of the rectus abdominis complexes and a tension-free or reduced tension closure. Recurrence rates of 5–30 % have been reported in the absence of mesh reinforcement, a respectable rate for complex abdominal wall hernias.

The major morbidity of open ACS techniques results from the creation of the lipocutaneous flaps. This dissection traditionally sacrifices the anterior perforator complexes, leading to potential flap ischemia/necrosis and the creation of large potential spaces that increase the risk of hematoma, seroma, and infectious complications. Modifications of open component separation result in the preservation of the periumbilical perforating vessels and the creation of smaller spaces thereby reducing wound complication rates [4].

Minimally invasive approaches have been formulated to minimize morbidities resulting from perforator loss and flap creation. Lowe and associates reported an open assisted subcutaneous endoscopic ACS using a balloon in 2000 allowing for incision of the external oblique aponeurosis from the subcutaneous plane [5]. Maas described a laparoscopic balloon-assisted subfascial approach in 2002 consisted of endoscopically performed dissection, with release through a small cutaneous counter incisions [6]. Rosen is credited with popularization of endoscopic ACS in 2007 as an adjunct to AWR in combination with mesh reinforcement [7]. Chen described a modification that simplified the transfascial approach by making the initial incision medial to the anterior superior spine and working cephalad with the help of an additional port, making it more ergonomic and easier to perform. Finally, Daes described in 2010 a totally endoscopic subcutaneous approach in which preoperative skin marking of the semilunar line under ultrasonic guidance precedes creation of a subcutaneous space with a balloon dissector and division

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_32

and undermining of the external oblique aponeurosis [8]. This modification imitates Ramirez approach and is ergonomic and familiar to surgeons.

32.2 Indications for ECS

1. As part of the totally laparoscopic abdominal wall reconstruction (AWR) together with endoscopic or transfascial closure of defects and the placement of a barrier underlay mesh or an unprotected sublay mesh. This has been the main indication for subcutaneous ECS in our group.
2. To facilitate an open AWR, especially for central defects not amenable to closure by tension-free primary repair. However, when performing a Rives procedure requiring mesh coverage of an area wider than the retrorectus space; posterior component separation-transversus abdominus release (PCS-TAR) is a better option.
3. When planning tension-free primary closure of ventral hernias during colostomy reversal, colon resection, or in other contaminated or infected fields, often without the use of mesh.
4. Endoscopic component separation (ECS) can be performed in the presence of a stoma without para-stomal hernias. In this case, ECS is performed lateral to the ostomy site without the need to relocate the stoma.
5. Finally, ECS can be performed to assist in the management of abdominal compartment syndrome.

32.3 Contraindications for ECS

1. Severe skin dystrophy requiring extensive resection or the creation of extensive flaps.
2. Defects that can be closed primarily without undue tension.
3. Defects disproportionally wider than longer.
4. Patients with noncompliant abdominal walls from multiple previous repairs/meshes. In these cases, an onlay or PCS-TAR may be more appropriate.
5. Patients who have undergone previous bilateral PCS-TAR. However, it is possible to use a PCS-TAR approach on one side (for stoma reversal) and an anterior CS on the other side.

32.4 Operative Steps

32.4.1 Preoperative Preparation

Skin preparation extends from the nipples to the upper thighs and should be laterally extended to beyond the posterior axillary lines. For clean operations, a single dose of a first-generation cephalosporin is administered during anesthetic induction. Urinary catheters are used in complex cases or when pelvic dissection is anticipated. Pneumatic compression devices are used in all patients. During clean contaminated or contaminated cases, ECS should be performed first.

32.4.2 Techniques of ECS

The three approaches to anterior ECS create exactly the same compound myofascial advancement flap. The subfascial approach has been used most extensively, followed by the modified subfascial approach and the more recently described subcutaneous ECS approach. The latter two approaches are considered more ergonomic and easier to perform because they imitate the traditional open technique. Moreover, they avoid the difficulty of dissecting in the costal area, they avoid operating in parallax, and they require only one additional trocar.

32.4.3 Operative Technique

32.4.3.1 Transfascial Approach

In this technique, the patient is placed in the supine position with both arms abducted. A 12-mm incision is made just below the tip of the eleventh rib using a S retractor. The subcutaneous tissues are bluntly divided, exposing the external oblique aponeurosis. The external oblique is sharply incised, exposing the internal oblique muscle. The potential space between the external and internal oblique aponeuroses is developed lateral to the semilunar line using a bilateral balloon dissector. A structural 12-mm balloon port is then placed and the space maintained with a CO_2 insufflation pressure of 12 mmHg. The areolar attachments are bluntly dissected under direct vision using a 10-mm 30° laparoscope. Two additional 5-mm ports are created, one at the level of the umbilicus on the posterior axillary line and another just above the inguinal ligament lateral to the rectus. This entire plane between the external and internal oblique muscles is dissected, extending from just above the costal margin to the inguinal ligament and from the semilunar line medially to the posterior axillary line laterally, where the oblique muscles meet the latissimus dorsi. Coagulating scissors are used for component separation, with the division of the external oblique aponeurosis released from the costal margin to the inguinal ligament. The external oblique muscle will be at the top of the screen, the internal oblique muscle at the bottom, and the semilunar line present medially. This process is repeated on the opposite side. Each of the lateral compartments is drained with a closed suction drain. A video of the technique can be found at https://www.youtube.com/watch?v=lKtKXDKIiRM.

32.4.3.2 Modified Subfascial Approach

An analogous transfascial endoscopic anterior component separation technique has been employed, using this same operative plane with equivalent release and a simplified operative approach. The external oblique aponeurosis is accessed 2 cm medially to the anterior superior iliac spine. In this location, the anatomy is easily recognized as the external oblique is less muscular and almost entirely aponeurotic. After making a 1-cm incision in the aponeurosis, a bilateral laparoscopic inguinal hernia balloon dissector is used to develop the plane in a similar fashion (Fig. 32.1). A structural 10-mm balloon port is placed, and CO_2 insufflation is initiated, to a pressure of 12 mmHg (Fig. 32.2). A single 5-mm port is inserted at the level of the umbilicus on the posterior axillary line. The areolar attachments between these muscle layers are dissected in similar fashion. Component separation is performed by incising the external oblique aponeurosis 2 cm lateral to the semilunar line. This release is continued well above the costal margin to the insertion of the external oblique on the ninth and tenth ribs. The inferior release from the port site to the inguinal ligament can be easily performed in an open fashion, using shears to divide the aponeurosis 2–3 cm to the inguinal ligament under direct visualization (Fig. 32.3). A closed suction drain is passed through the lateral 5-mm port and inserted into the intermuscular space. A video of the technique can be found at: https://www.dropbox.com/sh/6kri5u3ew2qoijg/AAAEHORMtofcfYgiw9OP_dMxa?dl=0&preview=Component+Separation+Project+Right+side.wmv.

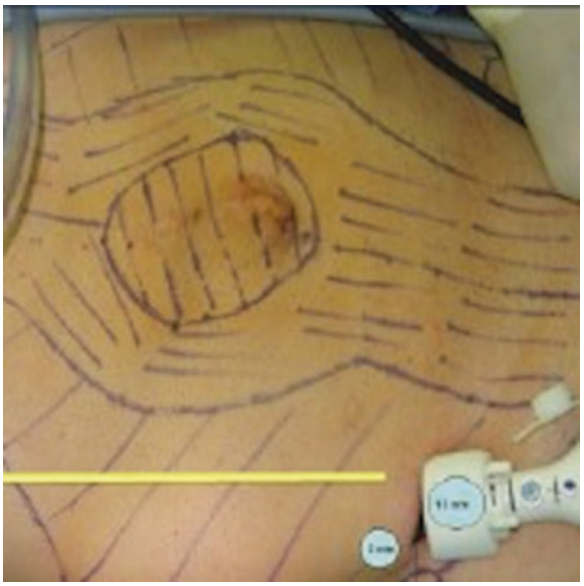

Fig. 32.1 External view with 12 mm balloon dissector placed medial to ASIS. Dissection proceed cephalad via 5 mm port

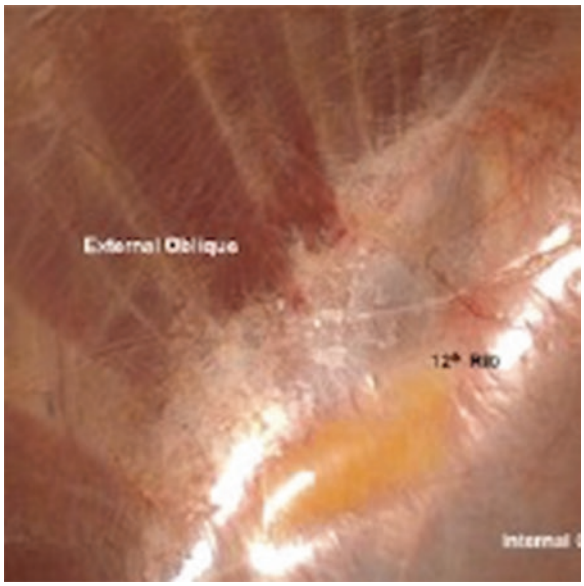

Fig. 32.2 View through dissecting balloon: external oblique above, internal oblique below

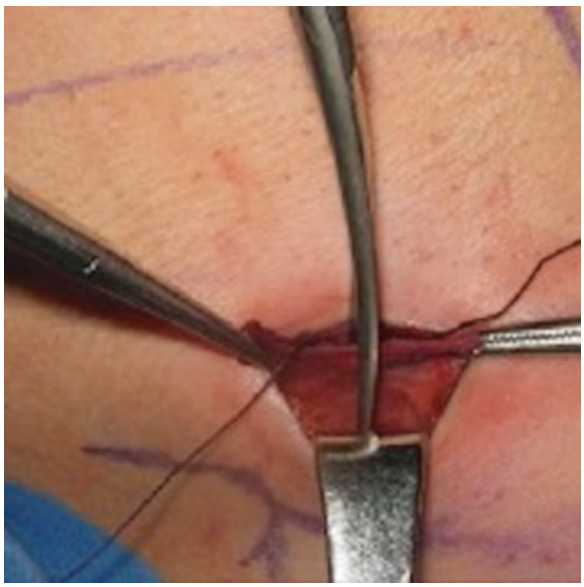

Fig. 32.3 External oblique release: operative view

32.4.3.3 Endoscopic Subcutaneous CS Approach

The patient is placed in a supine position with both arms tucked and padded at their sides. Under ultrasound guidance, the semilunar lines lateral to the rectus abdominis muscle are identified and marked on the skin bilaterally. Marking can be performed by the surgeon using portable ultrasound equipment immediately before skin preparation or can be performed by a radiologist in advance using indelible ink. A 12-mm incision is

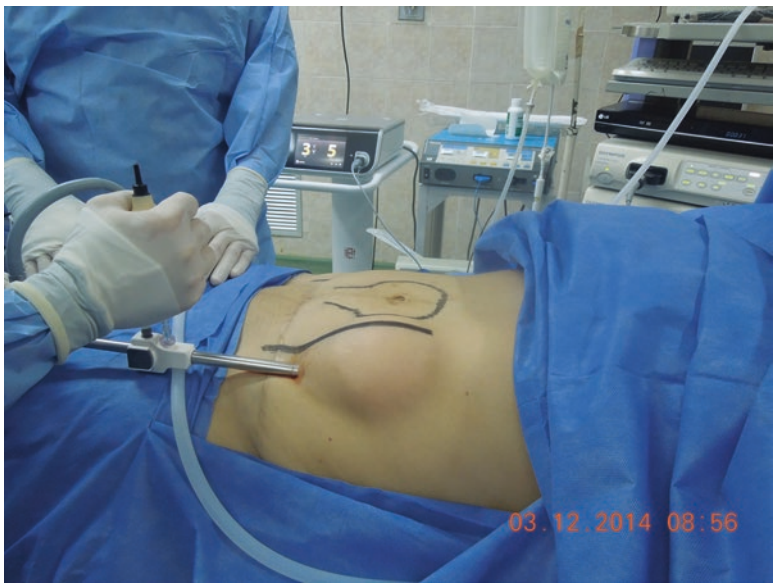

Fig. 32.4 Balloon dilatation of the subcutaneous space

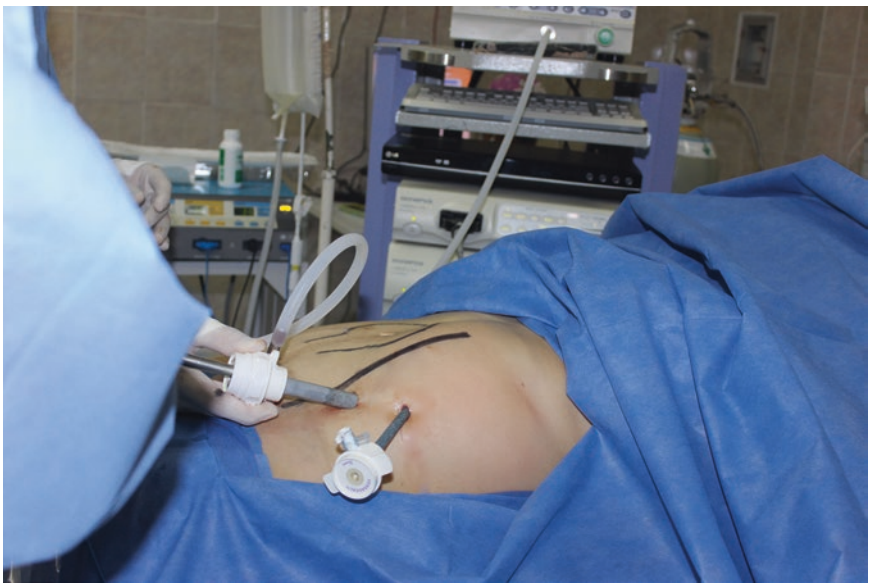

Fig. 32.5 Set up for a unilateral subcutaneous ECS. A 5 mm working port has been placed laterally and slightly superior to camera port

made in the lower lateral quadrant of the abdomen, lateral to the previously marked semilunar line. A balloon dissector is introduced and advanced over the anterior aponeurosis until the tip reaches the costal margin. The balloon is inflated at two levels using eight to ten pumps (Fig. 32.4). Occasionally, in obese or post-bariatric patients or in patients who have undergone previous abdominoplasty, a blunt rod (trocar interchanger) is used to create a subcutaneous tunnel over the fascia before introducing the balloon dissector. The balloon is then replaced by a simple 10–12-mm trocar. The space is maintained with CO_2 insufflation at a pressure of 10 mmHg. An additional 5-mm port is introduced at a position lateral and slightly superior to the camera port (Fig. 32.5). The external oblique aponeurosis is incised laterally to the left semilunar line, using the marking on the skin as a guide. Exposure of the fatty tissues without visualization of muscle ensures entry into the correct plane (Fig. 32.6). If muscle can be visualized at this level, either the rectus sheath medially or the muscular part of the external oblique laterally has been divided.

The external oblique aponeurosis is incised from this level to 4–6 cm above the costal margin. Above the costal margin, the aponeurosis changes to muscle and division should be performed carefully to avoid bleeding. An ultrasonic device may be useful for this purpose. Scissors and judiciously used cautery can be used to dissect under the external oblique muscle laterally in an avascular plane to provide maximum advancement (Fig. 32.7). With the camera turned downward, the incision in the external oblique muscle is continued below the camera port to include the inguinal ligament. Drains are not used routinely

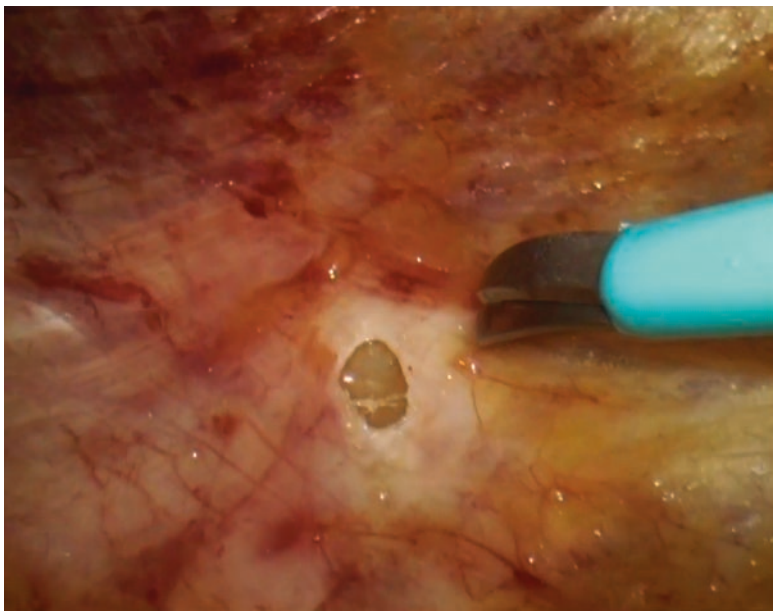

Fig. 32.6 The external oblique aponeurosis is incised laterally to the *left* semilunar line, using the marking on the skin as a guide

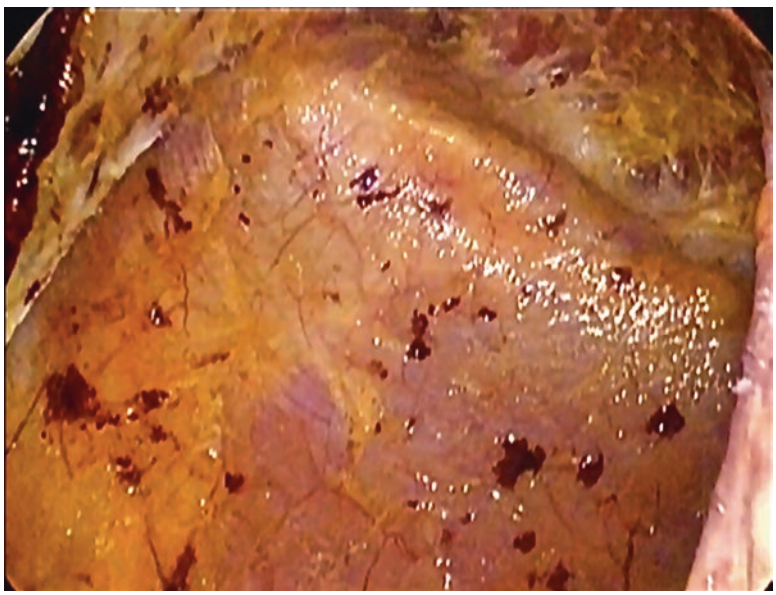

Fig. 32.7 Laparoscopic view of the completion of components separation from inguinal ligament to 5 cm over the costal margin

during this technique. The subcutaneous space is re-insufflated at the end of AWR to verify hemostasis. A video of the technique can be found at https://www.youtube.com/edit?video_id=4SpWz7U5uZ0&video_referrer=watch.

32.4.4 Pearls and Pitfalls

1. ECS is performed first when used as an adjunct to open AWR in clean contaminated and contaminated cases. It can also be undertaken first in totally laparoscopic AWR, when clinical examination and CT scanning provide thorough information; otherwise, laparoscopic exploration should be performed first.
2. Many times there is no need to perform a bilateral ECS. We have been able to laparoscopically close most defects 6–15 cm in width with a unilateral subcutaneous CS without dehiscence or abdominal wall asymmetry.
3. ECS can be used to repair any suitable lateral defect, not just central defects.
4. When defects are close to the semilunar line, ECS can be performed on the same side by dividing the external oblique muscle more laterally, thus avoiding the division of the semilunar line.
5. A vertical posterior rectus fascia release may be added to an ECS to assist in relieving tension on the closure.
6. To facilitate endoscopic closure of defects during laparoscopic AWR, a provisional single transfascial suture can

be placed at the midline of the defect to elongate the components and approximate the borders of the defect.
7. Mesh should be used to cover the ECS site, at least while surgeons are learning the procedure and when in doubt.

32.4.5 Evaluation of Results

A review of the literature involving endoscopic ACS found only 13 studies eligible for inclusion [9]. The authors concluded that, in general, these studies lacked selection criteria, long-term clinical follow-up, and a clear description of outcomes, and very few described follow-up imaging protocols. All were retrospective reviews. We recently submitted the first prospective evaluation of endoscopic subcutaneous ACS, with long-term clinical and imaging follow-up [10]. Twenty consecutive patients between 2012 and 2015 were evaluated. These patients had defects 6–15 cm in width, with length greater than size, and without skin dystrophy, loss of domain, or active infection. None of these patients had undergone multiple previous repairs/meshes and there was no reasonable suspicion of severe adhesions. Most ECSs were performed unilaterally as adjuncts to totally laparoscopic AWR (IPOM plus) and were followed clinically and by CT imaging for up to 38 months (mean, 21 months). In 19 of these patients, the repair remained sound clinically and by CT imaging, whereas one patient had a small limited disruption well protected by the underlying mesh. In eight patients, in which the area was not covered by mesh, there was no defect at the CS site. Morbidity was low, with no patient experiencing surgical site infection (SSI) or mesh-related complications. Cosmetic results were excellent; in particular, despite almost all ECSs being unilateral, we did not observe abdominal wall asymmetry and the degree of patient satisfaction was high.

32.5 Conclusion

The unique presentation of complex hernias requires a wide range of repair options. Posterior component separation via a transversus abdominis muscle release has increased in popularity owing to the natural anatomic extension from a retromuscular approach. However, endoscopic anterior component separation remains an important and effective technique in selected patients as an adjunct to both open and laparoscopic AWR. Advantages of ECS include the ease of operation with recognizable anatomy, minimal risk of dividing the incorrect layer and destabilizing the lateral abdominal wall, and finally, its effectiveness and low morbidity. Additionally, when paired with minimally invasive AWR techniques (intraperitoneal onlay mesh [IPOM], transabdominal preperitoneal [TAPP], extended-view totally extraperitoneal [eTEP]), endoscopic anterior component separation allows for a fast, efficient, and safe complementary technique to facilitate midline advancement.

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Alternate Methods to Components Separation

33

Bruce R. Tulloh and Andrew C. de Beaux

33.1 Introduction

In this chapter we explore some alternate techniques for incisional and other ventral hernia repair and consider their indications. A number of laparoscopic and open procedures are well established and surgeons try to tailor their approach to the hernia they face. Laparoscopic repair is excellent in certain situations but is not always feasible, especially with larger defects where it is associated with mesh bulge, mesh migration and recurrence [1, 2]. Such hernias are often better approached with open surgery where the retro-muscular or "sublay" mesh repair, the workhorse of the abdominal wall surgeon, is widely regarded as the procedure of choice [3, 4]. However, a straightforward sublay mesh repair is not possible when the hernia defect is too wide for primary fascial closure to be achieved, or where there is potential (or actual) loss of abdominal domain. Such operations fall into the category of abdominal wall reconstruction rather than hernia repair, and usually require special techniques.

In these cases the surgeon has several options to consider. One is to simply bridge the fascial gap with mesh, but this risks seroma formation and infection where the mesh lies subcutaneously and bowel adhesion, erosion and fistula formation where it is in contact with intraperitoneal contents. Subsequent laparotomy for any reason is also likely to be more difficult after the use of intraperitoneal mesh [5]. Bridging is still commonly used with laparoscopic repair, but laparoscopic bridging differs from open surgery in two important ways. First, at laparoscopy, meshes with anti-adhesive properties are used on the peritoneal aspect. These do not completely negate the problem of adhesions but do reduce them considerably in relation to conventional synthetic mesh. Second, in laparoscopic repairs the overlying skin remains intact and thus the risk of mesh contamination is minimal.

Another popular choice is one of the components separation techniques (CST), involving lateral release of either the anterior or posterior myofascial layers. These are described in Chapters 31 and 32. These operations are very effective at mobilising tissue layers medially but are restricted to use with midline hernias—that is, they are not applicable to transverse and other off-centre defects. Recurrences after previous CST can also be extremely difficult as the tissue planes have been disrupted and, at least after anterior CST, the lateral abdominal wall is already weakened.

Other adjunctive techniques include preoperative pneumoperitoneum, lateral intramuscular botox-A injection, or resection of bowel and/or omentum. These have their place but the first two require considerable preoperative planning, while bowel resection introduces the risk of contamination and infection.

This chapter describes an alternate technique for abdominal wall reconstruction known as the peritoneal flap hernioplasty. First described in a French textbook [6] it is derived from an earlier technique originally reported by da Silva [7]. The modern procedure utilises transposed flaps of preserved sac to effectively extend the fascial layers to support and envelop a piece of mesh between two strata of autologous tissue in a relatively tension-free manner. The term "flap" is appropriate as a flap can be defined as tissue transposed from one anatomical zone to another. Using this technique, peritoneum and anterior rectus sheath are transposed from one side of the defect to join with the posterior sheath on the other, and vice-versa. The flaps comprise peritoneum and attenuated fascia and scar; they can be thick and robust, especially in hernias of long-standing, although they can be thin and flimsy. This is not important, however, as the peritoneal flaps are not for strength; they are important only to provide a living tissue barrier on either side of the mesh. The mesh, with its generous overlap beneath the muscles on either side inviting excellent tissue ingrowth, provides the ultimate strength in the repair.

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_33

At completion, the mesh lies "sandwiched" between two layers of autologous tissue. This repair combines the benefits of a sublay repair with both closure of the peritoneal cavity and superficial coverage of the mesh, and it is a very useful and widely applicable addition to the hernia specialist's repertoire for selected cases where other techniques are either not available or not indicated.

33.2 Operative Technique

The technique is described for a midline hernia, although this technique can also be adapted to transverse and other non-midline incisions by considering the regional muscle and fascial anatomy.

33.2.1 Step One: Expose the Sac and the Fascial Margins

The previous operative scar is excised, often with an ellipse of skin if there is considerable redundancy. Skin and subcutaneous fat is elevated on each side just far enough to expose the sac and musculo-fascial margins of the defect. Too much mobilisation risks injury to perforating vessels and lymphatics, thus risking seroma and jeopardising the cutaneous blood supply.

33.2.2 Step Two: Open the Sac Down the Middle

The sac is opened over the full length of the defect in the long axis of the incision—in this case, the midline (Fig. 33.1). It may involve joining multiple defects together. Each half of the sac is carefully preserved. Peritoneal adhesions within the sac, and for several centimetres beyond the margins, are divided but an extensive intra-abdominal adhesiolysis is generally not required. The hernial sac in large, chronic ventral and incisional hernias comprises attenuated linea alba and peritoneum and is often very robust tissue.

33.2.3 Step Three: Create the Peritoneal Flaps

One side of the wound is elevated to expose the undersurface of the abdominal wall. The peritoneum and posterior rectus sheath on that side is incised over the entire length of the wound in a line parallel to the margin of the defect, just lateral to the palpable medial edge of the rectus muscle. There is usually an element of muscular diastasis in such large midline hernias and this fascial incision may lie several centimetres from the midline. Once opened, this incision provides immediate access to the retromuscular space on one side while simultaneously creating a sizeable "flap" of peritoneal sac which is contiguous with the anterior rectus sheath, joined to it by a small bridge of linea alba and posterior sheath which has been reflected off the muscle (Fig. 33.2). This flap is destined to form the final, superficial layer of the "sandwich" repair.

On the *opposite* side of the wound, the *anterior* rectus sheath is incised longitudinally in a similar fashion to the first side, but on the *ventral surface* of the rectus muscle. The medial edge of the incised anterior rectus sheath, with its leaf of preserved sac attached, is reflected to the midline which allows dissection to proceed medially around the muscle in to the retromuscular space (Fig. 33.3). The peritoneal flap thus created is contiguous with the *posterior* sheath on that side and destined to become the deep layer of the repair.

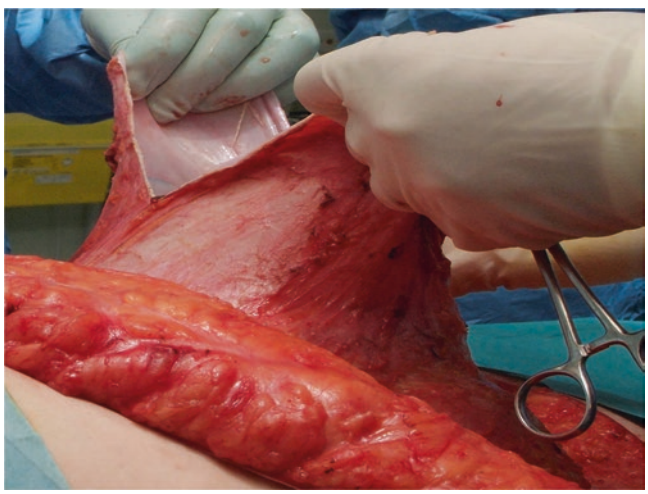

Fig. 33.1 Dividing the hernial sac down the midline. In this case a transverse wedge of skin and fat has already been excised as part of a concurrent abdominoplasty

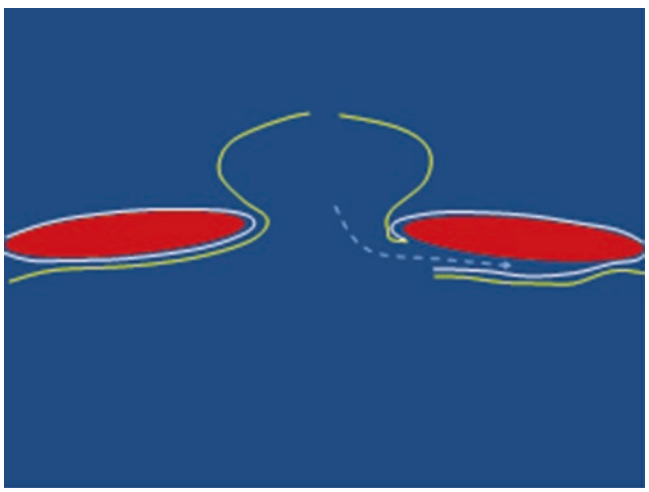

Fig. 33.2 Dividing the posterior sheath and entering the retrorectus space on one side turns one-half of the peritoneal sac into a flap which will be used later to cover the mesh

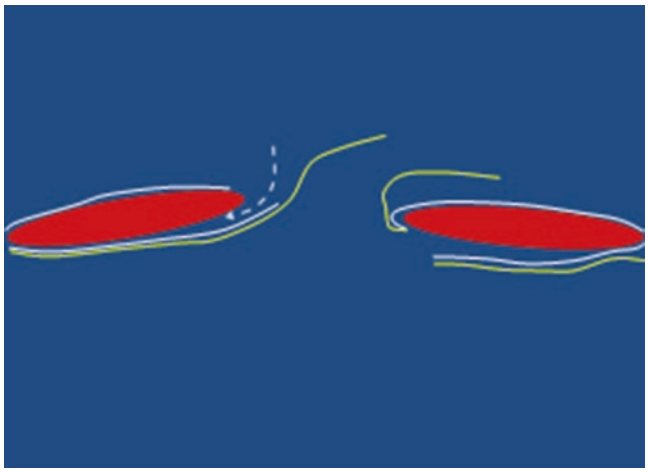

Fig. 33.3 The anterior sheath on the opposite side is incised and dissection continues around the medical border of the rectus muscle to enter the retromuscular space, thus mobilising that half of the sac medially to create the flap for closure of the abdominal cavity

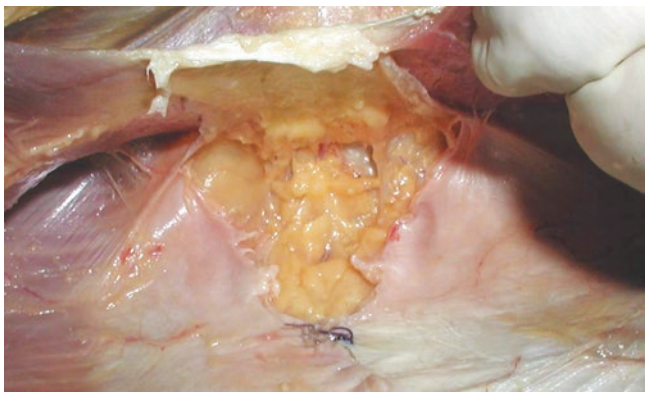

Fig. 33.4 Joining the retromuscular spaces across the midline in the upper abdomen involves dividing the posterior rectus sheaths close to the midline just deep to the linea alba and exposing the "fatty triangle" which is the root of the falciform ligament

33.2.4 Step Three: Develop the Sublay Plane

Dissection continues into the retromuscular space on each side, taking care to preserve branches of the superior and inferior epigastric vessels which should be elevated with the muscle. Joining the left- and right-sided spaces across the midline at the upper and lower reaches of the wound is straightforward if attention is paid to the anatomical planes. In the lower abdomen, below the arcuate line, the retromuscular plane extends into the retropubic space and across the midline. Above the umbilicus the space can be extended superiorly by dividing both posterior sheaths at their medial borders, deep to the linea alba. This opens into the extra-peritoneal space at the root of the falciform ligament, the so-called "fatty triangle" (Fig. 33.4). This space can extend up behind the xiphisternum and costal margins for some distance.

If necessary, the space can be extended laterally beyond the rectus sheath by incising transversus abdominis and entering the extra-peritoneal space. This is akin to a posterior components separation and will provide a great deal more medialisation of the fascial layers for a midline hernia. The plane between the External and Internal Oblique may be used as an alternative, especially in transverse incisions, but the plane between internal oblique and transversus should be avoided because it contains the segmental nerves and vessels of the abdominal wall (Fig. 33.5).

33.2.5 Step Four: Close the Peritoneal Cavity

The first peritoneal flap (comprising one-half of the sac and some of the reflected anterior rectus sheath from one side) is then laid across the hernial defect and sutured to the cut edge of the opposite posterior sheath, underneath (deep to) the rectus muscle (Fig. 33.6). A 2/0 slowly absorbable monofilament suture is appropriate. Once completed, the suture-line forms a gentle curve, parallel with the margins of the defect. With the peritoneal cavity closed, there is now a common plane extending across the midline from one retro-muscular space to the other. The hernial defect has been bridged by the flap with minimal tension, and the abdominal viscera are isolated from the remainder of the repair.

33.2.6 Step Five: Insert the Mesh

A suitable mesh such as medium-weight, large-pore polypropylene is cut to an elliptical shape and laid in the newly created retromuscular space and ensuring a generous overlap of the peritoneal sac/sheath suture line (Fig. 33.7). We advocate using as large a piece as will fit into the space. The mesh should lie smooth and flat and may be trimmed at its margins to avoid folding. It may be fixed to the posterior rectus sheath with a series of interrupted sutures, generally six or eight on each side, or with spots of tissue glue. Below the arcuate line, transmuscular sutures to the anterior sheath may be used instead, taking care to avoid the inferior epigastric vessels (Fig. 33.8).

33.2.7 Step Six: Complete the Fascial Closure

The repair is completed by suturing the remaining peritoneal flap to the cut edge of the anterior sheath, overlying the rectus muscle (Fig. 33.9). This "sandwiches" the mesh between two layers of preserved sac in what would otherwise have been a fascial gap. When this layer is complete the mesh is separated from the subcutaneous plane.

For oblique or transverse incisions, the appropriate tissue planes must be sought as described by Stumpf et al. [8].

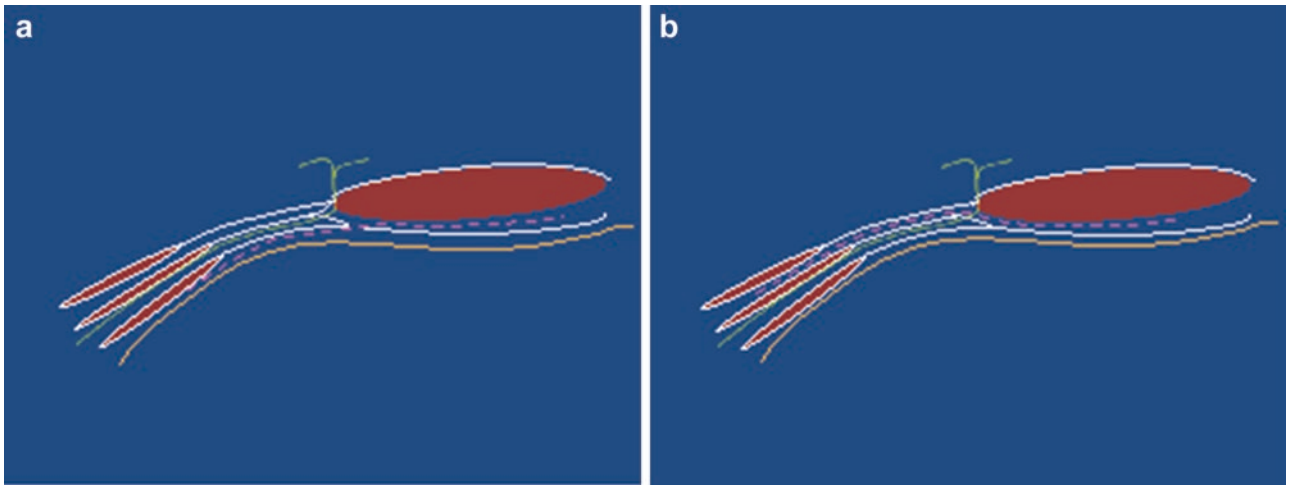

Fig. 33.5 If the dissection has to continue lateral to the rectus sheath, the extraperitoneal plane (**a**) is excellent for midline incisions as it avoids the neurovascular plane between internal oblique and transversus abdominis. For transverse incisions the plane between external oblique and internal oblique (**b**) is often easier to obtain. One neurovascular bundle may be at risk at the level of the incision but there is sufficient dermatome overlap for this not to cause any objective sensory loss

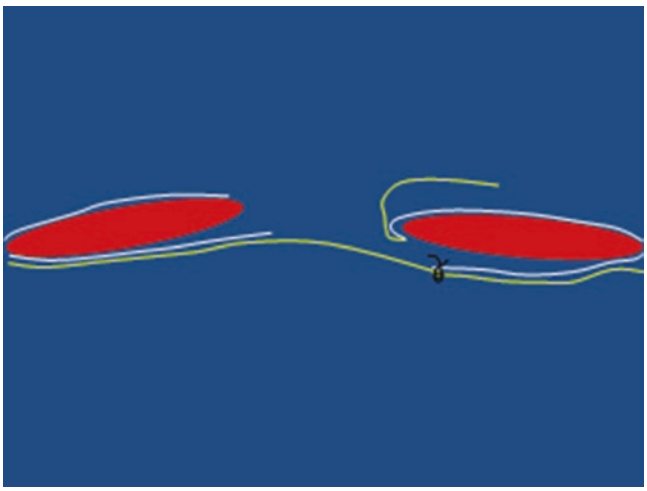

Fig. 33.6 The flap of sac from one side is sutured to the cut edge of the posterior rectus sheath on the other side to close the abdominal cavity

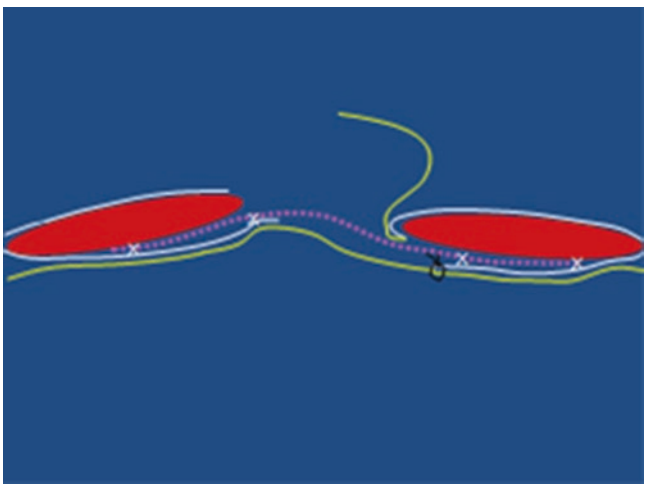

Fig. 33.7 Mesh is laid into the common retromuscular space and may be sutured or glued to the posterior sheaths

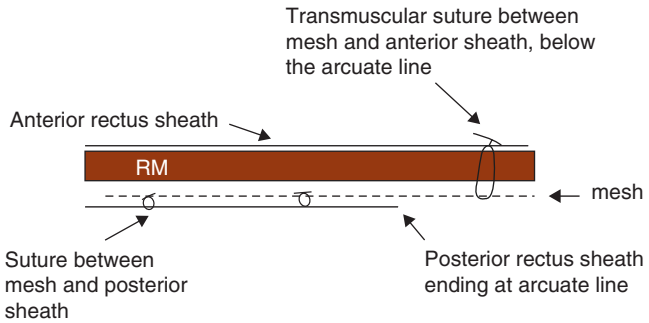

Fig. 33.8 Para-sagittal section through the rectus muscle and sheaths illustrating fixation of the mesh to the posterior sheath above the arcuate line, and transmuscular sutures to the anterior sheath below the arcuate line. *RM* rectus abdominis muscle

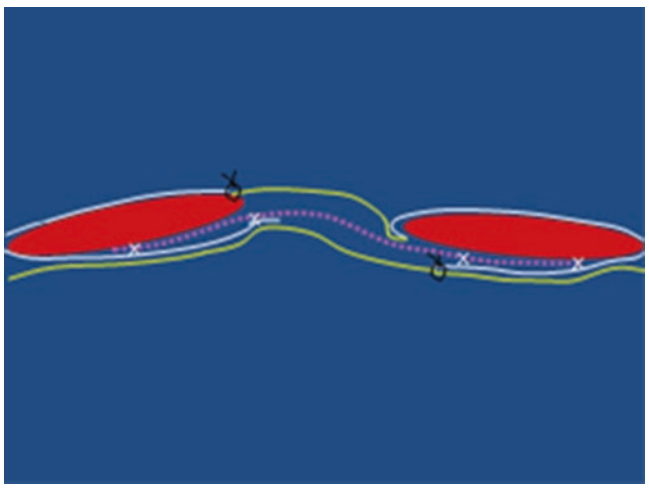

Fig. 33.9 The repair is completed by suturing the remaining peritoneal flap to the cut edge of the anterior sheath, thus sandwiching the mesh between two layers of autologous tissue

Lateral to the rectus sheath, the preferred plane is that between the external and internal oblique muscles layers. The extraperitoneal plane may be used instead but is more difficult to establish with transverse incisions. As for midline hernias, care must be taken when joining the spaces at each end of the wound to ensure that a common plane is maintained.

Drains may be placed in the plane of the mesh and/or in the subcutaneous layer. The subcutaneous fat layer may be approximated with some absorbable sutures and the skin can be closed with sutures or staples. Postoperatively, abdominal binders or compressive dressings may be used to support the repair according to the surgeon's preference.

33.3 Postoperative Complications

The general postoperative course is the same as that for most open abdominal wall reconstructive operations. However, in contrast to an open bridging mesh repair, troublesome bowel adhesions, erosions and fistulation are not to be expected because the continuity of the peritoneum is restored deep to the mesh. Furthermore, unlike onlay mesh repairs, the risk of mesh exposure or chronic wound sinus formation in the event of wound breakdown is reduced because the mesh is not in the subcutaneous plane. Extensive skin excision with or without some form of abdominoplasty is commonly performed in conjunction with repair of very large ventral and incisional hernias and this is associated with considerable wound morbidity such as skin edge necrosis, superficial wound breakdown, or wound collections with or without infection. In a peritoneal flap repair the mesh remains covered by a layer of living tissue which is important in reducing the risk of mesh exposure and mesh infection in the event of such wound problems. In one published series of 21 peritoneal flap repairs there was only once case requiring late mesh explanation and this was because of necrosis of both fascia and skin which left the mesh exposed [9]. The tissue necrosis was attributed to excessive skin and fascia flap mobilisation aggravated by underlying microvascular disease from smoking.

Flap necrosis is a serious complication leading to abdominal wall dehiscence and mesh exposure, requiring mesh removal and often leading to multiple reoperations as for the management of an open abdomen. Thus it is important to maintain a broad attachment of each peritoneal flap along the margins of the defect. It is also useful to trim the leaves of preserved sac down to size immediately prior to closure, but closure under tension will also lead to tissue necrosis, so this must be done cautiously.

The peritoneal flap repair is sometimes referred to as the "mesh sandwich" repair as a single layer of mesh is sandwiched between two flaps of autologous tissue. However, the term has also been used to describe an operation where a sheet of biologic underlay mesh is added to a lightweight polypropylene onlay mesh in an otherwise traditional CST-assisted midline closure—in other words, an operation in which the fascial repair is "sandwiched" between two layers of mesh [10, 11]. Thus the term "mesh sandwich repair" is ambiguous and surgeons need to be clear about which procedure they mean when using it.

The anterior and posterior components-separating techniques (CST) remain popular and very useful for repairing large defects, and are discussed in detail elsewhere in this book (see Chapters 31 and 32). All CST procedures aim to achieve primary fascial closure in the midline by the advancement of musculo-fascial flaps after lateral releasing incisions are made, this increasing abdominal domain. Re-opposing the rectus muscles in the midline is considered important in restoring the physiological function of the abdominal wall [12], although many otherwise healthy (but overweight) people function well enough with a degree of natural diastasis. The peritoneal flap hernioplasty does not attempt to restore the rectus muscles to the midline; its primary goal is provide a viable fascial layer across the gap in order to support and protect the inlaid mesh. Nevertheless there is always a degree of improvement in the rectus separation (Fig. 33.10a, b).

Both the CST and the peritoneal flap hernioplasty technique bring about an increase in the abdominal domain—the CST laterally, and the peritoneal flap hernioplasty at the site of the repair. However, unlike the CST, the peritoneal flap repair does require the presence of a peritoneal sac. In cases such as laparostomy where there is no sac, the peritoneal flap hernioplasty is not applicable and in such cases components separation is the procedure of choice.

Key Points

- The Peritoneal Flap repair is one of several options available to the surgeon when the defect is so wide that primary fascial closure cannot be achieved.
- It is a modification of the non-mesh da Silva repair, first described in [7].
- The peritoneal flap repair utilises preserved sac from each side of the hernia defect to reapproximate the facial edges and allow a retromuscular mesh repair with the mesh "sandwiched" between two layers of viable, autologous tissue.
- It must be distinguished from other "sandwich" repairs which involve two layers of mesh sandwiching a single layer of fascia in between, as described to reinforce the midline closure in conjunction with a CST procedure.
- The peritoneal flap operation is applicable to both midline and non-midline hernias, but requires the presence of a well-defined hernia sac and is thus not suitable for laparostomy defects.
- Flap necrosis is a disastrous complication and is best avoided by preserving a broad fascial attachment to each half of the sac and trimming off excess sac to allow a neat but tension-free closure.

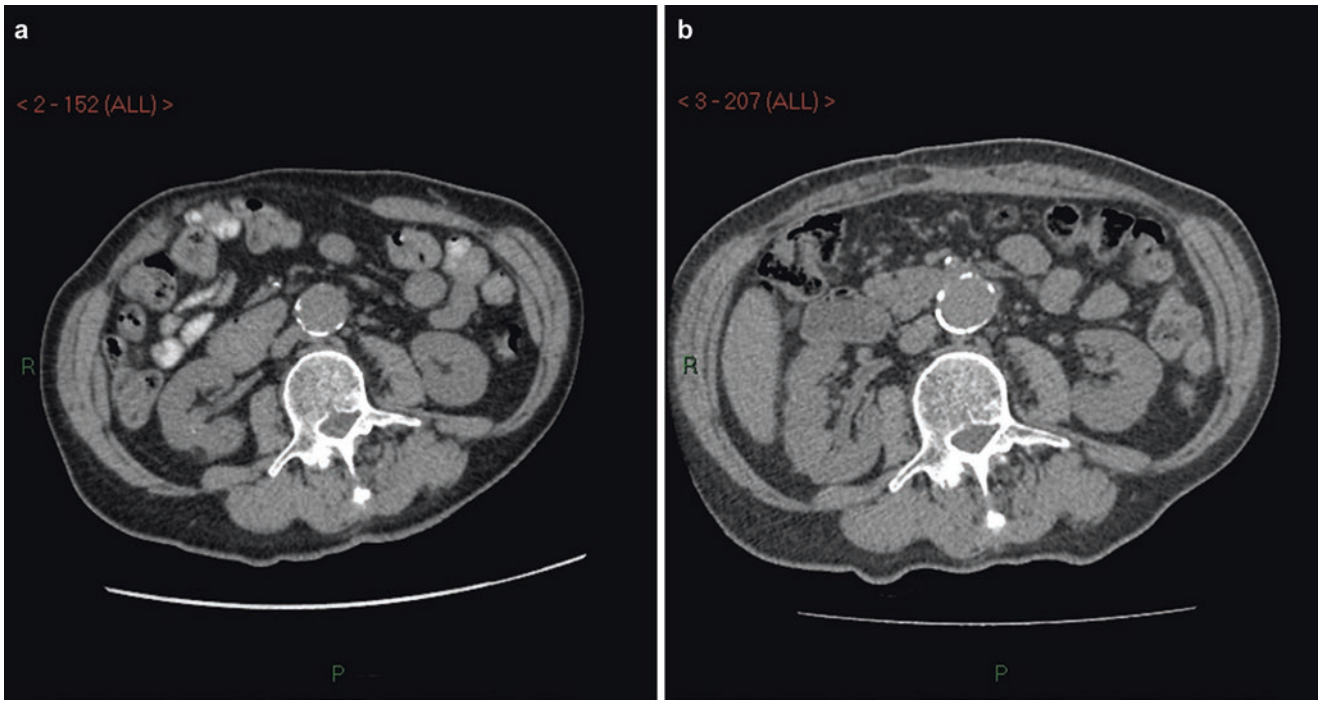

Fig. 33.10 (**a**) CT scan prior to a peritoneal flap hernioplasty repair showing wide separation of the rectus muscles. (**b**) Postoperative CT scan of the same patient showing the extent to which the rectus muscles have been drawn back towards the midline

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Plastic Surgery Considerations for Abdominal Wall Reconstruction

34

Ibrahim Khansa, Terri Zomerlei, and Jeffrey E. Janis

34.1 Introduction

Surgical-site infection, seroma, dehiscence, and skin necrosis are complications that may affect the skin and soft tissue of the abdominal wall after complex hernia repair. These complications may actually jeopardize the entire hernia repair, as hernia recurrence has been shown to be significantly more common when infectious complications occur [1]. Several evidence-based strategies can be employed to reduce the risk of wound healing complications. These include the preservation of abdominal wall perforators, the resection of redundant skin and adipose tissue, the resection or reconstruction of the umbilicus, the obliteration of anatomic dead space, the generation of new tissue via tissue expansion, the closure of the skin and soft tissue using optimal techniques, and the judicious use of negative pressure wound therapy.

34.2 Perforator Preservation

Perforating vessels to the abdominal wall derive from the inferior and superior deep epigastric vessels. There consist of a medial and a lateral row, with the periumbilical perforators (located within 3 cm of the umbilicus) being the most important [2, 3]. Traditional open components separation requires widely undermined skin flaps, and thus results in high rates of wound healing complications [4]. Attempts to perform components separation without significant undermining started with Lowe's description in 2000 of endoscopic components separation, where the linea semilunaris was accessed through a separate lateral incision located 5 cm medial to the anterior superior iliac spine, and an endoscopic balloon was used to dissect a subcutaneous plane over the mid-axillary line [5]. The external oblique aponeurosis was then incised using laparoscopic instruments inserted into that pocket. This was followed in 2002 by Saulis and Dumanian's description of a technique for the preservation of the periumbilical perforators, where the linea semilunaris was accessed through subcutaneous dissection superior and inferior to those perforators, without disturbing them [6]. A refinement of this technique was described in 2011 by Butler et al., where the linea semilunaris was accessed via a single 3-cm-wide tunnel located 2 cm inferior to the costal margin [7]. Finally, in 2016, Janis et al. published a further modification using laparoscopically derived techniques of percutaneous transfascial suture fixation of mesh together with a minimally invasive anterior components separation to maximize composite tissue, preserve blood supply, and minimize complications [8].

There is strong evidence that preservation of as many of the abdominal wall perforators as possible improves the blood supply to the skin and subcutaneous tissue, and lowers the risk of skin necrosis and other wound healing problems. Berger et al. demonstrated that skin undermining of greater than 2 cm increased the risk of wound healing complications two- to threefold [9]. Lowe et al. demonstrated a significant reduction in wound healing complications using their endoscopic technique in comparison to open components separation (infection 0 % vs. 40 %; dehiscence 0 % vs. 43 %) [5]. Rosen et al. also demonstrated a decrease in wound healing complications from 52 to 27 % using a similar method [10]. Butler et al.'s technique lowered skin dehiscence from 14 to 4 %, and seroma from 6 to 2 %, compared to traditional open components separation [7]. Using their comprehensive approach, which included minimally invasive components separation, as well as resection of any tenuous tissue, Janis et al. found a 4.5 % rate of delayed wound healing/dehiscence with their described technique [8].

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_34

Perforator preservation is also an important consideration when choosing what plane to place mesh in during hernia repair. Overlay mesh requires some degree of skin undermining in order to obtain adequate overlap between the fascia and the mesh. In contrast, mesh may be placed in the retrorectus or underlay positions without subjecting the skin and soft tissues to any undermining. Albino et al. performed a systematic review of published literature on mesh position, which demonstrated that placement of mesh in the overlay position had a higher rate of seroma than the underlay and retrorectus positions [11].

34.3 Skin Management

34.3.1 Panniculectomy

Patients with complex hernias often have excess abdominal skin. In some patients, this is due to obesity. In others, it is due to the tissue expansion effect that the hernia has on the abdominal wall [12].

In obese patients, both medical and surgical complications are increased after abdominal wall reconstruction [13, 14]. Excess skin and adipose tissue may place traction and shear on the incision, which not only increases the risk of dehiscence, but also allows bacterial migration into the incision [15]. In cases where synthetic mesh has been utilized, the avoidance of bacterial translocation into the incision becomes even more imperative as many of the commonly used meshes do not tolerate infection.

In order to address these issues, aggressive resection of the any overhanging pannus with either a horizontal or a combined horizontal and vertical ("fleur-de-lis") resection has been advocated. While the resection of redundant skin has been shown to improve postoperative patient function and satisfaction [16], and can potentially make ostomy placement or relocation easier [17, 18], it is unclear what its effects on complication rates are. Studies examining the outcomes of simultaneous panniculectomy and hernia repair have included two distinct groups of patients: patients with a history of morbid obesity who had sustained massive weight loss [19–21], and patients who are currently morbidly obese [22]. Studies where panniculectomy was performed on patients with excess skin due to massive weight loss found good outcomes for simultaneous panniculectomy and hernia repair, and most wound healing complications that occurred could be managed nonoperatively [19–21]. In contrast, studies where combined panniculectomy and hernia repair were performed on patients who were morbidly obese at the time of surgery found increased wound healing complications when hernia repair was combined with panniculectomy, compared to hernia repair alone [22]. In a large analysis of NSQIP data, Fischer et al. found that, in patients undergoing combined hernia repair and panniculectomy, BMI greater than 35 increased the risk of surgical complications by 89 %, while BMI greater than 40 increased the risk of surgical complications by 166 % [23]. This highlights the importance of patient optimization before elective hernia repair, which includes weight loss. The same study found that another major modifiable risk factor for complications in patients undergoing combined hernia repair and panniculectomy was smoking, which increased the risk of surgical complications by 41 %, thus the importance of absolute smoking cessation for at least 4 weeks before any elective abdominal wall reconstruction is undertaken [24, 25].

Technical considerations also play an important role in determining complication rates. In fleur-de-lis abdominoplasty, high complication rates would be expected if the upper triangular flaps were widely undermined with significant perforator sacrifice, and if the T-junction were placed caudally in the hair-bearing pubic area. Butler described the Mercedes panniculectomy, which is a modification of the fleur-de-lis panniculectomy, where the upper triangular flaps end in a more obtuse tip, and the T-junction is more superior and further away from the pubic area [18]. This results in the upper triangular flaps being shorter and wider, which improves vascularity at their tips. Importantly, the inferior skin flap has a robust axial blood supply derived from the bilateral superficial inferior epigastric arteries. With this technique, tension on the T-junction is reduced, and vascularity of the tips of the triangular flaps is improved, resulting in lower rates of wound healing problems.

In patients who are not morbidly obese, there may also be excess skin due to the hernia itself. This excess skin is often undermined, tenuous, and vascularly embarrassed, placing it at risk for necrosis. This skin can be easily excised through the vertical laparotomy incision itself as a vertical panniculectomy. Most surgeons typically perform this excision as an ellipse, with equal width superiorly and inferiorly [12]. Since most patients often carry a greater amount of skin infraumbilically (irrespective of gender), they may be better served with a teardrop-shaped excision, where the width of the ellipse is greater inferiorly, as described by Janis et al. (Fig. 34.1) [8].

The determination of the amount of skin to be excised is based on several factors, the two most important of which being tension on the closure and vascularity of the remaining tissue. Excision must never be so aggressive that undue tension results. One reliable technique to ensure safe skin excision is "tailor tacking" (Fig. 34.2) [8]: before any skin excision, a skin stapler is used to reapproximate the incision in such a way that excess skin is imbricated into the wound. This maneuver simulates the appearance of the final closure if the imbricated skin were to be excised. It also allows any adjustments to be made easily. The apposed skin edges are then marked, and the staples removed. This usually results in a teardrop-shaped mark, which indicates the amount of skin

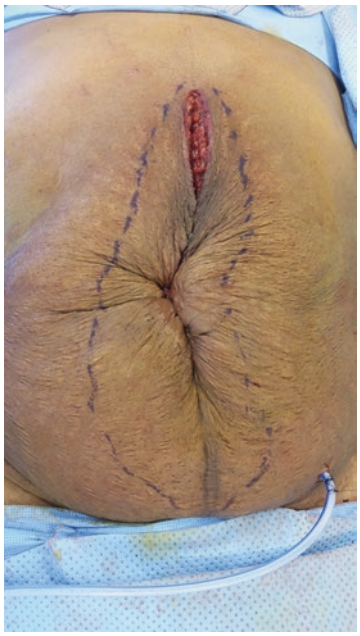

Fig. 34.1 Typical teardrop-shaped excision pattern to remove redundant, undermined, and marginal skin

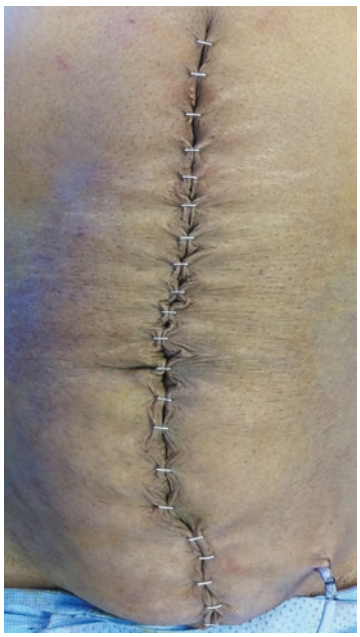

Fig. 34.2 In staple-assisted tailor tacking, surgical skin staples are used to imbricate the peri-incisional skin to simulate the excision. This allows safe skin excision, avoiding over-resection and undue tension

that can be safely excised. Another skin resection strategy is to elevate the excess skin with the assistance of piercing towel clamps and estimating the skin resection using a pinch test, which is then demarcated with an indelible marker (Fig. 34.3). Accommodation for the skin flap thickness is taken into account before definitive resection, often using a "double crown" technique as described by Aly [26].

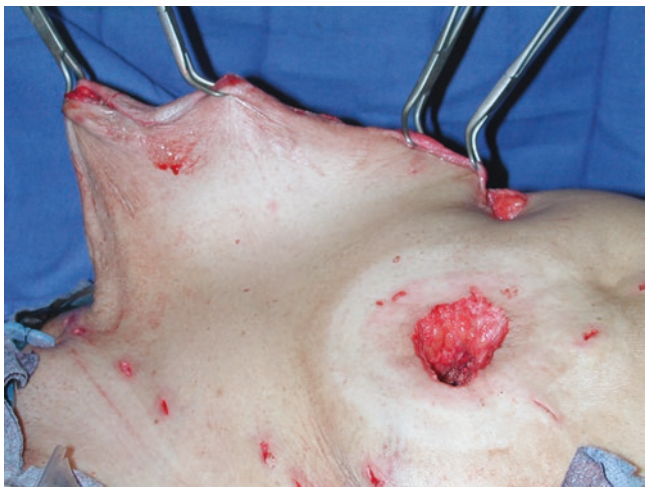

Fig. 34.3 In towel clamp-assisted skin excision, penetrating towel clamps are used to grasp the two edges of the incision, which are then pulsed upwards. A manual pinch test then allows an estimation of the borders of the skin excision

The other important assessment to be made is skin vascularity. This can be done clinically by observing skin edge bleeding, color, and capillary refill. Recently, several studies have evaluated the technology of indocyanine green fluorescence angiography (ICG-FA) in the AWR population in order to establish the ability of this tool to predict skin and soft tissue necrosis, and thus provide real-time intraoperative guidance to the surgeon [27]. In a double-blinded randomized controlled trial comparing ICG-FA to clinical assessment in patients undergoing abdominal wall reconstruction, Wormer et al. found that ICG-FA successfully identified patients at risk for wound healing problems, but that modifying the surgical plan based on its results did not lower complications significantly (although the study may have been underpowered) [28].

34.3.2 Umbilical Resection and/or Reconstruction

Oftentimes there is significant scarring and disruption of vascularity from prior midline incisions, especially in recurrent cases. Although it is proven that sparing peri-umbilical perforators results in improved outcomes [5–10], sometimes these have already been sacrificed, placing the umbilicus and surrounding skin in jeopardy, especially if undermined by the hernia sac or the surgeon during repair. Leaving this tenuous tissue behind can start a vicious cycle of necrosis, infection, and ultimately a high rate of recurrent hernia [8]. Therefore careful evaluation at the end of the case and clinical decision-making that may involve umbilectomy is advised. Patients should be made aware of this possibility preoperatively so that they are involved in the decision-making process.

Conversely, while reconstruction of the abdominal wall is primarily a functional procedure, management of the skin and soft tissues in a cosmetically sensitive manner can enhance patient satisfaction. Depending on the specific surgical circumstances, the umbilicus may be (1) relatively untouched, (2) relocated (umbilical transposition), (3) removed entirely (umbilectomy), or (4) removed and recreated (umbiliconeoplasty).

The umbilicus is a three-dimensional structure located along a horizontal plane at the level of the superior iliac crests [29]. While numerous techniques for reconstruction of the neo-umbilicus have been described, most techniques share the common goal of restoring the essential features of an aesthetically pleasing umbilicus, which include a central sulcus, vertical orientation, and a superior hood [30]. Although there are numerous techniques for umbiliconeoplasty, such as the dome technique [31], the "pumpkin teeth" technique [32], the rectangular flap technique [33], and others, most of the techniques have a general theme in common: developing local abdominal flaps, and suturing them to the rectus fascia in order to create an epithelial tube [34, 35]. It should be noted that in male hirsute patients, avoiding reconstruction of the umbilicus may be prudent to prevent undesirable hair growth within the umbilicus [32].

34.4 Dead Space Obliteration

Any time a plane is dissected, fluid may accumulate in that plane and form a seroma. In and of themselves, seromas may not be harmful to the patient, other than possibly causing discomfort and requiring repeated aspirations. However, they can have major consequences if allowed to accumulate. A fluid collection between biologic mesh and native tissue may interfere with neovascularization and incorporation of the mesh. Seromas are also prone to infection, and can therefore transform into abscesses, which can jeopardize mesh and require operative intervention. The obliteration of dead space is therefore an essential component of safe and successful hernia surgery [36].

The placement of closed-suction drains has been shown to decrease the risk of seroma formation in abdominal surgery [37, 38]. However, closed-suction drains may become ineffective, or even harmful, if used incorrectly. Studies have shown that meticulous drain care, including frequent stripping [39], compressing drains bulbs side to side, and emptying drains when they are 50 % full, is essential to prevent clogging and maintain a high pressure gradient between the body cavity and the drain bulb. Keeping drains in place until their output is below 30 cm^3 a day for two consecutive days with the patient ambulatory has been shown to result in fewer seromas than removing the drains on a predetermined postoperative day [40–43].

In abdominal wall reconstruction, potential planes for seroma formation include the plane between the mesh and the fascia, the subcutaneous plane, and the site of external oblique fasciotomy (when anterior components separation is performed). Drains should be placed in each of these planes. This implies that drains will often be in contact with mesh, and many surgeons are reluctant to allow contact between drains and mesh, out of concern for inoculation of the mesh. However, there is little evidence that placing drains in contact with mesh increases rates of infection (as long as appropriate postoperative drain care is performed) [44]. In fact, there is some evidence that drain use may actually decrease the risk of mesh infection [45].

The use of sutures has emerged as a complementary maneuver to help reduce seroma formation. Progressive tension sutures are placed between the underside of the Scarpa's fascia and the anterior rectus sheath (Fig. 34.4) [46]. These sutures serve three functions: they eliminate dead space in the subcutaneous plane, they immobilize the skin flaps against the anterior rectus sheath and thereby prevent the shear forces that have been implicated in seroma formation [47, 48], and they distribute the tension over a larger area, thereby offloading the tension off the incisional closure. While progressive tension sutures mainly address subcutaneous dead space, we have devised another type of sutures, termed *central suspension sutures*, to obliterate dead space between the mesh and the fascia when the mesh is placed in an intraperitoneal or a retrorectus position (Fig. 34.5) [8]. These #1 polyglyconate sutures start on one edge of the fascia, then full-thickness through the midline of the mesh, then through the other edge of the fascia. These sutures ensure close apposition of the mesh against the underside of the fascia, which not only reduces fluid accumulation, but also can provide a better environment for neovascularization and incorporation when biologic mesh is used. Care is taken to avoid tissue strangulation when these sutures are employed, but when used correctly, they can be a useful adjunct to improve outcomes [8].

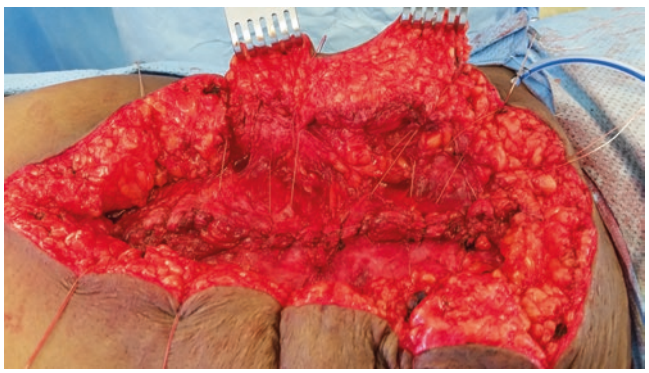

Fig. 34.4 Progressive tension sutures (PTS), placed between the underside of Scarpa's fascia, and the muscular fascia, allow advancement of the skin flaps toward the incision, as well as obliteration of dead space

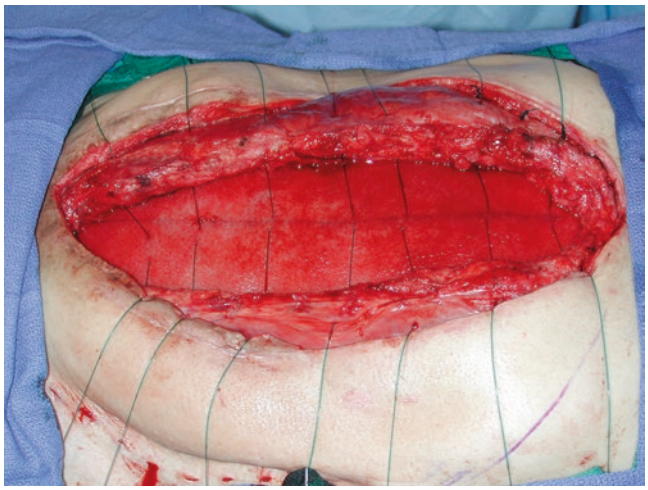

Fig. 34.5 Central suspension sutures (CSS), placed between the underlay mesh and the overlying fascia, are placed before fascial closure and tied afterwards, in order to ensure close apposition of the mesh to the fascia

34.5 Tissue Expansion

Initially developed by Neumann [49], then popularized by Radovan [50], tissue expansion is one of the most useful rungs of the reconstructive ladder. Tissue expansion is capable of stimulating mitotic activity and collagen synthesis to generate new tissue [51]. It also improves the vascularity of the expanded tissue by stimulating angiogenesis [52].

Tissue expansion is usually used in abdominal wall reconstruction in cases where there is a deficit of skin and subcutaneous tissue [53]. This is often the case in thin patients, and those with significant wounds, ulcerations, or skin grafts on viscera. The reconstruction involves at least two stages: in the first stage, an incision is made adjacent to the anticipated skin defect and a subcutaneous plane is developed to place the tissue expander. Expansion then is undertaken in the outpatient clinic environment until sufficient tissue is available, and a second stage procedure is performed where the tissue expander is removed, the tissue transposed to establish soft tissue coverage, and the hernia repaired.

34.6 Skin Closure Techniques and Technology

In abdominal wall reconstruction, especially in cases where mesh is used, meticulous closure is essential to ensure adequate healing of the incision and to prevent exposure/infection of the mesh and potential loss of the entire reconstruction. A layered closure is essential to offload tension off the skin [54]. Most surgeons agree that the Scarpa's layer should be closed with absorbable sutures, followed by closure of the deep dermis. The deep dermal sutures serve to evert the skin, which is known to accelerate healing and result in a more favorable scar [55–57]. A subcuticular layer of absorbable suture is then placed. Tissue glue may be used as an impervious dressing after the subcuticular layer [58, 59], or as a replacement for that subcuticular layer altogether [60, 61]. Similarly, staples may be used to replace the subcuticular layer without loss of quality, although they tend to be painful to the patient [62].

34.7 Negative Pressure Wound Therapy

34.7.1 Traditional Negative Pressure Wound Therapy

In wounds that are too contaminated to close, or in cases of postoperative dehiscence, the application of negative pressure wound therapy (NPWT) has the potential to accelerate healing compared to standard dressings. It has been shown that NPWT increases blood flow, enhances granulation tissue formation, and decreases bacterial counts in wounds [63]. It has also been demonstrated that NPWT modulates the cytokines in the wound to an anti-inflammatory profile that is conducive to healing [64], and applies microstrain to wound cells that culminates in enhanced cellular proliferation and angiogenesis [65]. Many surgeons use NPWT mainly to salvage exposed mesh (particularly biologic mesh) in cases of dehiscence. There is growing evidence, however, that some synthetic meshes, namely macroporous, monofilament light, and mid-weight polypropylene meshes can also be successfully salvaged in certain circumstances with NPWT in cases of exposure and contamination [66].

34.7.2 Incisional Negative Pressure Wound Therapy

The application of NPWT over closed incisions is a novel tool that has been added to the armamentarium of the surgeon performing abdominal wall reconstruction [67]. Incisional NPWT, applied for 5–7 days over high-risk abdominal incisions, has been proven to reduce the risk of wound healing complications from 63.6 to 22 %, and the risk of dehiscence from 39 to 9 %, compared to standard dressings [68]. It has also been shown to reduce the risk of surgical-site infection by two-thirds [69]. Similar results have been demonstrated in high-risk patients undergoing median sternotomies [15], groin vascular surgery incisions [70], and fixation of lower extremity fractures [71]. One of the common findings in most studies on incisional NPWT is its ability to reduce seroma formation [72], which does not appear to be related to a direct suction effect, but rather to enhanced lymphatic clearance [73].

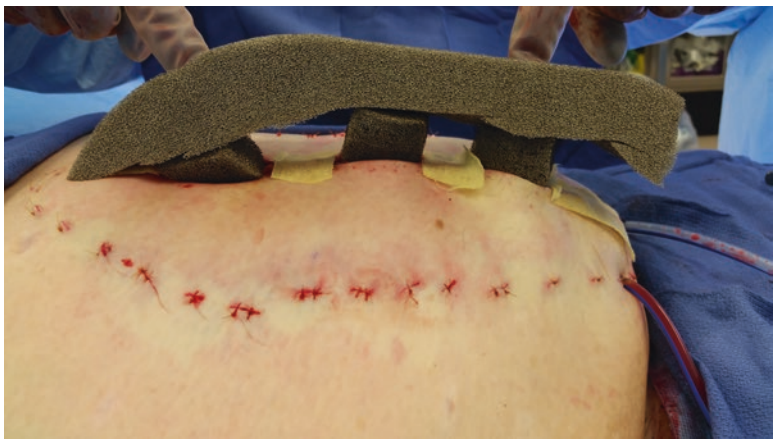

Fig. 34.6 In the string-of-pearls, French fry technique the incision is closed intermittently, and struts of polyurethane foam are placed in the open parts, then connected with a foam crossbar

34.7.3 Putting It All Together: The String-of-Pearls Technique

As described above, the application of NPWT to both open wounds and closed incisions offers distinct advantages. One technique that we have employed in very high-risk patients, termed the "String-of-Pearls, French Fry Technique," takes advantage of the benefits of open and incisional NPWT (Fig. 34.6). At the completion of the hernia repair, the skin incision is closed intermittently. The closure consists of 2-0 polyglactin in the Scarpa's fascia, followed by 3-0 poliglecaprone in the deep dermis then either staples or a subcuticular running 4-0 poliglecaprone. Intermittent closure for 5 cm, interspersed with open areas measuring 5 cm, is performed. The closed parts of the incision are covered with a non-adherent dressing such as Xeroform (Covidien, Mansfield, MA) or Adaptic (Johnson & Johnson, New Brunswick, NJ). Struts of polyurethane foam are then cut and inserted into the open areas all the way to the abdominal fascia, and connected over the closed incisions with a foam "crossbar." Adhesive is then applied, and seal obtained at 125 mmHg of continuous suction.

The "String-of-Pearls, French Fry" technique allows partial closure of the wound, aggressive removal of effluent, and a delayed primary closure of the open areas left within the incision, which accelerates eventual wound healing. The foam struts help improve blood flow to the open parts of the wound. In essence, it facilitates the management of high-risk incisions by achieving a controlled dehiscence.

34.8 Conclusion

Careful management of the skin and soft tissue of the abdominal wall is essential to achieving low complication rates, and high patient satisfaction, after complex hernia repair. The vascularity of the skin and soft tissue must remain a priority in the mind of the surgeon, from the beginning of the operation when the perforators are encountered, to the conclusion of the operation when the skin is closed.

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Robotic Transabdominal Preperitoneal (rTAPP) Hernia Repair for Ventral Hernias

35

Conrad Ballecer and Alexandra Weir

35.1 Introduction

Robotic hernia repair is an emerging technique born from well-established principles of both laparoscopic and open ventral hernia repair. Its growing popularity in the United States perhaps can be explained by enhanced 3D visualization, precision, and ergonomics. There are also inherent limitations of conventional laparoscopy which make it difficult operating high on the anterior abdominal wall, many of which may be overcome with the use of the robotic instrument.

There is a growing body of literature which promotes keeping mesh out of the intraperitoneal cavity secondary to bowel erosion and adhesions which may complicate subsequent abdominal operations [1, 2]. The robotic platform enables exploitation of the individual layers of the abdominal wall. Virtually any well-established surgical plane of the abdominal wall can be exploited and dissected for the subsequent placement of mesh in a sublay position, effectively protected from the visceral cavity by the body's own autologous tissue. While this approach has been demonstrated with conventional laparoscopy, it remains technically challenging [3].

In this chapter, we introduce the robotic transabdominal preperitoneal (rTAPP) approach for hernias of the anterior abdominal wall.

35.1.1 Surgical Anatomy

It is critical to have a thorough understanding of the layers of the abdominal wall in order to properly execute this technique. The technique of r-TAPP ventral hernia repair is borrowed from conventional laparoscopic TAPP for inguinal hernias in which the peritoneum is incised and dissected off the transversalis fascia, the hernia sac is reduced, and a mesh is placed within this retroinguinal space. For hernias of the anterior abdominal wall, preperitoneal mesh size is based on the original size of the defect and adheres to the well-established principles of maintaining 5 cm overlap in all directions.

This approach is best suited for smaller or medium size hernias that do not require component separation and can include hernias in atypical locations such as flank, suprapubic, retrosternal, and subxiphoid defects.

The authors feel that there are many advantages to placing mesh in a preperitoneal position:

1. Eliminates the requirement for placing coated intraperitoneal mesh (IPOM).
2. Allows the mesh to incorporate on both faces, eliminating placement of full-thickness transfascial suture fixation which is associated with both acute and chronic pain [4, 5].
3. Minimizes complications associated with leaving mesh in an intraperitoneal position, i.e., adhesions and bowel fistula.

35.1.2 Preoperative Considerations

Obtaining a thorough history and physical is mandatory to coordinate and execute an effective preoperative plan. Specifically, certain comorbidities, such as diabetes, obesity, smoking, prior hernia repairs, and prior history of abdominal wall infection, may critically affect the approach as well as the risk/benefit ratio for surgical intervention versus watchful waiting. The majority of primary umbilical hernias detected on physical exam warrant no preoperative further work-up.

CT scan of the abdomen and pelvis may be ordered for atypical hernias or small to moderate incisional hernias in order to correctly diagnose and delineate the size, position, as well as the content of the hernia defect.

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_35

35.2 r-TAPP Hernia Repair for Umbilical or Small Mid-Abdominal Incisional Hernia Repair

35.2.1 Patient Positioning

Patients with small mid-abdominal midline defects are positioned supine with the arms tucked unless trocar access to the lateral abdomen is obscured by the position of the tucked arm. In this situation, the arm is abducted 90° from the trunk. In patients with small torsos, it is helpful to position the patient under the kidney rest at the level of the umbilicus (Fig. 35.1). After obtaining safe intraperitoneal access, the kidney rest is raised which increases the distance between the costal margin and the anterior superior iliac spine. This allows for port placement with adequate separation. Patient positioning must be performed prior to docking of the robot. Foley catheterization is not generally required unless the surgeon expects a prolonged case or the hernia defect extends to the lower abdomen.

35.2.2 Port Positioning, Docking, and Instrumentation

The positioning of ports is similar to conventional laparoscopy (Fig. 35.2). It is important to place the trocars as far from the defect as possible without sacrificing range of motion based on potential collisions with the upper and lower extremities.

The first step in any minimally invasive surgery is to gain safe intra-abdominal access which may be difficult in the multiply operated abdomen. Sites of previous operative intervention will certainly influence the strategy. Optical entry with a 5 mm trocar at Palmer's point with or without initial Veress needle insufflation in the left upper quadrant is generally safe.

A 12 or 8 mm trocar for the camera is placed as far lateral to the ipsilateral edge of the defect. As a general rule we place the camera trocar a minimum of 15 cm away from the ipsilateral edge of the hernia defect. This allows for visualization, dissection, and instrumentation on the side closest to the ports. An 8 mm robotic trocar is placed in the lower lateral abdomen and the initial 5 mm optical trocar is then replaced with an 8 mm trocar. Final configuration of the trocars for an SI robot is typically in a V configuration (Fig. 35.2). Additional trocars on the contralateral abdomen or an assist trocar is typically unnecessary, but this may vary depending on surgeon comfort.

Once ports are placed and positioning is satisfactory, the robot is docked directly over the lateral abdomen and in line with the trocar sites (Fig. 35.3). Instrumentation consists of a grasper, monopolar scissors, and a needle driver. A 30° up scope is used to begin the case and may need to be switched to a 0 or 30° down when progressing to the contralateral abdomen.

35.2.3 Adhesiolysis and Developing a Preperitoneal Plane

As with conventional laparoscopy, the anterior abdominal wall is cleared of all adhesions to delineate the full extent of the defect as well as uncover any other sites of herniation. This must be performed meticulously to avoid not only injury to intraperitoneal viscera, but also to avoid injury to the peritoneum which may complicate preperitoneal dissection. If bowel manipulation is required, a lower grip strength grasper is utilized to avoid iatrogenic serosal injury.

Starting a minimum of 5 cm from the edge of the defect the peritoneum is incised using scissors (Fig. 35.4). This will allow for the placement of mesh with a minimum of 5 cm overlap on the side ipsilateral to the working ports. The ideal

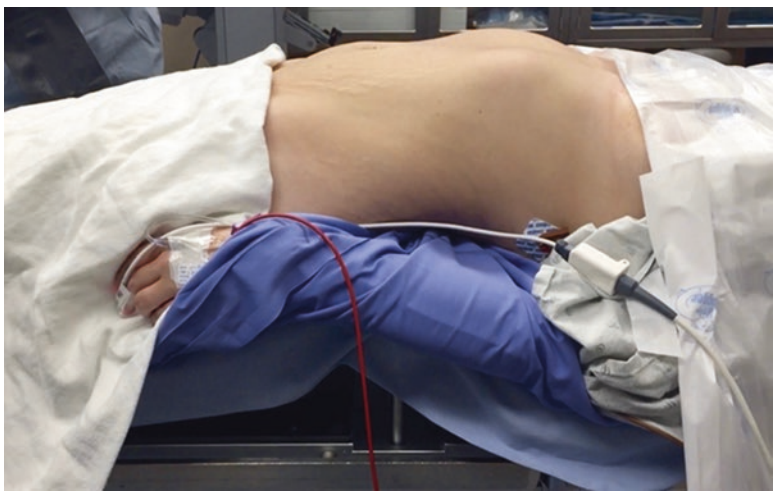


Fig. 35.1 Kidney rest positioning

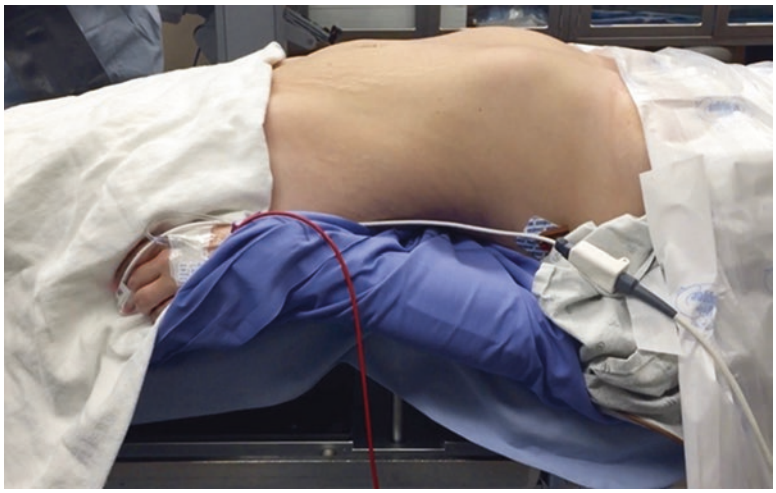


Fig. 35.2 rTAPP port position

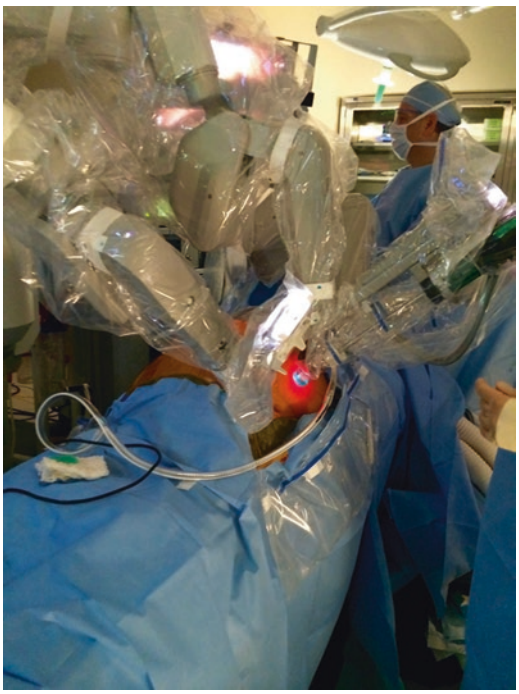


Fig. 35.3 rTAPP docking for midline abdominal wall hernias

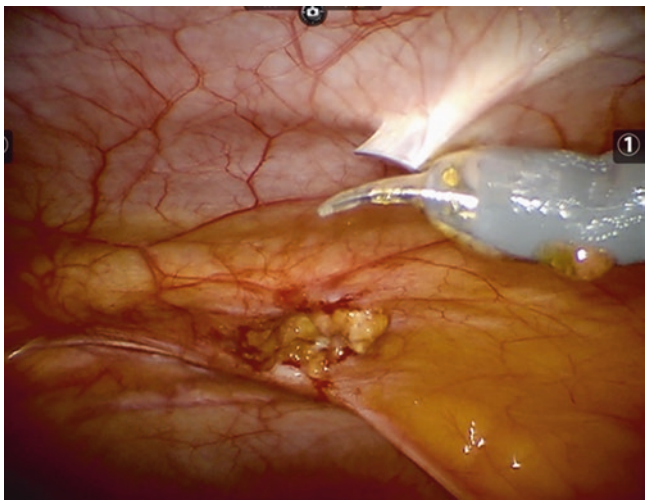


Fig. 35.4 Peritoneal incision

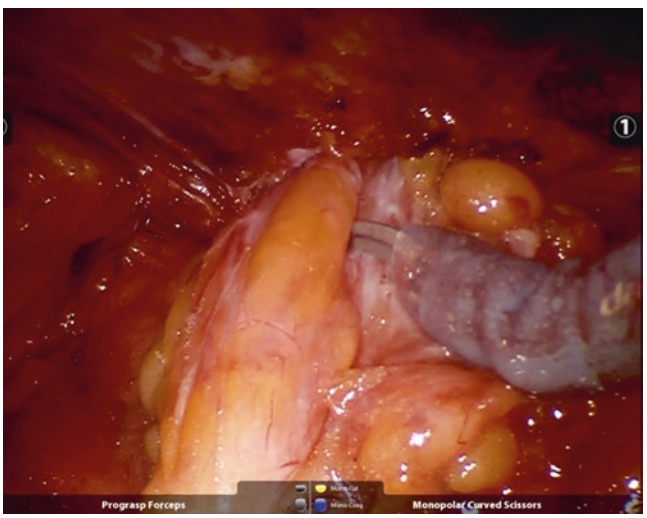


Fig. 35.5 Reducing the hernia sac

location to start the incision is often made within the visible preperitoneal fat that underlies the rectus muscle. The plane for dissection is more easily entered in this manner without causing disruption of the overlying posterior sheath. The preperitoneal plane is developed widely in a cephalad to caudad direction with a combination of meticulous blunt and sharp dissection. Sweeping with the blunt edge of the scissors is an effective technique to separate the peritoneum off the posterior sheath. Cautery is judiciously applied so as to avoid thermal injury which may result in peritoneal defects. The hernia sac is reduced and further dissection continues laterally (Fig. 35.5). Wide preperitoneal dissection is performed to allow for the placement of a large mesh based on the original

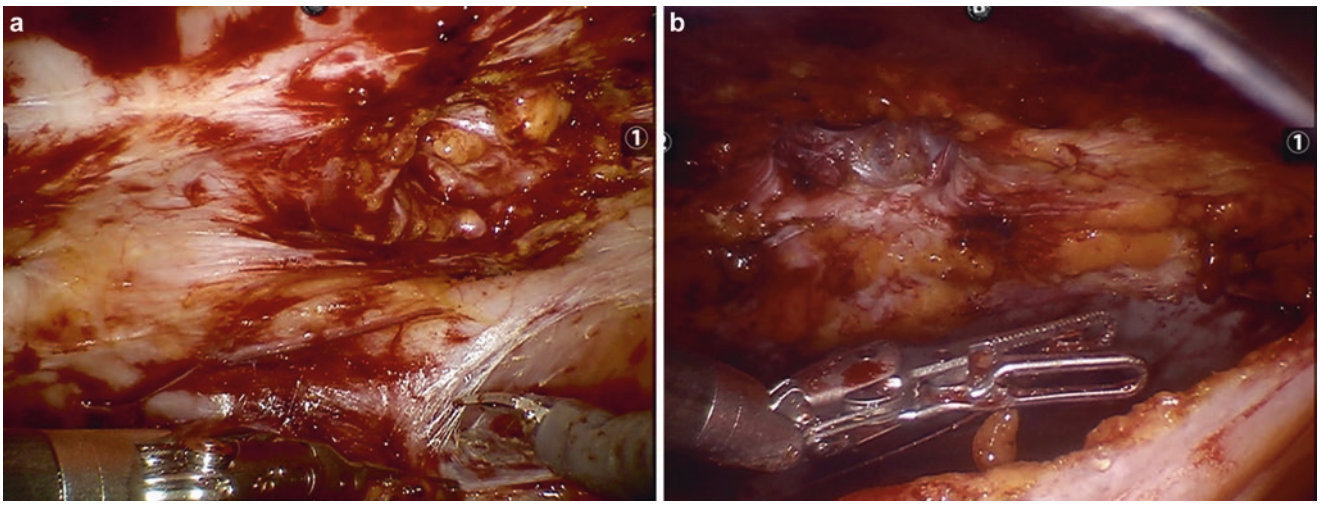


Fig. 35.6 (**a**) Preperitoneal dissection; (**b**) preperitoneal dissection

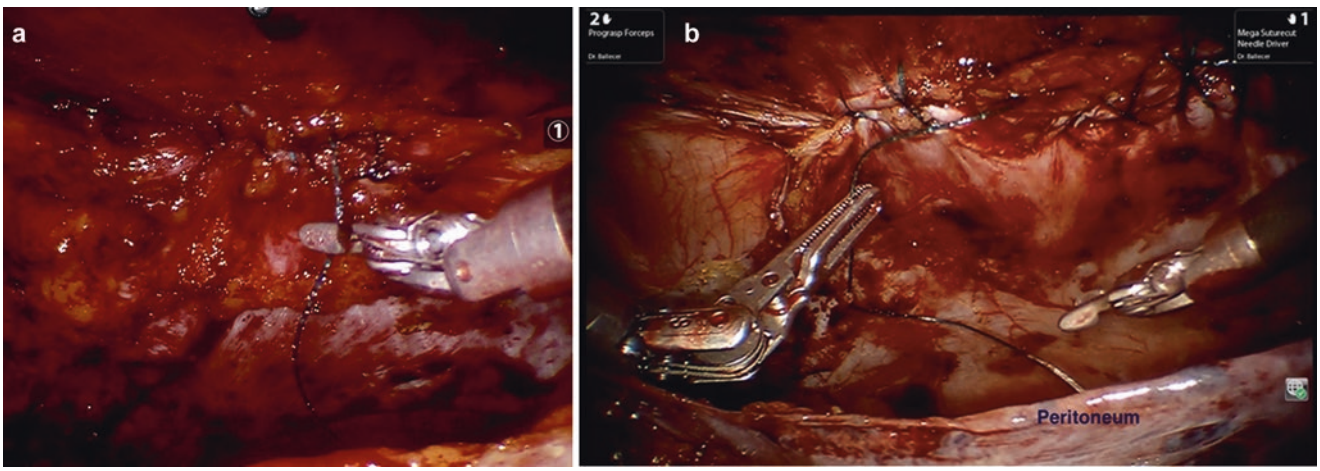


Fig. 35.7 (**a**) Primary defect closure; (**b**) primary defect closure

size of the defect (Fig. 35.6a, b). If the preperitoneal space is deemed inaccessible, the procedure may be converted to placement of an intraperitoneal coated mesh subsequent to primary closure of the defect.

35.2.4 Primary Closure of Defect

After the preperitoneal space is widely dissected, the hernia defect is primarily closed with absorbable barbed suture in a running fashion (Fig. 35.7a, b). The subcutaneous tissue situated at the dome of the defect is incorporated within the primary closure, effectively obliterating the anterior dead space in order to minimize the risk of seroma formation. Desufflation of the abdominal cavity to a pressure of 6–8 mmHg may facilitate primary closure.

35.2.5 Mesh Placement, Fixation, and Reperitonealization

An appropriately sized uncoated mesh is introduced into the abdominal cavity via the 8 mm trocar. The mesh is placed flat against the abdominal wall and fixated with either tacks or sutures placed at cardinal points (Fig. 35.8a, b). A minimum of fixation points are used to accomplish flat approximation of mesh against the abdominal wall.

Following adequate fixation, the peritoneum is re-approximated to completely cover the mesh with either running suture or tacks (Fig. 35.9a, b). Peritoneal rents should be repaired so as to not leave mesh exposed to the visceral content. All port sites 10 mm or greater are closed with absorbable suture.

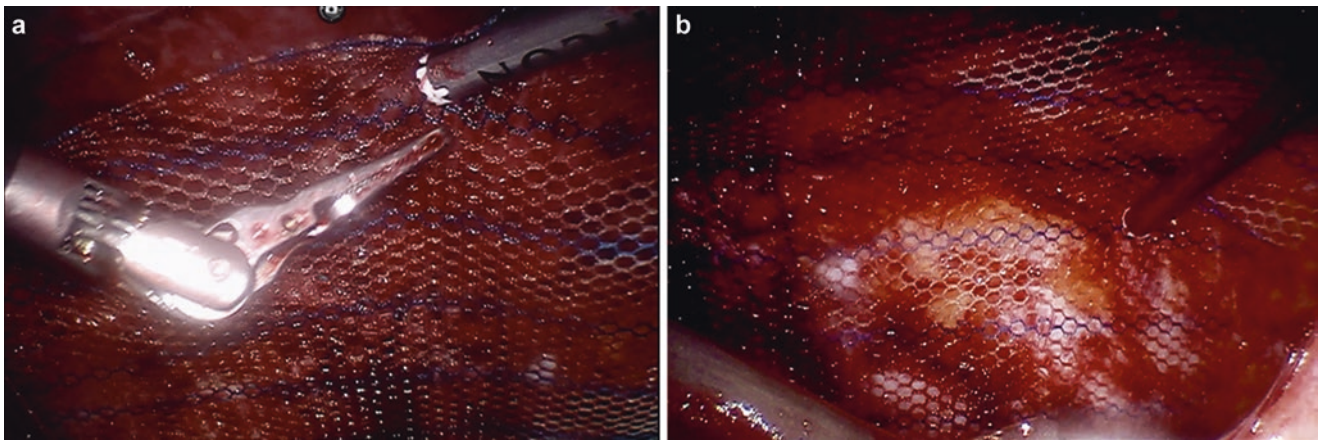


Fig. 35.8 (**a**) Mesh placement and fixation; (**b**) mesh placement and fixation

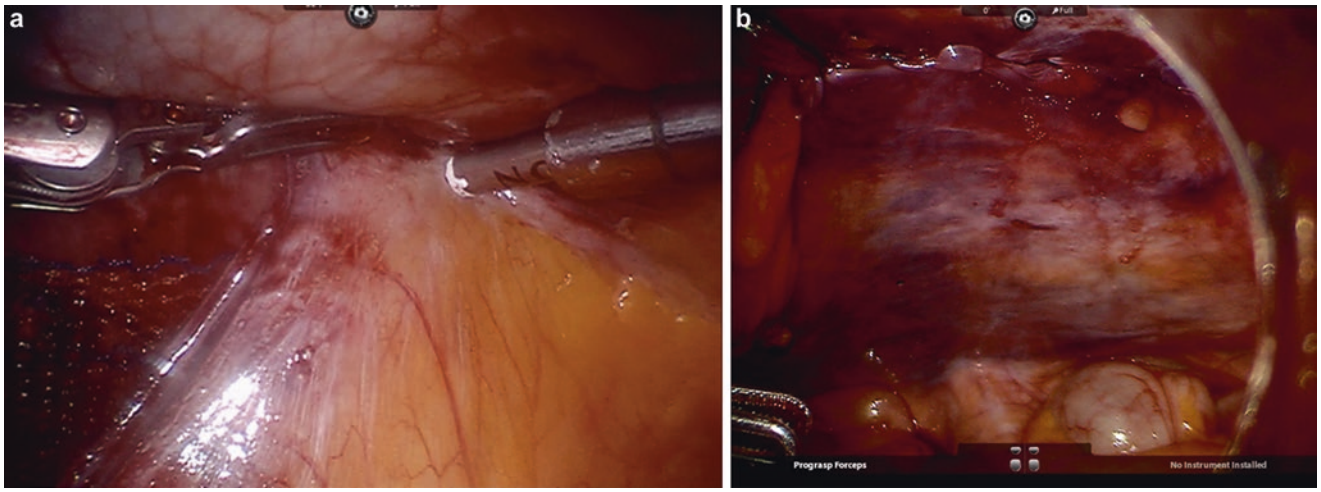


Fig. 35.9 (**a**) Tack reperitonealization of mesh; (**b**) suture reperitonealization of mesh

35.3 rTAPP Repair of Atypical Hernias

35.3.1 Introduction

Atypical hernias such as suprapubic and retrosternal hernias are classically more difficult to repair due to anatomical constraints in dissection as well as limited points of fixation due to bony prominences. Wide preperitoneal dissection is required to gain adequate overlap of reinforcing mesh following defect closure. Suprapubic hernias require wide dissection of the retropubic space, bladder mobilization, and entry into the space of Retzius.

35.4 rTAPP Repair of Suprapubic Hernias

35.4.1 Patient Positioning, Trocar Placement, and Docking

The repair of suprapubic hernias require a wide dissection of the retropubic and Retzius space to accommodate an adequately sized mesh which extends well beyond the area of the parietal defect. This may require exposure of the myopectineal orifice bilaterally in order to achieve 5 cm overlap in all directions. Therefore, a thorough comprehension of the anatomy of these spaces is required to both minimize the potential for injury and execute a durable repair which minimizes the risk of recurrence.

The patient is placed in supine lithotomy position with both arms tucked. A three-way Foley is placed to distend the bladder for proper identification. The camera port is placed at least 15 cm above the cephalad aspect of the suprapubic defect. Two instrument ports are placed in line with the camera trocar (Fig. 35.10). The patient is placed in a Trendelenburg position and the robot is docked between the legs which enables complete evaluation and dissection of the right and left retropubic spaces (Fig. 35.11).

35.4.2 Operative Steps

A preperitoneal plane is incised a minimum of 5 cm cephalad to the superior aspect of the hernia defect. Dissection is carried

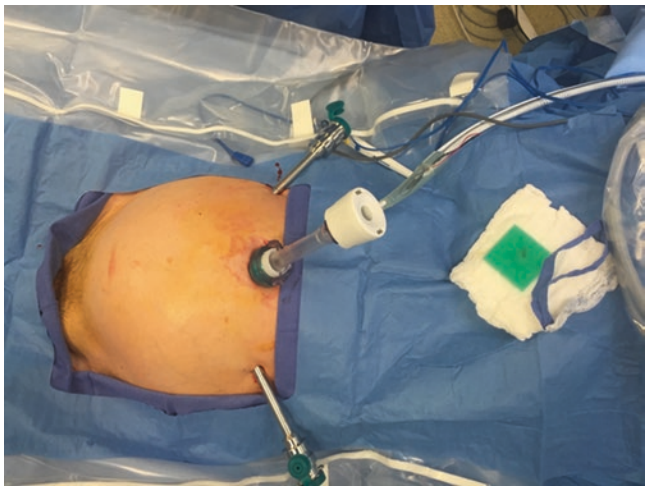


Fig. 35.10 Port position and docking for suprapubic hernias

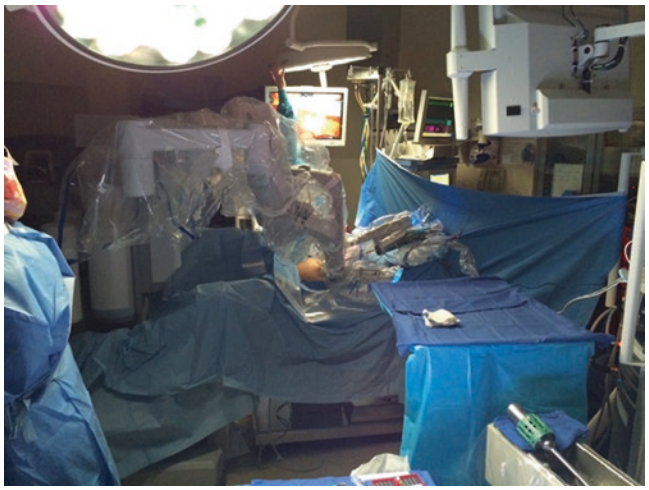


Fig. 35.11 Docking for suprapubic hernias

widely, encompassing at minimum both the right and left lateral umbilical ligaments in order to accommodate a large sheet of overlapping mesh.

The hernia sac is encountered and reduced. The superior dome of the bladder may occupy the hernia sac and therefore, careful dissection is performed to avoid bladder injury. Proper identification of the bladder is facilitated by instilling 200–300 cc of saline into the bladder (Fig. 35.12). The retroinguinal space (space of Bogros) is developed bilaterally to expose Cooper's ligament. Posterior mobilization of the bladder reveals the space of Retzius (Fig. 35.13). This space can be dissected inferiorly to insure adequate overlap of mesh inferior to the caudal aspect of the hernia defect. For larger suprapubic hernias, the bilateral retropubic spaces are exposed (Fig. 35.14a, b).

The hernia defect is primarily closed with running barbed suture (Fig. 35.15). Partial desufflation of the abdominal cavity may be required to facilitate defect closure. The space of preperitoneal dissection is then measured and an adequately sized mesh is introduced into the preperitoneal space. Absorbable tacks or sutures are placed to secure the mesh to the abdominal wall. A series of interrupted sutures are used to secure the mesh to Cooper's ligament bilaterally, as well as the symphysis pubis (Fig. 35.16). Upon completion of mesh fixation, the mesh is reperitonealized with running suture or tacks.

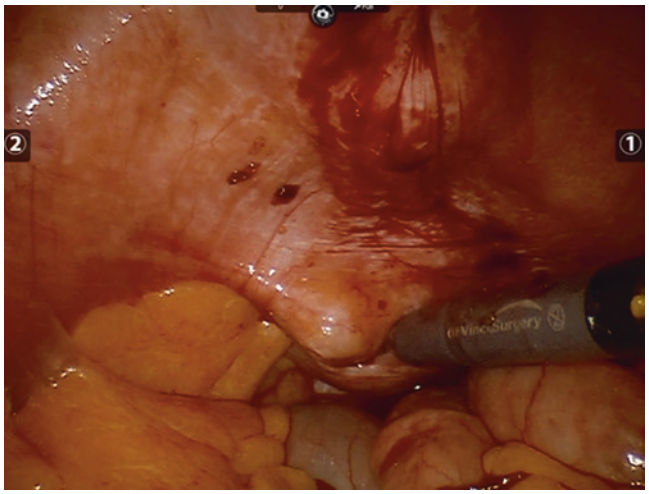


Fig. 35.12 Bladder distension

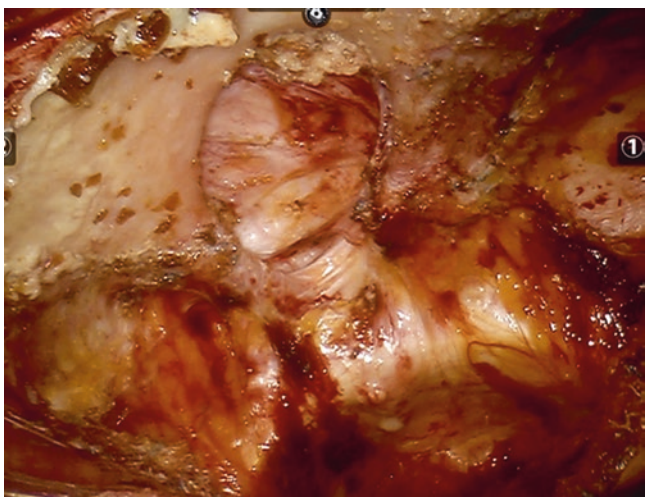


Fig. 35.13 Space of Retzius

35.5 rTAPP Repair of Morgagni Hernias

35.5.1 Clinical Anatomy

As the rTAPP approach can be employed for hernias of the lower abdomen, upper abdominal hernias are amenable to the robotic preperitoneal technique. To illustrate this versa-

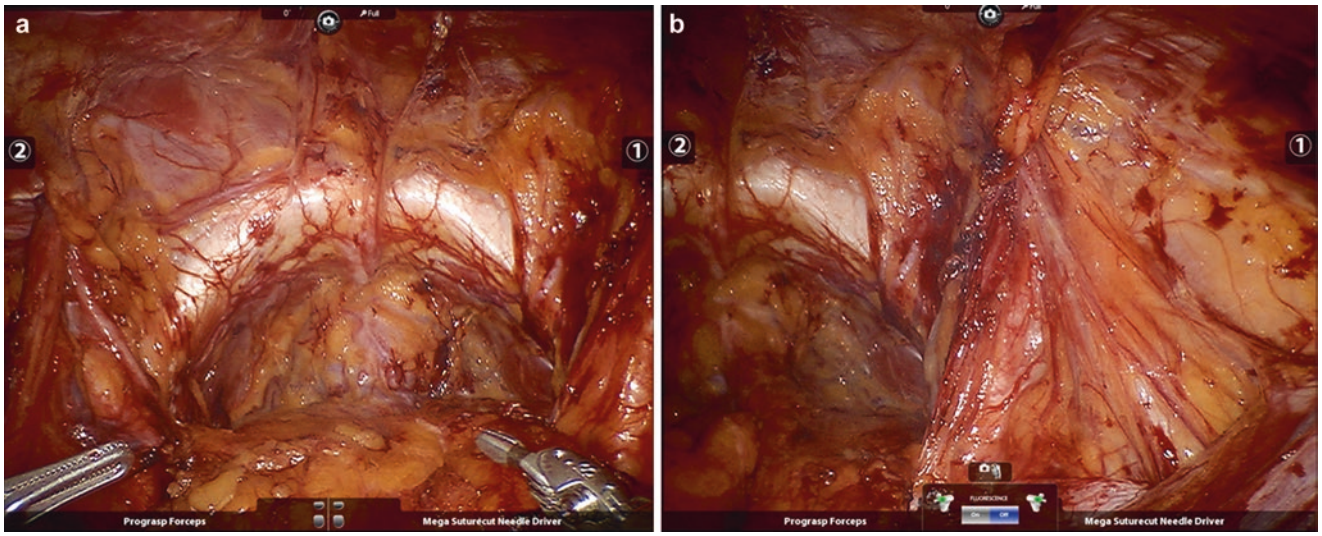


Fig. 35.14 (**a**) Wide bilateral myopectineal dissection; (**b**) wide bilateral myopectineal dissection

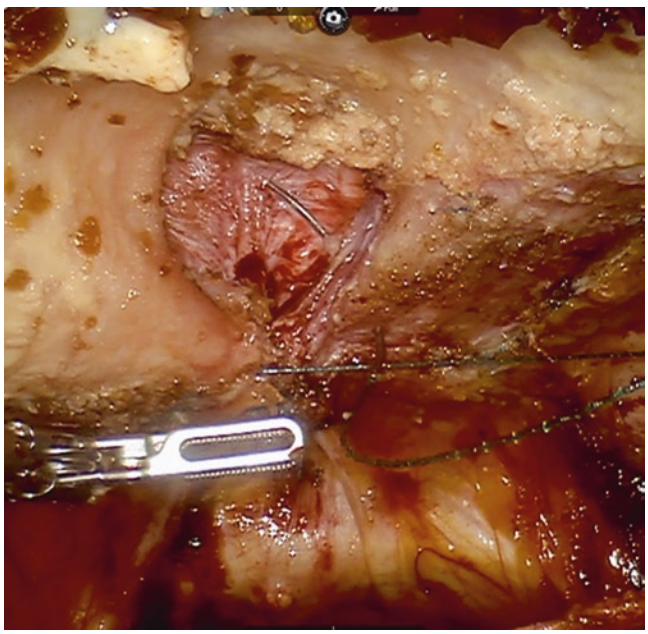


Fig. 35.15 Primary defect closure

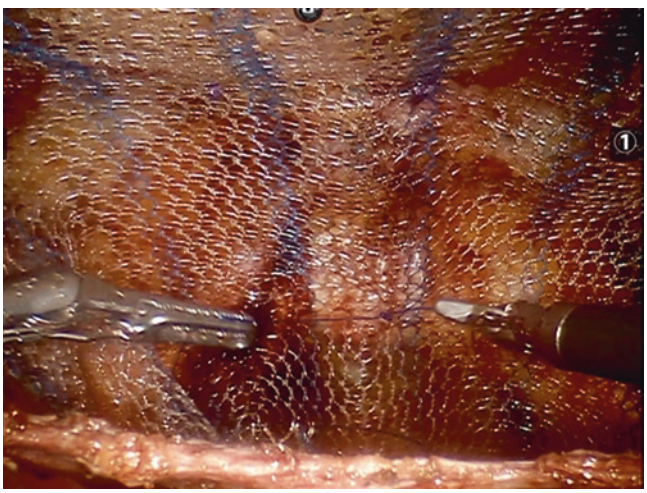


Fig. 35.16 Mesh placement and fixation

tility, we describe the rTAPP repair of anterior diaphragmatic hernias such as the hernia of Morgagni.

Morgagni or retrosternal hernias are considered as rare forms of congenital diaphragmatic defects located immediately adjacent to the xiphoid process of the sternum. Its hernia content can include omentum, liver, or any portion of the GI tract, all of which must be reduced safely prior to preperitoneal dissection. Patient positioning and operative steps are similar to rTAPP repair of high epigastric and subxiphoid hernias.

35.5.2 Patient Positioning, Trocar Placement, and Docking

Patient is placed in a supine position with the arms tucked and padded. The camera port can generally be placed at the paraumbilical position assuming the umbilicus is situated at least 15 cm from the xiphoid process (Fig. 35.17). Two 8 mm instrument trocars are then placed 10 mm apart from the camera port. The patient is placed in a slight reverse Trendelenburg position and the robot is then docked over the left or the right shoulder which allows for unimpeded access

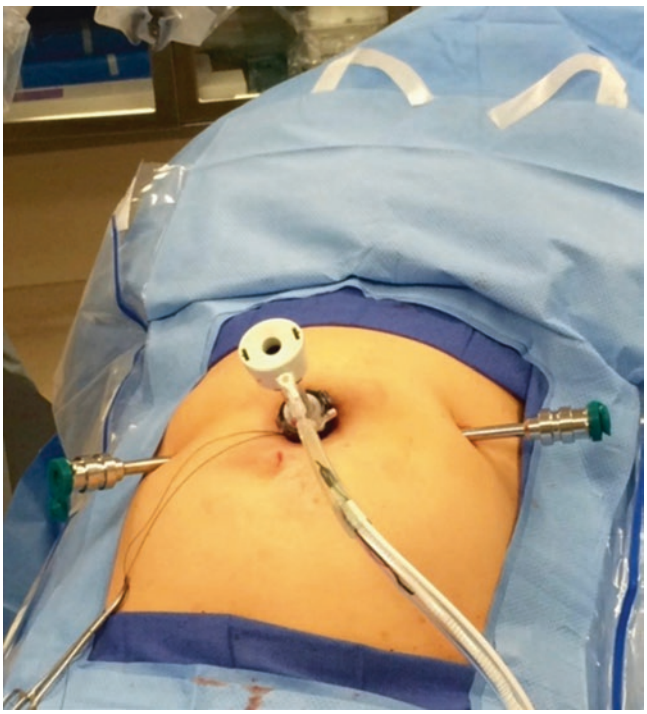


Fig. 35.17 Morgagni hernia port placement

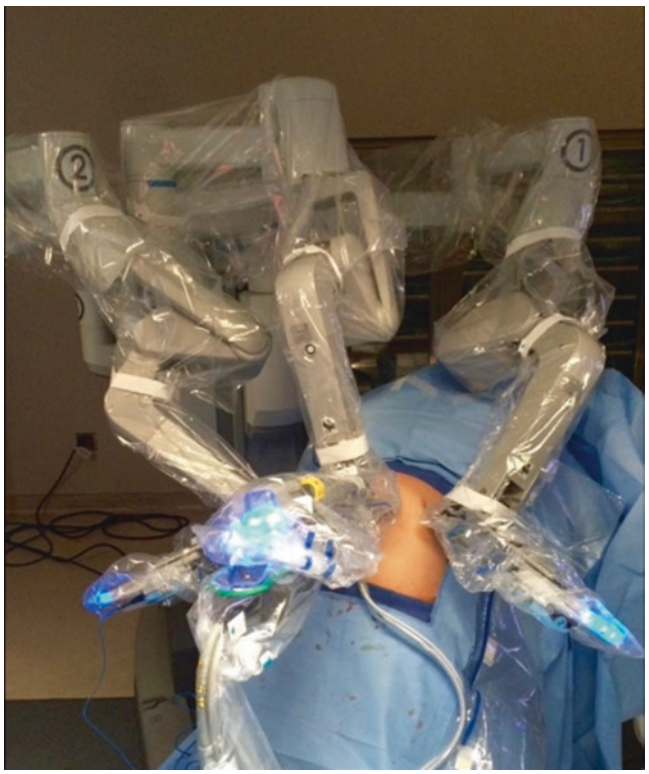
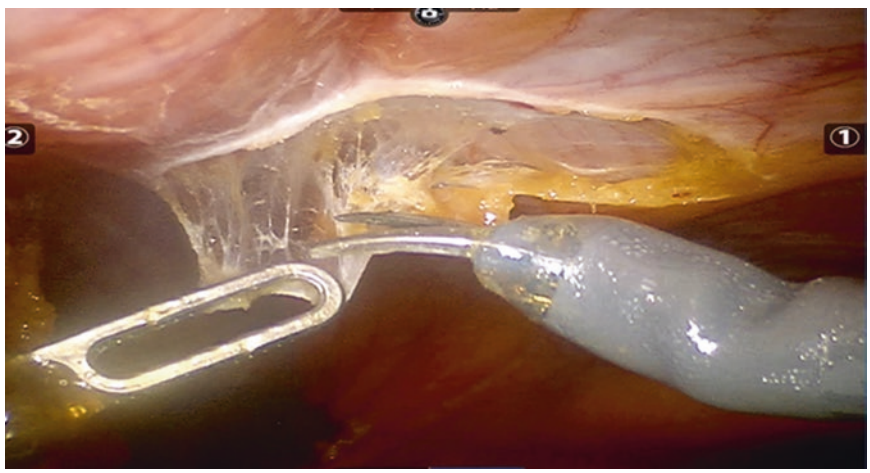


Fig. 35.18 Morgagni hernia docking position

Fig. 35.19 Peritoneal incision for Morgagni hernia



to both the left and right upper quadrants (Fig. 35.18). A 30° up camera is utilized to effectively view the anterior abdominal wall.

35.5.3 Operative Steps

As described above, meticulous adhesiolysis is performed to clear the anterior abdominal wall while avoiding injury to the peritoneum. The hernia content of the diaphragmatic defect is carefully reduced.

Incision of the peritoneum is performed at least 5 cm caudal to the xiphoid process (Fig. 35.19). Confluent with preperitoneal dissection, the falciform ligament is also mobilized off the abdominal wall providing a source for peritoneal tissue for the eventual reperitonealization of mesh. Once the hernia sac is encountered, it is reduced. Preperitoneal dissection is continued cephalad to the defect including the central tendon to allow for adequate superior overlap.

Primary closure of the defect is performed with either running barbed suture or interrupted sutures (Fig. 35.20a, b).

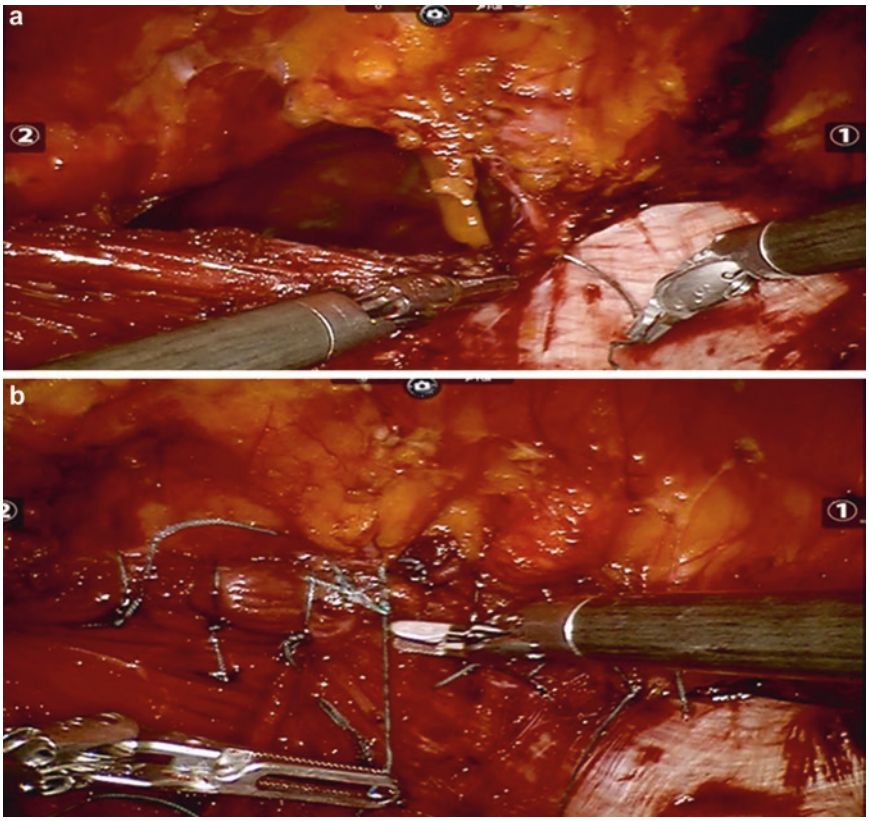


Fig. 35.20 (**a**) Diaphragmatic defect closure; (**b**) diaphragmatic defect closure

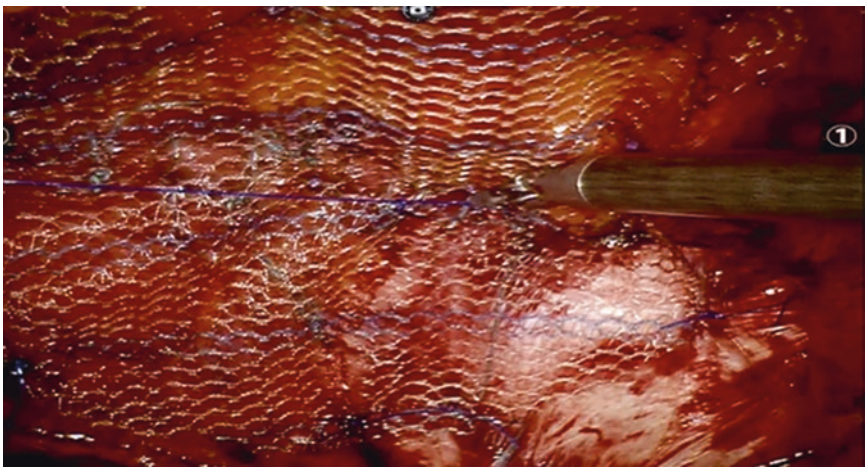


Fig. 35.21 Subdiaphragmatic suture fixation

Suitable mesh is chosen based upon the original defect size. Mesh is then placed within the preperitoneal pocket. Either tacks or sutures are employed to secure the mesh to the abdominal wall. Sutures are placed above the level of the costal margin. Subdiaphragmatic sutures are meticulous placed at cardinal points for superior fixation of mesh (Fig. 35.21). The mesh is then reperitonealized by re-approximating the peritoneal flap with either suture or tacks.

35.6 Conclusion

The rTAPP approach in the repair of abdominal wall and diaphragmatic hernias are reproducible for smaller defects not requiring component separation. Not only is this approach reproducible, but it is also versatile in the repair of virtually any hernia in any location not requiring myofascial advancement releases.

Potential advantages of the technique include minimizing the risk of mesh exposure to the intraperitoneal content, the ability to use a less expensive uncoated mesh, and potentially decreasing postoperative pain by utilizing less abdominal wall fixation as compared to that of traditional IPOM.

The rTAPP approach should be considered as another possible option in the repair of abdominal wall hernias. It is important to note that the dissection of a preperitoneal plane may be inaccessible due to numerous reasons including prior surgical interventions and the requirement of mesh explantation. Therefore, it is important to be well versed in other options and techniques of repair.

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Robotic IPOM-Plus Repair

36

Eduardo Parra-Dávila, Estefanía J. Villalobos Rubalcava, and Carlos Hartmann

36.1 Introduction

Ventral hernia repair is one of the most common surgical procedures; however, the complexity is increasing and the repair remains a constant challenge [1–3].

Karl LeBlanc introduced the laparoscopic approach for ventral hernia repair in 1992.

Its recurrence rates are similar to open ventral hernia repair rates, and it leads to improvements in recovery time, decrease in hospital length of stay, and complication rates. The initial technique described in the literature detailed placement of a mesh after reducing the contents of the hernia, but did not include closure of the abdominal wall defect (bridging) [1–3].

Defect closure by laparoscopy requires a high degree of specialized dexterity and incurs a significantly longer procedure time, which can deter the method [4, 5]. The bridging technique for hernia repair can cause functional problems with patients, due to no musculo-aponeurotic coverage, resulting in adynamic areas of the abdominal wall. The bulging of the mesh into the hernia sac and development of a seroma at the created "dead" space are the most common complications [1, 2, 5, 6].

The major goal of any ventral or incisional hernia repair is to restore the integrity of the abdominal wall anatomy and unify of the rectus muscles.

36.2 Definition

IPOM-Plus repair, as described in the guidelines for laparoscopic treatment of ventral and incisional abdominal wall hernias of the International Endohernia Society, is a superior repair, by closing the defect with two options: running suture intra-abdominally or interrupted transfascial suture transabdominally [1].

The robotic approach allows smoother intracorporeal suturing of the fascia allowing primary repair, improved physiological abdominal wall movements, and greater overlap of the mesh surrounding the defect's edges. Robotic ventral hernia repair also offers enhanced suturing options under excellent visualization for repair of difficult hernias with bony margins, such as lumbar, suprapubic, and subcostal hernias [7–9].

The IPOM-Plus technique can reduce the hernia size to zero, eliminating bulging, decreasing the rate of seromas, and reducing the patient's discomfort [1, 2]. It also has recurrence rates compared with classical IPOM, mimicking open repair [1, 5].

Limitations of this technique are clear. Large defects are not feasible to close without tension. Occasionally a combination with the endoscopic components separation technique or a transversus abdominal release [10] may be needed to lower the tension and enable the closure [2, 4]. Other challenges include trocar placement, instrument collisions, difficulty with angulations, and removal of soft tissue when indicated [4].

36.3 Surgical Technique

36.3.1 Patient Positioning

For the procedure, the patient is given general anesthesia with endotracheal intubation. Intravenous prophylactic antibiotics are given. The patient is placed in the supine position with the arms tucked laterally on the side.

36.3.2 Trocar Placement

Access to the peritoneal cavity is gained using a Veress needle placed in the left upper quadrant subcostal region at the midclavicular line or an area where no previous surgeries are

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_36

noted in order to avoid adhesions. After adequate pneumoperitoneum is established, a 5-mm optiview port is placed in the lateral position on the opposite side of the hernia. It is critical to place the ports as far from the defect as possible to allow for increased range of motion and effectiveness. Depending on the size of the abdomen, three or four robotic arms are used and additional placement of an assistant port is common. The most lateral position of the camera and two instrument arms will allow for full range of motion which facilitates dissection and suturing on the hernia defect. The accessory port is used to aid with the mesh introduction, traction, suction, suture removal, and suture cutting.

36.3.3 Docking

Patient position manipulation must be performed prior to docking of the robot. The robotic cart is driven directly towards the abdomen and over the trocar sites. The robotic docking is done from the side of the hernia to align the center column of the robot with the target and the camera.

36.3.4 Adhesiolysis

Adhesiolysis of the abdominal wall to isolate the hernia defect must be performed meticulously so as to avoid iatrogenic injury to the abdominal viscera. For laparoscopic surgery lysis of adhesions is the most challenging, but the Da Vinci Surgical System platform facilitates adhesiolysis through its 3D visualization, extended range-of-motion, tremor-less precision, and superior ergonomics.

Complete adhesiolysis is mandatory to insure complete evaluation of the abdominal wall. If necessary, the falciform ligament is taken down to allow the placement of mesh against the abdominal wall. In the setting of dense adhesions the robotic harmonic scalpel or Da Vinci vessel sealer may facilitate hemostasis.

36.4 Closure of the Defect

The entire repair is performed under direct visualization, with precise placement and confirmation of depth into the posterior fascia for all sutures placed. The ability to primarily close defects without component separation is based on the principles of Ramirez regarding width and location of the hernia defect [11]. Of course this is based on open technique and not working against the forces of pneumoperitoneum. As a general rule, less than 10 cm wide defect is amenable to primary closure but also depends on body habitus, age, and abdominal wall compliance. Desufflating the abdominal cavity to 6–8 mmHg pneumoperitoneum may be necessary. The fascial sutures encompass 1-cm bites of fascia, minimizing trauma to the abdominal wall, the robotic platform allows the surgeon to take precise bites of tissue to anchor the mesh repair. Successful primary closure of the defect is facilitated by the use of the barbed V-loc suture (Covidien) or Stratafix suture (Ethicon).

The suture is introduced into the intra-abdominal cavity through the 8 mm dV trocar or the accessory port. By opening and bending the needle slightly will facilitate both introduction and subsequent removal of the suture will accomplish this if an 8 mm trocar is used.

36.4.1 Placement of Mesh with Running Suture

After choosing the size of the mesh, it is rolled and prepared to be inserted into the peritoneal cavity. Once inside, it is unrolled and oriented. With the mesh positioned on the abdominal wall by using a scroll technique or by using a self-expanding mesh device (Echo mesh, Bard), it should be fixated by the use of a full length nonabsorbable monofilament suture (00 or 0). The suture is introduced into the intra-abdominal cavity through the trocar of the needle holder. Because the mesh is placed during full insufflation, it is likely that as the abdomen is desufflated the mesh will loosen a bit. A tacking device or sutures or a self-expanding mesh maybe used to place the mesh to the anterior abdominal wall.

In a running fashion, the suture is then placed around the circumference of the mesh. It may be necessary to use a few more sutures for larger prosthetics.

36.4.2 Closure of the Port Defects

Upon completion of mesh fixation, the robot is undocked. Only the assist 10–12 mm trocar fascial sites are closed with a suture passer under direct laparoscopic vision.

36.5 The da Vinci Xi

With the new system the docking is simpler and is designed to be user friendly. It is guided by a "port placement menu" and a laser light for the best approach.

The patient can be repositioned safely without undocking when used with the new operating table, and the learning curve for this system appears to be shorter than anticipated.

This robot has smaller and thinner arms with newly flex joints that offer a wide range of motion than the earlier versions making the reach of different areas of the abdomen easier. The Xi robot has been optimized for multi-quadrant surgical areas.

The scope can be placed into any of the four robotic arms with its autofocus reassigning the camera to a different port with utilization of the retargeting feature.

The laparoscope has a digital end mounted crystal-clear camera on the top of the scope for improved and better vision.

With the new system the double docking for larger hernias is easier since the robotic boom rotates 180° to accommodate to the other side without moving the patient or the column of the robot as in the components separation technique.

In summary, the new robot allows closer port placement, double docking without moving the patient or the operating room table by rotating the boom to the contralateral side and has more reach since the arms are longer than the previous versions.

Innovations of new surgical platforms will also improve ergonomics and efficiency in minimally invasive surgery.

36.6 Pearls

Reconstruction of the rectus muscle in robotic hernia repair improves the functionality of the abdominal wall.

Additional components separation facilitates the closure and should be used for larger defects.

Robotic ventral hernia repair facilitates the operator to offer traditional open repair techniques (Rives–Stoppa) through minimally invasive incisions.

The robotic approach visualizes the entire abdominal wall, thus detecting any impalpable hernia defect that also may be repaired at the same time. The successful primary closure of the defect is facilitated by the three-dimensional imaging and superior ergonomics.

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Laparoscopic Closure of Defect

37

Sean B. Orenstein

37.1 Introduction

While both open and laparoscopic techniques allow successful ventral herniorrhaphy, there are distinct advantages to minimally invasive approaches. Benefits of laparoscopic ventral hernia repair (LVHR) include reduced wound morbidity including infection, quicker return of bowel function, reduced length of stay, and improved cosmesis [1–5]. Many consider restoration of an intact midline linea alba to be crucial for a successful repair in open approaches; however, this philosophy has not become standard practice for laparoscopic repairs. Commonly, LVHR are performed with mesh placed as an underlay, essentially bridging one or multiple defects. In an effort to provide a more durable repair, laparoscopic defect closures have been implemented to create a more functional repair by combining primary defect closure along with mesh reinforcement. Thus, laparoscopic defect closure combines attributes more aligned with traditional open repairs, while still preserving the benefits of minimally invasive surgery.

37.2 Concept of Defect Closure

37.2.1 Abdominal Wall Mechanics

Laparoscopic VHR traditionally involves reduction of hernia contents followed by placement of a large mesh prosthetic in an underlay fashion, thereby bridging the defect. While this may be successful for some repairs it has the potential to put undo tension and shear force at the hernia repair site. Such tension can result in mesh "eventration," whereby the mesh gets pushed up through the unclosed hernia defect with resultant hernia recurrence. Adequate transfascial mesh fixation may prevent mesh eventration; however, even with wide mesh overlap and suture fixation, the Law of LaPlace ($T = P \times R/W$) dictates that there will be increased tension on the mesh directly underneath the unclosed defect [6–9] (Fig. 37.1). With intra-abdominal pressure being equal throughout the abdomen (Pascal's Principle), the Law of LaPlace has great potential to assist with hernia repairs utilizing underlay and sublay mesh placement by keeping the mesh pressed up against the abdominal wall or preperitoneal inguinal sites. However, this benefit can dramatically turn against us and negatively affect sites directly under unclosed hernia defects. The only way to equalize the tension on the abdominal wall is to close the areas with greater radius, i.e., the hernia defects.

The concept of defect closure may be more important now, given the severe rise in obesity. Increased abdominal mass and girth lead to increased intra-abdominal pressure in obese patients. Abdominal wall thickness affects tension, with a thinner walled region above the hernia defect resulting in increased tension at that site. Additionally, differing abdominal wall thickness adjacent to hernia defects may lead to shear stress transmitted to the mesh as a result of abrupt tension changes within the vicinity of defects. Thus, the increased width (radius), wall thickness, and pressure will lead to unfavorable physical dynamics at sites of abdominal wall defects, possibly leading to worse outcomes following traditional LVHR with bridging as our population continues to increase in size.

37.2.2 Functional and Dynamic Repair

One of the key goals of abdominal wall reconstruction (AWR) is medialization of the rectus abdominis muscles by restoring the linea alba, the major insertion point of abdominal wall musculature [10, 11]. By restoring the native anatomy, a more functional and dynamic abdominal wall is likely to be created. This is routinely discussed for open VHR; however, there is limited discussion for laparoscopic repairs. Bridging has been shown to significantly increase the risk for hernia recurrence

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_37

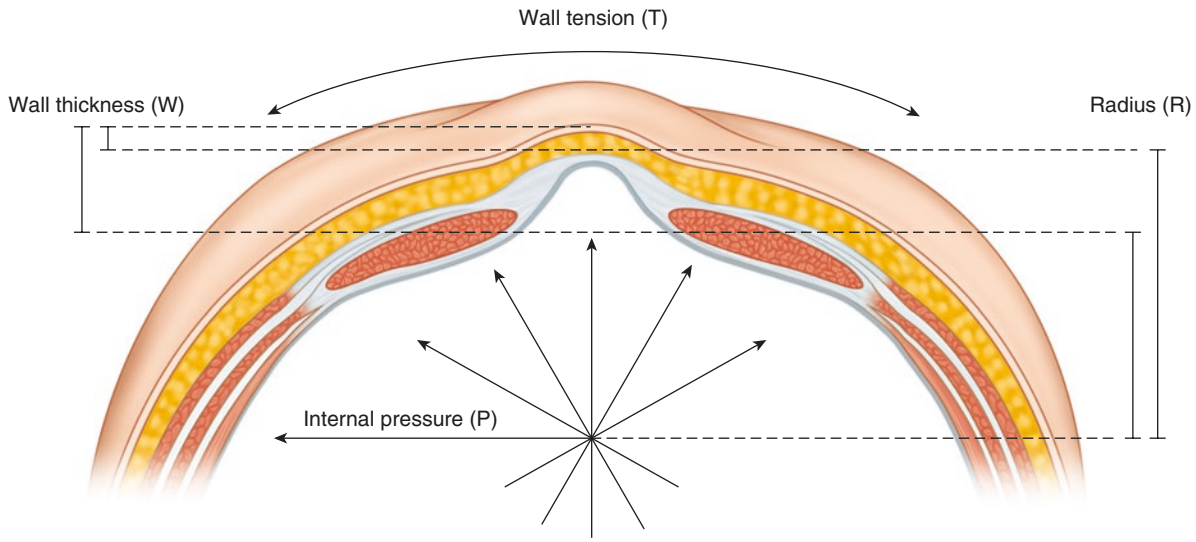

Fig. 37.1 Law of LaPlace. A simplified equation for LaPlace's law is $T = P \times R/W$, whereby T is the tension exerted on the abdominal wall; P is the intra-abdominal pressure, which, according to Pascal's principle, is equal throughout the abdominal cylinder or sphere; R is the radius; W is the wall thickness

as well as quicker progression to recurrence for open repairs [12]. If it makes sense to restore the abdominal wall to a more native and functional level in open repairs, then why not use the same philosophy for laparoscopic repairs? As already discussed, traditional LVHR typically relies on the support of a bridged defect with mesh prosthetic, which may be detrimental to the patient. Mesh bridging may result in regions of friction and shear force at the edges of the defect with excessive pressure centrally, leading to mesh instability, stretching of the sutures causing increased postoperative pain, as well as bulging [13]. Additionally, without direct contact between the anterior abdominal wall and the mesh there can be no ingrowth at sites of hernia defects. Closing the defect not only leads to equalization of tension along the mesh and abdominal wall, but also allows complete incorporation of the mesh prosthetic for a more durable repair.

Laparoscopic defect closure combines the components of primary fascial closure along with prosthetic mesh reinforcement. Recurrence rates for primary closure alone in open repairs are substantial, with recurrences seen in 18–63 %. The use of mesh has markedly reduced recurrence rates down to 2–32 % [14–18], thus making mesh reinforcement a necessary element of successful repairs, be it open or laparoscopic repair. However, even with mesh placement and routine trans-abdominal fixation significant tension may still exist along the primary fascial closure site. As discussed in our initial experience with defect "shoelacing" because of the increased tension on the fascial closure, additional trans-abdominal sutures are placed to off-load some of that tension [19]. By placing interrupted buttressing sutures on either side of the shoelace closure, tension is transferred from the closed repair to the mesh itself. Importantly, while some surgeons argue for double-crown tacking as the sole source of fixation during LVHR, this would not be sufficient for laparoscopic defect closure, as trans-abdominal fixation remains an essential component for defect closure repairs to off-load tension from the closed defect.

37.3 Advantages of Defect Closure

Because defect closure reduces the hernia width a smaller mesh can theoretically be used. A generous overlap of at least a 5 cm is still recommended. Therefore, with defect closure at least a 10–12 cm wide mesh is still required. Reduced implanted foreign body theoretically reduces fibrosis, scar plate formation, and visceral exposure to synthetic materials, all of which may impact patients' symptoms and mobility. While it is unclear what the true clinical significance in the long term is as there is limited data thus far, this author strives to use only what is necessary when it comes to implanted foreign bodies.

The benefit of reduced recurrence rate has not been completely elucidated for laparoscopic defect closure due to the lack of any randomized trials and only a small number of comparative studies, however, recent data is encouraging. In their review paper of the 11 studies involving LVHR with defect closure Nguyen et al. describe recurrence rates of 0–7.7 % [20]. Three of those studies retrospectively compared closure vs. nonclosure and discovered significant reductions in recurrence rates, with recurrence rates of 0–5.7 % for defect closure, compared to a range of 4.8–16.7 % for traditional bridged LVHR [21–23]. Newer retrospective studies display conflicting results for laparoscopic defect closure, with one study demonstrating favorable recurrence and wound morbidity in a large cohort of 1326 patients [24], while another study showed similar results in groups with or without defect closure [25].

Additional benefits of laparoscopic defect closure are based on obliteration of the dead space that is typically present in traditional bridged LVHRs. Reduction of the dead space results in decreased seromas and potential infectious complications of seromas. We previously described our cohort of 47 patients that underwent laparoscopic shoelace closure, none of whom returned with seroma or hernia recurrence [19]. Likewise, all other studies with the exception of one demonstrate low seroma rates, ranging from 0 to 11.4% [20]. Comparatively, LVHR without defect closure results in seroma rates of up to 32%, though many are not clinically significant [20, 26].

Additionally, if wound infections should arise requiring wound opening or if the skin dehisces, defect closure provides an additional barrier of tissue above the mesh, thus limiting mesh exposure and possible contamination or infection. Finally, defect closure may offer a cosmetic advantage in the long term. While initial postoperative wounds tend to demonstrate bunched up tissue under the skin, the lax tissues anterior to the defect tend to tighten up as myofibroblast contraction takes place, resulting in a reduction in subjective bulging and more cosmetically appealing repair.

37.4 Disadvantages of Defect Closure

Any technique that is novel or without randomized trials has its potential shortcomings, and not every patient is a candidate for laparoscopic defect closure. First, defect closure can result in significant fascial tension. While trans-abdominal buttressing sutures are routinely placed to offload tension onto the mesh for larger defects, closure of abdominal wall defects without significant laxity may result in excessive tension. This fascial strain may result in fascial dehiscence and possible hernia recurrence if insufficient mesh overlap exists. Also, because of the increased need for permanent trans-abdominal sutures there lies a greater risk for suture granuloma formation and possible suture abscess. It is, therefore, important to ensure all sutures are tied down appropriately and buried deeply within the subcutaneous tissue to reduce abscesses. Cosmetically, initial postoperative wounds may display signs of bunched up tissue over the repair. As discussed above, while this typically flattens out over time, it should be noted cosmetic benefits might not be apparent for weeks to months following repair.

Intraoperatively, there is an increased risk of bowel injury, as viscera can become entrapped within the hernia sac and sutures. Astute attention is required to reduce visceral entrapment. One of the possible strategies is to tie the knots down under direct visualization using low insufflation pressures. Finally, defect closure can result in significant postoperative pain as a result of fascial tightening as well as additional trans-abdominal sutures. Therefore, adequate multimodal analgesia is an essential part of postoperative management. Except for small defects, patients are routinely admitted for at least one night to ensure adequate pulmonary function and sufficient pain control prior to discharge.

37.5 Patient Selection

The size, quality, and location of the defect greatly determine whether laparoscopic repair with or without defect closure is feasible. In general, if the defect is too large or complex for defect closure then other means of repair should be strongly considered, including traditional (bridged) LVHR or open hernia repair. While there is no strict cutoff for width of defect able to be closed, I routinely close defects up to 6 cm in width and selectively for defects 6–8 cm. Large, multiple Swiss cheese defects or those with poor tissue integrity should be considered for traditional LVHR without defect closure or open repair.

Hernia location is another determination for defect closure. Flank hernias may be amenable to defect closure; however, care must be taken to avoid entrapment of neurologic structures and to secure the mesh appropriately with adequate overlap which may require bone anchors for secure fixation. Parastomal hernias can be repaired utilizing a Sugarbaker technique, using defect closure as an adjunct with LVHR. In this setting, the defect size is reduced enough to allow adequate room for bowel prior to placement of mesh. On the other hand, defects close to bony prominences such as subxiphoid defects may not be amenable to defect closure due to their proximity to the xiphoid process and costal margin, resulting in an inability to adequately reapproximate the fascial edges as well as risk injury to neurovascular structures. Suprapubic defects may be amenable to defect closure, provided there is adequate fascial tissue above the pubic bone. Very low suprapubic defects immediately adjacent to the pubis may not be amenable to defect closure, and may require a bridged repair.

37.6 Laparoscopic Defect Closure Technique

- Setup: Laparoscopic defect closure employs a combination of primary fascial closure of the hernia sites along with mesh prosthetic placement for reinforcement. The case is initiated using standard LVHR technique. Positioning the patient supine with arms tucked aids in adhesiolysis and tacking from various angles around the patient. For suprapubic or low midline defects a three-way Foley catheter is placed preoperatively for instillation of saline to assist in bladder identification. An iodine-impregnated plastic skin wrap is routinely placed to reduce skin flora contamination and to assist with external marking.
- Access: Access is typically achieved using optical trocar entry via left upper quadrant subcostal entry. 5-mm accessory trocars are placed under direct visualization, with eventual bilateral trocar placement after sufficient adhesiolysis. Eventually, a 12-mm trocar is placed to allow for mesh insertion. This trocar is placed in an area that will eventually be covered by mesh, typically as

close to midline as possible without going directly through the hernia sac. This allows for subsequent mesh coverage of the port site, thus reducing the chance of a trocar site hernia.

- Supplies:
  - #11-blade scalpel
  - Spinal needles
  - Marking pen and ruler
  - Suture passer (e.g., Carter-Thomason, Cooper Surgical Inc, Trumbull, CT, USA)—Disposable device recommended as reusable devices tend to have dull tips over time, and multiple passes are necessary.
  - Suture: Multiple #1 permanent monofilament sutures (e.g., Prolene) with needles cut off. One #1 resorbable monofilament suture (e.g., PDS or Maxon) with needle cut off for 12-mm trocar site closure.

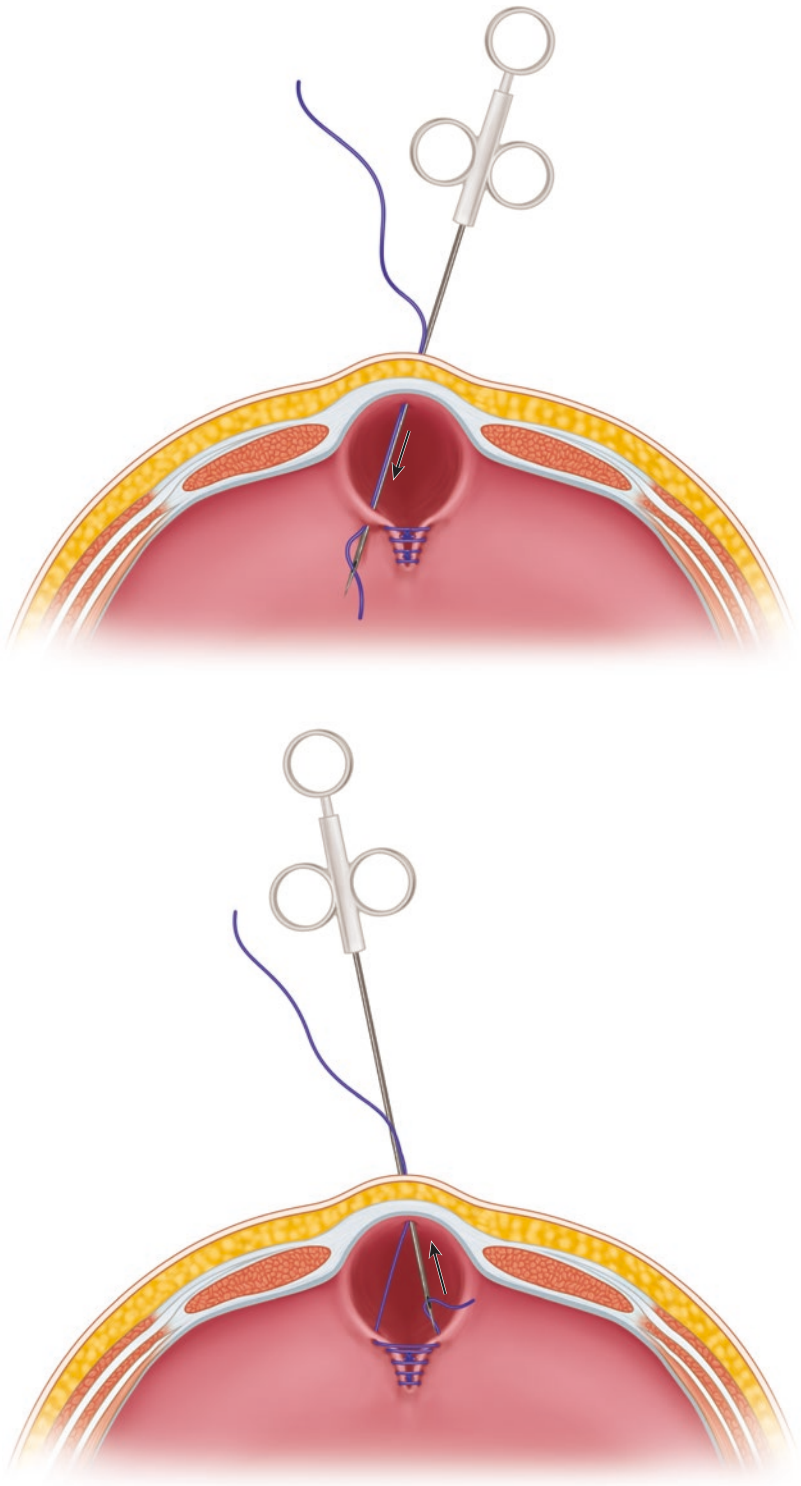

Fig. 37.2 Defect closure technique (please see text for details regarding steps)

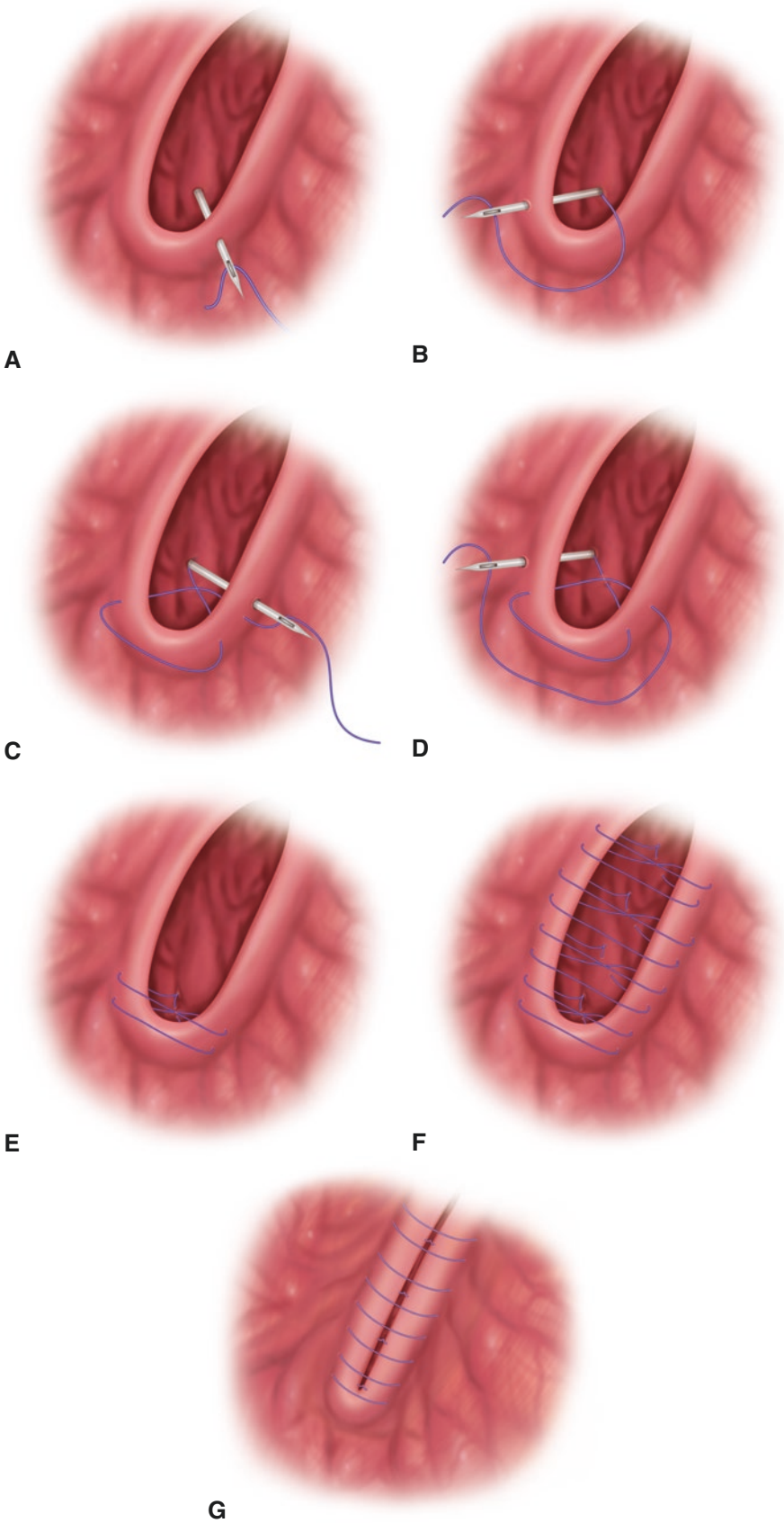

Fig. 37.2 (continued)

  - Hemostats
  - Laparoscopic grasper (e.g., Maryland dissector)
- Defect closure technique: (Fig. 37.2)
  - An external vertical line is drawn on the skin through the central portion of the defect(s). Using spinal needles the superior and inferior edges are identified and marked. Sites for figure-of-eight sutures are marked approximately every 3 cm on the vertical line.
  - Prepare each #1 Prolene suture by cutting the needle off, placing a hemostat on one end to prevent pull-through, and grasping the other end with the suture passer.
  - Starting at one end, a stab incision is made with the #11 blade. Under direct visualization, using the suture passer, the first #1 Prolene suture is passed through the stab incision centrally, then advanced through one fascial edge approximately 1 cm from the edge. A Maryland dissector is used to grasp the suture from the suture passer.
  - Using the same stab incision advance the suture passer through the contralateral fascial edge, passing the suture from the Maryland dissector to the suture passer. Withdraw it externally, leaving the suture within the suture passer so that it is ready for the next pass.
  - Again, using the same stab incision, advance the suture passer with suture into the ipsilateral fascial edge, advancing approximately 1 cm along the midline. After passing the suture to the Maryland dissector, replace the suture passer in the contralateral fascia, grasping the suture and withdrawing it externally. Grasp both ends of the suture with the pre-placed hemostat, thus completing placement of one figure-of-eight suture. Sutures will be tied after all have been placed.

    Tip: Instead of advancing the suture passer/suture through the skin and fascia in one motion, advance it in two steps. Initially, pass the suture passer/suture through the skin centrally vertically through the hernia sac, down in the abdominal cavity without incorporating any fascia. Then, back the suture passer tip up slightly into the hernia cavity before entering the fascial edge. This helps limit oblique passing of the suture through the sack and puckering the skin.
  - Continue placing additional figure-of-eight sutures along the length of the pre-marked line every 3 cm in an identical manner. Take care to avoid locking subsequent sutures on previously placed figure-of-eights. Gentle outward traction of previously placed sutures may help by reducing excess suture within the hernia cavity.
  - Hernia defect closure proceeds after placement of all figure-of-eight sutures. In order to facilitate defect closure, ensure the patient has received adequate paralysis prior to tying sutures down. To reduce tension on the central aspect, knots are tied sequentially, starting at the superior and inferior ends and advancing centrally. Knots are buried in the subcutaneous tissue; after cutting the suture tails the skin/dermis is released with the tip of a hemostat or with tooth graspers to prevent dermal and skin puckering.

    Tip: Pneumoperitoneum should be released to reduce tension on the abdominal wall and facilitate closure. However, bowel or omentum can entrap itself within your closure, causing visceral injury. One method of preventing this is to maintain a very low pneumoperitoneum (e.g., 3–5 mmHg), and tie each knot down under direct laparoscopic visualization.
- Mesh placement: Defect closure may allow placement of smaller meshes, though at least a 5 cm overlap is still recommended. For mesh insertion, the 12-mm trocar should be placed close to midline without disrupting the closed defect. The central location allows adequate mesh overlap of the large trocar site, thus reducing trocar site herniation. After mesh insertion and trocar removal, the site is closed in a simple or figure-of-eight fashion with #1 resorbable monofilament suture (PDS or Maxon) using the same closure technique described above. This can be tied down at this time. The mesh is then fixated to the abdominal wall using standard LVHR technique utilizing tacks and trans-abdominal sutures. While various techniques for mesh fixation have been described, an outer crown of resorbable tacks along with four cardinal trans-abdominal sutures using permanent monofilament sutures provides a durable combination of fixation. If a mesh-positioning device is used, the outer crown of tacks can be placed first, followed by the cardinal sutures. For classic LVHR without a mesh-positioning device, it is helpful to pre-place the four cardinal sutures prior to inserting the mesh into the abdomen.
- Buttressing sutures: To relieve tension on the newly reapproximated midline following closure of larger defects, additional buttressing sutures are placed alongside the defect closure. Using permanent monofilament sutures (#1 Prolene), full-thickness trans-abdominal (including mesh) simple U-stitches are placed every 4–5 cm bilaterally, approximately 1–2 cm lateral to the midline (Fig. 37.3). Use caution when tying these sutures down—they should be snug but not so tight as to buckle the mesh. Figure 37.4 demonstrates the completed closure and placement of all sutures with mesh in situ.

Tip: Passing both the suture passer with the suture in its grasping tip can create a wider hole in the mesh then if the suture passer was not grasping suture. Therefore, the suture is initially placed intracorporeally through an accessory trocar, passed to the suture passer below the mesh and pulled from the inside out. The empty suture passer is then passed through same skin incision and through the mesh 1–2 cm away from the previous pass, grasping the second end of the stitch to pull out.

- Alternative defect closure techniques: Common themes of current literature describing defect closure favor the use of permanent suture for closure of the hernia defects as well as placement of multiple interrupted sutures. Additionally, most studies demonstrate extracorporeal suture placement using percutaneous suture-passer

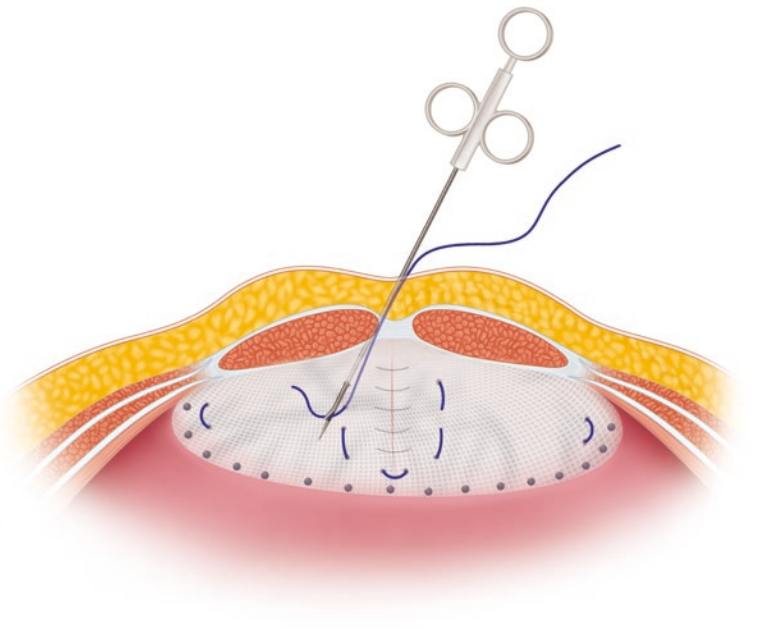

Fig. 37.3 Buttressing sutures (please see text for details regarding steps)

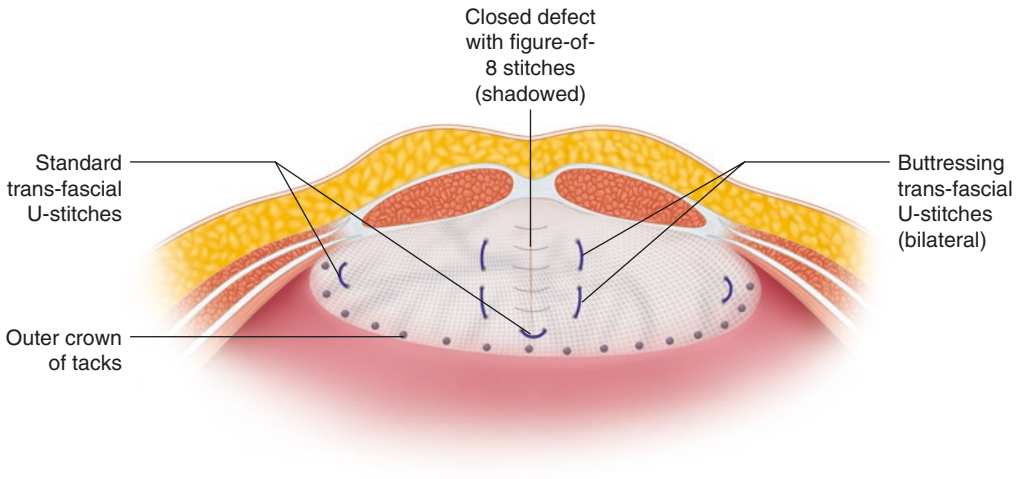

Fig. 37.4 Defect closure completion. Internal view following completion of LVHR with defect closure components of repair

devices. However, other techniques have been described with similar rates of success. Instead of percutaneous interrupted closure Palanivelu et al. describe closure by running a monofilament nylon suture intracorporeally [27]. Zeichen et al. closed defects in three ways using braided polyester: percutaneously with a suture passer, intracorporeally using standard laparoscopic needle drivers, as well intracorporeally using an EndoStitch device (Covidien plc, Dublin, Ireland) [23]. In two papers Agarwal et al. described their unique "double-breasted" defect closure using two spinal needles as suture passers to force the medial edges of fascia and rectus muscles to overlap, with no recurrences reported at a mean of 34 and 58 months [13, 28]. More recently, with the advent of barbed sutures, surgeons are closing the defect intracorporeally in a running fashion either laparoscopically or with robotic assistance. Such barbed sutures allow easier sequential tightening of the defect using running sutures.

37.7 Summary

Laparoscopic ventral hernia repair with defect closure offers a more functional and dynamic repair, similar to open ventral hernia repairs, while preserving the benefits of minimally invasive surgery. While no randomized controlled trials exist yet, potential benefits of defect closure include the use of somewhat smaller mesh prosthetics, obliteration of dead space with reduced wound morbidity such as seromas, and less postoperative bulging. Early data also demonstrate potential for reduced

recurrences, though conflicting data have been published. However, not every ventral hernia is destined for laparoscopic repair with defect closure. For example, hernias in the immediate subxiphoid location may be difficult to close during LVHR. Furthermore, complex defects that are large, made of multiple Swiss cheese-like defects with poor tissue integrity should be considered for open repair. While prospective randomized trials are necessary to truly demonstrate long-term durability and clinical advantages, defect closure is advocated to produce beneficial outcomes for our patients undergoing laparoscopic ventral hernia repair.

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Treatment of Incarcerated and Strangulated Ventral and Incisional Hernias

38

Vladimir P. Daoud and Gina L. Adrales

38.1 Introduction

The incarcerated ventral hernia presents a formidable challenge. In the non-emergent setting, the surgeon must weigh the risks and benefits of repair versus continued observation with the patient. At the outset, this scale may appear tipped toward operation. Unless patient comorbidities pose a prohibitive risk, the symptomatic ventral and incisional hernia should be repaired. However, the ever-increasing rate of obesity and the recognized benefit of modifiable risk reduction, such as glycemic control, adds complexity to the decision. It is not simply a decision of repair versus observation but also a matter of timing. Central to this discussion is a concern that the incidence of incarceration or strangulation is a time-dependent risk.

38.2 Natural History

To date, there are very few studies regarding the natural history of the ventral or incisional hernia. In the United States, a small watchful waiting prospective cohort trial enrolled 41 patients with ventral or incisional hernias and followed them for 2 years [1]. Only one of the 23 patients available for follow-up developed incarceration and none had deterioration of the Activities Assessment Scale, leading the authors to conclude that watchful waiting was safe. A larger Danish trial met the same conclusion. In this recent retrospective single-center cohort study involving 569 patients with an incisional hernia and 789 patients with an epigastric/umbilical hernia who underwent watchful waiting, the probability to receive surgical care over the ensuing 5 years was 19 % for the patients with an incisional hernia and 16 % for the epigastric/umbilical hernia group. The probability of requiring emergent repair for both groups was 4 % after 5 years, suggesting that watchful waiting of patients with ventral hernias can be safe; however, the authors did not distinguish between patients presenting with reducible or incarcerated ventral hernias [2]. A Netherlands retrospective study conducted at a single academic site investigated the outcome of incisional hernia patients who presented between 2004 and 2009 and were treated by watchful waiting or repair [3]. During the follow-up period (median 68 months), 33 % of the patients crossed over from observation to operative treatment. There were eight (24 %) emergency repairs in the crossover group for incarceration at a median follow-up of 1 month. There was a significantly increased risk of intraoperative bowel perforation, postoperative fistula, and mortality for the crossover group compared to the operative group. Indeed, in a prospective cohort study utilizing the Danish Hernia Database, Helgstrand et al. showed that emergency ventral/incisional hernia repair was associated with a 15-fold higher mortality, reoperation, and readmission rates when compared to elective ventral/incisional hernia repair [4]. Risk factors leading to the need for emergency hernia repair were older age, female gender, umbilical hernia defects between 2 and 7 cm, or incisional hernia defects up to 7 cm. There was also a significantly higher rate of bowel resection associated with emergency hernia repairs when compared to those undergoing elective repairs.

The disparate results of these studies highlight the challenge of counseling patients with ventral/incisional hernias. While approximately one-third of the patients in the Netherlands watchful waiting group were asymptomatic, the presence of comorbidities (23 %) or obesity (22 %) were reasons for opting for watchful waiting [3]. The larger Danish

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_38

study found similar reasons for adoption of watchful waiting including minimal symptoms in 55% of the incisional hernia patients and comorbidities as the reason in 20% [2]. When the diversity of the patient population is considered, the true rate of incarceration or strangulation is difficult to determine and the stakes may be high should an emergency hernia event arise.

38.3 Clinical Presentation and Diagnosis

Ventral/incisional hernia repair is one of the most common procedures performed by the general surgeon. In the United States alone in 2003, there were approximately 105,000 incisional hernias repaired and 255,000 other ventral hernias (including umbilical, epigastric, Spigelian, etc.) repaired in that 1-year period [5]. The incidence has remained high with associated increasing healthcare costs with Poulose et al. reporting an incidence of 348,000 ventral hernia repairs in 2006 at an estimated cost of $3.2 billion [6].

Patients with ventral and incisional hernias may present with discomfort, an enlarging bulge, or acutely with bowel obstruction (Figs. 38.1, 38.2, 38.3, and 38.4). The hernias may be found incidentally on exam; however, patients with incarcerated ventral/incisional hernias tend to present with more pain. This was noted in a cost-utility analysis conducted in 2014 based on an observational study of 243 total patients with reducible hernias treated under three strategies, including (1) watchful waiting, (2) operative repair only when incarcerated, and (3) hernia repair while reducible [7]. Patients with incarcerated hernia repairs were more likely to have pain, strangulation, and bowel obstruction at the time of repair than those with reducible hernias or those being observed. However, the recurrence rate was the same at 22% versus 26% for reducible hernia repair with a mean follow-up of approximately 4 years. Elective repair of the nonincarcerated hernia was cost effective. There were lower quality of life utility scores for those who did not undergo repair compared to those after repair of the reducible hernia with an incremental cost effectiveness ratio of $8646 per quality-adjusted life-year. Interestingly, patients who were treated nonoperatively and who underwent repair at time of incarceration were of lower socioeconomic status and had a higher rate of cardiac disease.

The need for preoperative imaging is at the discretion of the operating surgeon. CT may be beneficial for preoperative planning for repair of the chronically incarcerated ventral hernia (Fig. 38.5). In the acute setting, imaging is helpful in the assessment of bowel obstruction and other abdominal pathology. In a study on the preoperative use of CT scanning to measure the size of the hernial orifice, hernia size and abdominal wall thickness measurements were associated with the increased requirement for component separation,

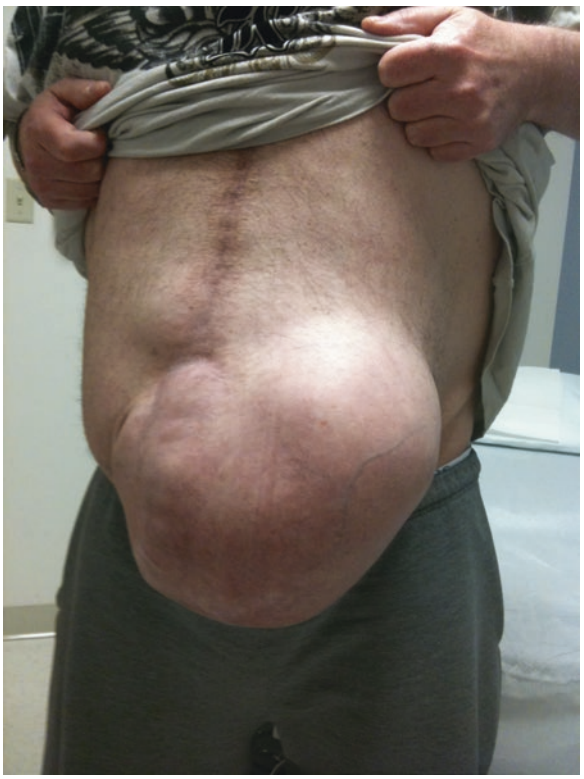

Fig. 38.1 Patient with chronically incarcerated but not obstructed ventral incisional hernia

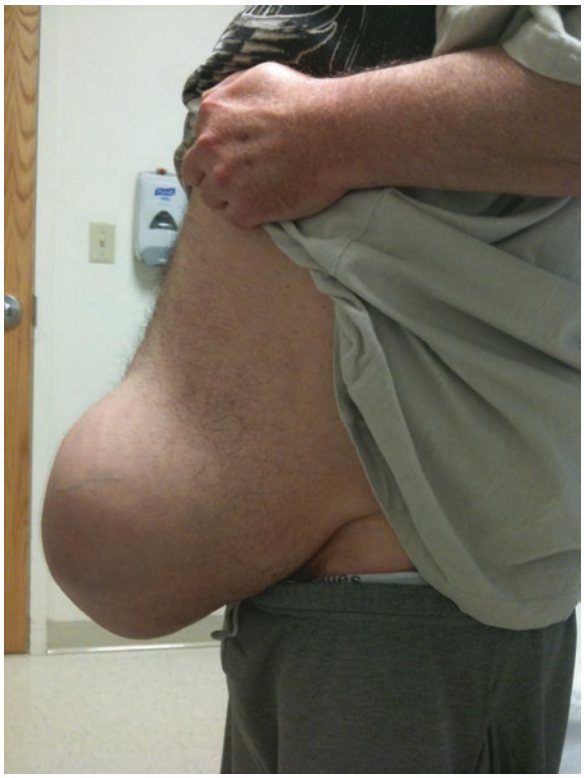

Fig. 38.2 Patient with chronically incarcerated but not obstructed ventral incisional hernia

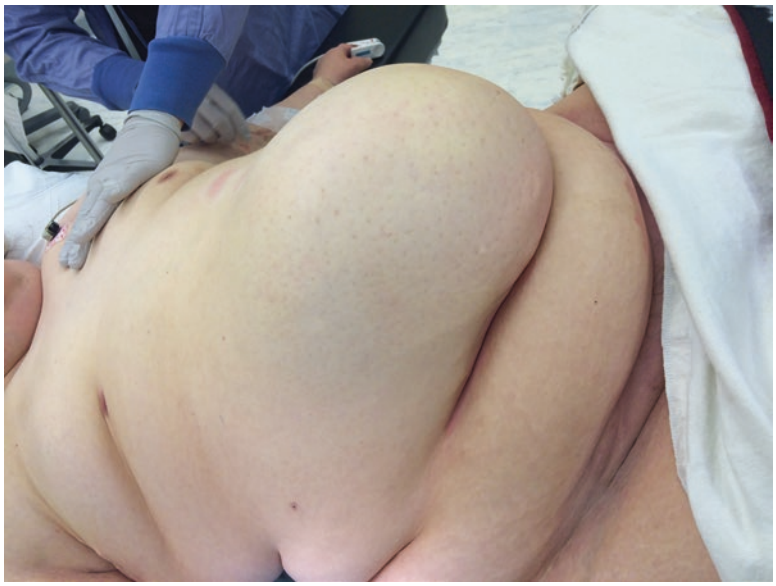

Fig. 38.3 Acute presentation of incarcerated ventral hernia with strangulated bowel

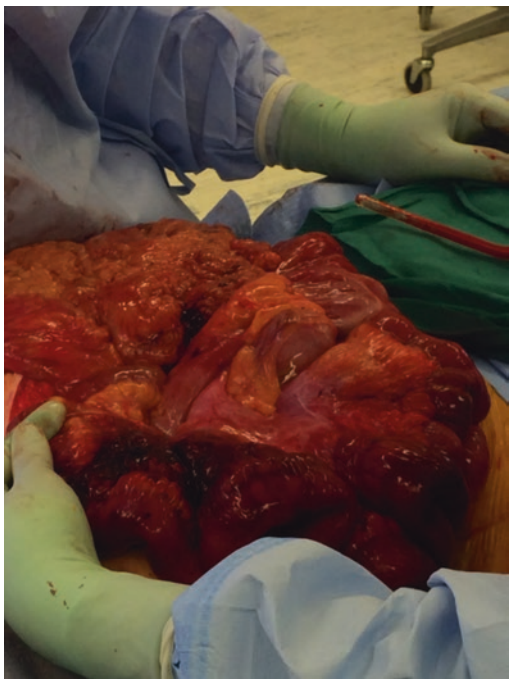

Fig. 38.4 Acute presentation of incarcerated ventral hernia with strangulated bowel

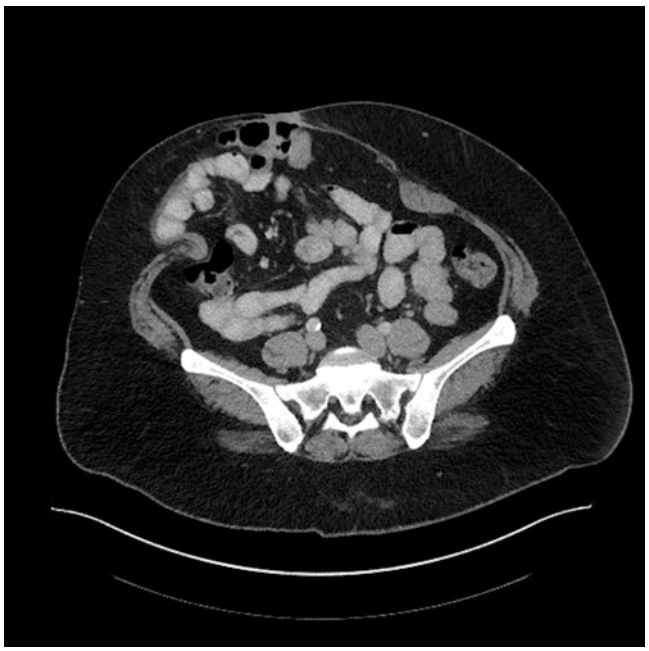

Fig. 38.5 CT image of an incarcerated ventral incisional hernia recurrence

need for panniculectomy and higher rates of wound and overall complications [8]. The authors found that hernia defect areas > 164 cm^2 or a width > 8.3 cm on preoperative imaging were associated with the need for performing component separation. This has implications for a more detailed discussion with the patient regarding the procedure itself, as well as the subsequent risks associated with component separation, including increased risk of wound infection, dehiscence, ischemia, and hernia recurrence [9].

38.4 Surgical Management

With regard to operative approach, published research which is currently limited by subject volume and length of follow-up does not support the superiority of laparoscopic or open

repair in terms of both efficiency and efficacy [10]. It is therefore imperative that the surgeon uses his or her judgment and experience, as well as individual and institution capabilities, when selecting the optimal treatment for these challenging patients. Specific technical descriptions of various open and laparoscopic approaches including components separation are described in detail elsewhere in this book. The following overview will serve to highlight evidence pertinent to the incarcerated or strangulated ventral/incisional hernia and the special considerations of concomitant bowel obstruction and contaminated fields.

38.4.1 Open Repair

Open repair of the incarcerated and strangulated ventral/incisional hernia has long been regarded as the gold standard operation of choice. However, there are many factors at play that should determine which approach is more appropriate, not the least of which are patient factors, such as comorbidities and pertinent anatomy. It is important to note that the patient with a strangulated hernia may be in extremis and may not tolerate the hemodynamic insults associated with insufflation of the peritoneum, and thus may be best served with an open repair of the hernia, especially if it mandates bowel resection.

There are several techniques described for open ventral/incisional hernia repair that can be utilized in the patient with an incarcerated or strangulated hernia. The *onlay* technique with mesh placement anterior to primary closure of the anterior abdominal fascia may be the most expedient repair in the acutely ill ventral hernia patient. This has been associated with a short operative time compared to sublay positioning [11]. When placed in this fashion, the mesh does not come into contact with the peritoneal contents; however, there are several disadvantages, including high rates of seroma formation and the potential for extension of a superficial wound infection to the mesh implant. Furthermore, recurrence rates have been reported to be as high as 23 % [12]. A single site study with 7- and then 10-year reported results of the use of a polypropylene onlay in the repair of acutely incarcerated and/or strangulated ventral hernias found a low complication rate (17.5 %) and a wound infection rate of 6 %, even in situations where bowel resection was required [13, 14].

The *underlay* technique employs an intraperitoneal barrier mesh and is another commonly utilized method of repair. This can be used as a bridging technique across the hernia defect. This may be favored in the acute setting where fascial midline approximation may not be possible allowing components separation to be employed in the future as needed. Intraperitoneal mesh may hinder future laparotomy [15, 16], making the retrorectus *sublay* repair an attractive option. The retromuscular, retrorectus, or the Rives–Stoppa method involves placing the mesh posterior to the rectus abdominis but anterior to the posterior rectus sheath [17, 18]. Advantages of this approach include the isolation of the mesh from the peritoneal cavity and a relatively low recurrence rate, with rates reported as low as 5 % with a follow-up period of 70 months and a patient satisfaction rate of 89 % in a study of 254 patients [19]. Complications included wound infection (4 %), hematoma/seroma formation (4 %), and mesh infection (3 %) [19].

Component separation of the lateral muscular aponeuroses of the abdominal wall may be used to facilitate midline fascial closure in the repair of the incarcerated or strangulated ventral/incisional hernia. The combination of release of the external oblique fascia and the posterior rectus sheath can allow for up to 20 cm of fascial mobilization toward the midline [20].

A meta-analysis comparing endoscopic component separation to traditional open component separation has shown a decrease in the incidence of surgical site infection, skin necrosis, abscess of the subcutaneous space, seroma, skin dehiscence, cellulitis, and fistula [9]. In the acute setting, particularly when combined with bowel resection, the open approach is likely most expedient. In addition, the complexity of the acutely or chronically incarcerated ventral hernia may require lateral and suprafascial dissection obviating any advantage that an endoscopic or minimally invasive approach may provide.

38.4.2 Laparoscopic Repair

Laparoscopic repair of incarcerated and strangulated ventral and incisional hernias is not considered by many to be the gold standard. There are studies which show an advantage of the laparoscopic approach in terms of recurrence and com-

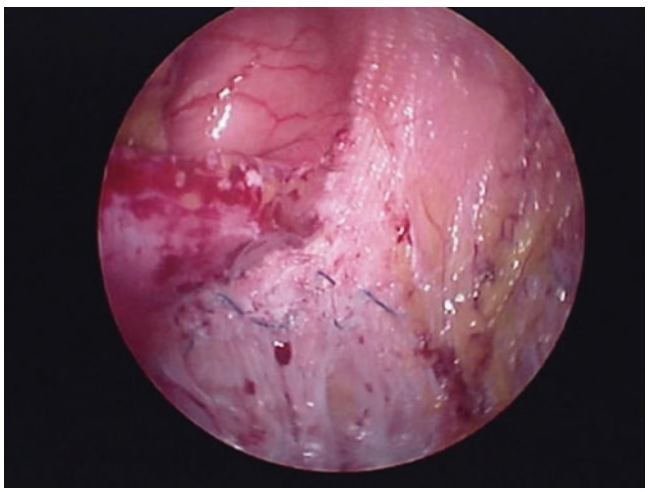

Fig. 38.6 Laparoscopic approach to reoperative and chronically incarcerated ventral hernia

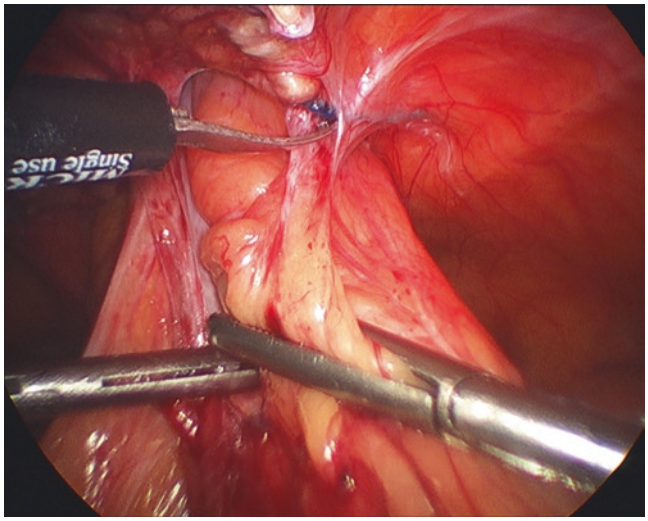

Fig. 38.7 Laparoscopic reduction of hernia contents

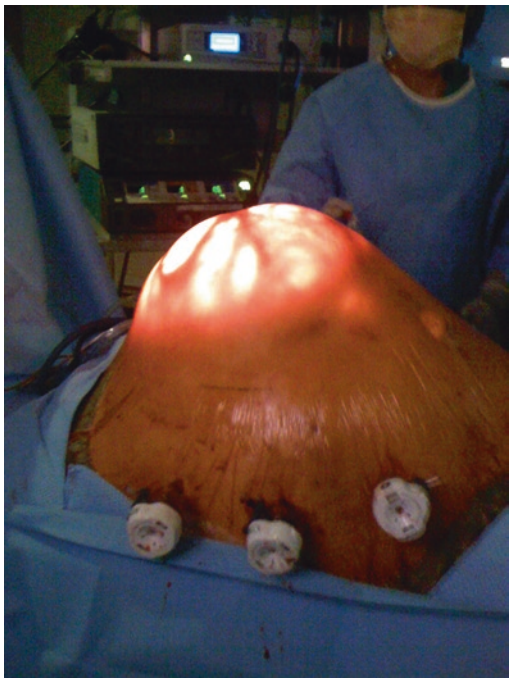

Fig. 38.8 Laparoscopic repair of the large ventral hernia with limited working space

plications, particularly surgical site infection, but there is only short-term follow-up [21, 22]. The majority of comparative effectiveness studies of laparoscopic and open ventral hernia repair focus on elective repair for reducible ventral hernias. The laparoscopic approach can be very challenging in both chronically incarcerated ventral hernias where fibrous scarring can be difficult to distinguish from intestine (Fig. 38.6) and the acutely incarcerated or strangulated ventral hernia where bowel edema and inflammation may hinder reduction of the hernia contents without bowel injury (Fig. 38.7). External palpation and pressure to aid hernia contents reduction and exposure for adhesiolysis is helpful. Working space to conduct the adhesiolysis and repair may be limited (Fig. 38.8). Additional trocar placement as well as conducting the operation above and below the mesh may facilitate repair. Despite the challenges, laparoscopic repair may be favored. In a population-based study with a subgroup analysis of patients undergoing repair of incarcerated/strangulated anterior abdominal wall hernias, the patients who underwent laparoscopic repair had a significantly lower overall morbidity rate (4.7 %) compared to those having undergone an open repair (8.1 %). Interestingly, there were no significant differences in outcomes between laparoscopic and open repairs in patients with reducible hernias undergoing outpatient surgery [23].

38.4.3 Management of Bowel Obstruction and Ventral Hernia

Bowel obstruction in association with ventral hernia poses a distinct challenge to the surgeon who must weigh the risk of mesh infection versus the risk of hernia recurrence. The timing of operative intervention for the bowel obstruction and whether the definitive hernia repair should be attempted at that time must be thoughtfully considered. There is the hypothetical risk of surgical site infection due to bacterial translocation across the obstructed bowel wall. However, in a retrospective National Surgical Quality Improvement Program (NSQIP) database study, multivariate logistic regression analysis of data from over 17,000 patients with hernia-related obstruction, bowel obstruction was not independently associated with surgical site infection [24]. Additional analysis of the NSQIP database from 2005 to 2011 of almost 17,000 patients presenting with ventral hernia with obstruction included a patient population of 28 % who underwent delayed ventral hernia repair more than 24 h after admission [25]. After adjusting for comorbidities and ASA score, patients who underwent delayed repair had worse outcomes including surgical site infection, concurrent bowel resection and mortality. There are limitations to these retrospective short-term studies, but it does appear that prompt exploration and ventral hernia repair produces more favorable results. Furthermore, and bowel obstruction alone does not increase the risk for surgical site infection when considering placement of mesh.

38.4.4 Contaminated Operative Field

The strangulated ventral hernia raises considerable concern regarding the risk of surgical site infection. However, there is

mounting evidence that contaminated operative fields should not preclude the use of synthetic permanent mesh. While once valued as the safe solution to the problem of the contaminated abdominal wall defect, the value of biologic mesh in the contaminated setting has been questioned due to hernia recurrence risk. Rosen et al. reviewed their prospectively collected database to assess single-stage ventral hernia repair in a contaminated field with biologic mesh over a 5-year period [26]. They found that while it was a safe repair, there remained a high wound complication rate of 48 % and a hernia recurrence rate of 31 % with mean follow-up of 21.7 months. For clean-contaminated hernia defects, a 2016 cost-utility analysis suggested that synthetic mesh is more cost-effective than acellular dermal matrix repair with expected cost of $15,776 and quality-adjusted life-year (QALY) value gained of 21.03 versus $23,844 and QALY of 20.94 [27]. Carbonell et al. reviewed their outcomes at two institutions for lightweight polypropylene retrorectus repair in clean-contaminated and contaminated fields in 100 patients with a 30-day surgical site infection rate of 7.1 % for clean-contaminated cases and 34 % contaminated cases [28]. The mesh removal rate was low but caution is urged when colon resection is required. In this study, mesh removal was required in four patients, two of whom had anastomotic leak and one with stomal disruption. NSQIP analysis of ventral hernia repair in clean-contaminated and contaminated cases showed a significantly increased odds ratio of complications in patients who underwent ventral hernia repair with mesh compared to nonmesh repairs in clean contaminated cases [29]. Longer term data are needed. At this time, the use of prosthetic mesh should be individualized.

38.5 Summary

With the rise of obesity, abdominal wall reconstruction remains a challenging procedure. The successful management of incarcerated or strangulated ventral and incisional hernias requires careful consideration of the timing of surgery favoring early treatment of bowel obstruction and emergent hernia repair. There is increasing evidence to support the use of synthetic mesh in clean-contaminated and contaminated fields, particularly when weighing this against the morbidity of hernia recurrence and subsequent repair, the aptly named “vicious cycle of complications” [30]. Focus should be placed on the prevention of incisional hernia development as well as on the effective treatment of the symptomatic reducible ventral/incisional hernia to avoid the morbidity of ventral hernia bowel obstruction and strangulation.

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Treatment of Atypical Hernias

39

Salvatore Docimo Jr. and Eric M. Pauli

39.1 Introduction

Atypical hernias are those located close to the abdominal wall margins. They approach or are adjacent to bony structures such as the xiphoid, pubic symphysis, anterior superior iliac spine, and costal margin. Lumbar hernias are also included under the category of atypical hernias because they are adjacent to the costal margin and iliac crest [1]. Hernias in such atypical locations can be challenging to repair due to difficulty in obtaining a tension-free fascial closure and constraints in providing wide mesh overlap and fixation. Atypical hernias are generally associated with previous surgical incisions, often presenting within the first postoperative year. Incidence rates are noted to be 0.5–6 % after laparoscopic procedures and up to 32 % following open operations [1]. In this chapter we review the literature on atypical hernias and provide recommendations for the operative management of each type.

39.2 Preoperative Planning

Surgical repair begins with adequate patient evaluation. A preoperative computed tomography (CT) scan allows the surgeon to diagnosis, localize, and measure the defect (Fig. 39.1). Based on the patient's history, comorbid conditions, and the characteristics of the hernia (and whether any attempt has been previously made to repair the defect and whether there is mesh in situ), a decision can be made regarding the ideal operative approach. Repair of atypical hernias can be performed by laparoscopic or open approaches, following the same treatment paradigm as midline hernias: tension-free tissue approximation, adequate overlap of mesh beyond the hernia boundaries, and mesh fixation (with transfascial sutures, tacks, or a tissue adhesive). Mesh, unless otherwise contraindicated, should be utilized as it offers a lower hernia recurrence rate [2, 3].

As outlined below, there are several technical considerations unique to the repair of atypical hernias not commonly employed in the repair of a routine ventral hernia. These include (1) the need for visceral mobilization (falciform ligament takedown and bladder, colon, or kidney mobilization), (2) the need for alternative means of mesh fixation (including bone anchors and tissue adhesive/sealants), (3) the possibility of partly intraperitoneal and partly retro/preperitoneal mesh placement, (4) possible alternative (generally lateral) patient positioning, and (5) the likely need to place transfascial sutures away from the lateral edges of the mesh.

39.3 Subxiphoid Hernias

Subxiphoid incisional hernias most commonly occur following a previous surgical incision, such as an upper midline laparotomy incision, a median sternotomy, a mediastinal drainage tube incision, or a laparoscopic procedure (Fig. 39.2) [4]. The incidence of subxiphoid hernias following a median sternotomy that extends into the epigastric region ranges from 1 to 4.2 % [3, 5–7]. However, the incidence is believed to be underestimated considering many subxiphoid hernias are small and asymptomatic. Furthermore, long-term follow-up studies evaluating hernia after median sternotomies are lacking [8]. A recent review of the literature pertaining to subxiphoid hernias revealed only seven retrospective studies comprising a total of 113 patients with clinical subxiphoid hernias [5]. Such hernias uncommonly result in bowel obstruction as the typical contents are preperitoneal or falciform ligament fat, liver or stomach.

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_39

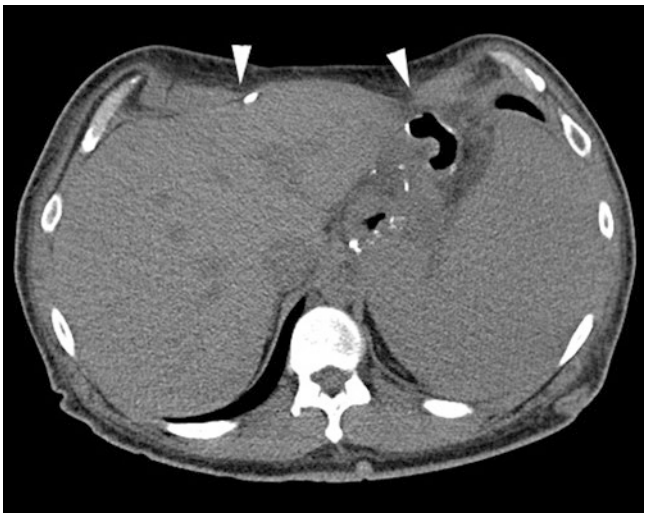

Fig. 39.1 Axial computed tomography scan of a patient with a subxiphoid hernia following open bariatric surgery. The medial edge of the rectus muscles are noted (*arrowheads*). The hernia contains the *left* lateral segment of the liver

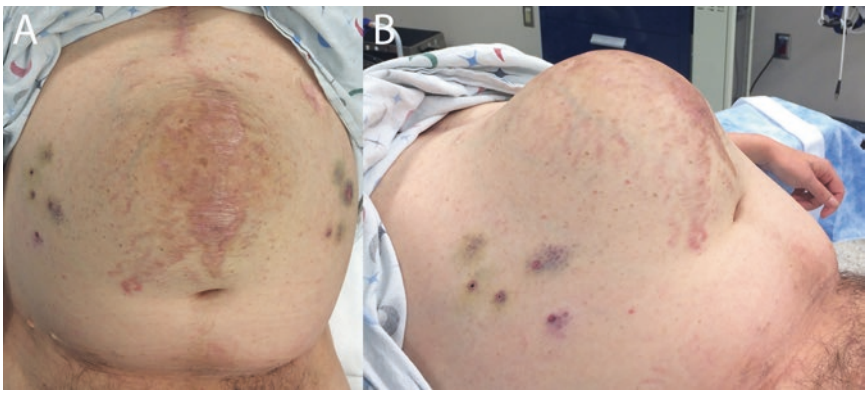

Fig. 39.2 (**a**) Anterior and (**b**) lateral views of a subxiphoid hernia following median sternotomy and upper midline incision for aortic root replacement

39.3.1 Surgical Anatomy

The borders of the subxiphoid space consist of the sternum and ribs superiorly, the diaphragm posteriorly and inferiorly, and the rectus abdominis muscles and linea alba anteriorly. The diaphragm, posterior rectus sheaths, and the linea alba each insert onto the sternum and xiphoid process. Arterial blood is supplied to the xiphoid by the xiphoid artery, a terminal branch of the internal thoracic artery and also branches of the superior epigastric artery [9]. Decreased blood flow to the area can occur if the internal thoracic or superior epigastric arteries were damaged or utilized during previous bypass procedures.

Subxiphoid hernias generally occur in the midline and are caudal to the tip of the xiphoid. By European Hernia Society classification, they occur within 3 cm of the xiphoid and are termed midline (M)1 hernias [10]. Subxiphoid hernias can also occur off of the midline, most often in the setting of a previous incision from a prior mediastinal drainage tube [4]. Repair of subxiphoid hernias is difficult due to the convergence of boney structures and soft tissues, such as the rectus abdominis muscles, linea alba, and the diaphragm [5–7]. In particular, medialization of the rectus can be difficult in this location because its lateral boarder inserts onto the chest wall preventing the relatively easy medial movement seen in the periumbilical region.

39.3.2 Open Repair

The previous surgical incision can be utilized as the location of entry. Complete adhesiolysis should be performed. We favor a retrorectus dissection to permit adequate mesh overlap, but this approach can be technically challenging due to two reasons: first, the insertion of the posterior rectus sheath on the xiphoid process inhibits appropriate superior mesh overlap of the boney border unless divided appropriately (Fig. 39.3), and second, the myocardium can be adhered to the posterior sternum (in the case of a prior median sternotomy related hernia) which increases the risk of myocardial injury as the dissection proceeds in a cranial fashion [5]. The retroxiphoid/retrosternal dissection should be carried as cephalad as possible, being mindful of myocardial injury risk, and as inferior as needed to afford adequate mesh overlap in both directions. After the retrorectus space has been

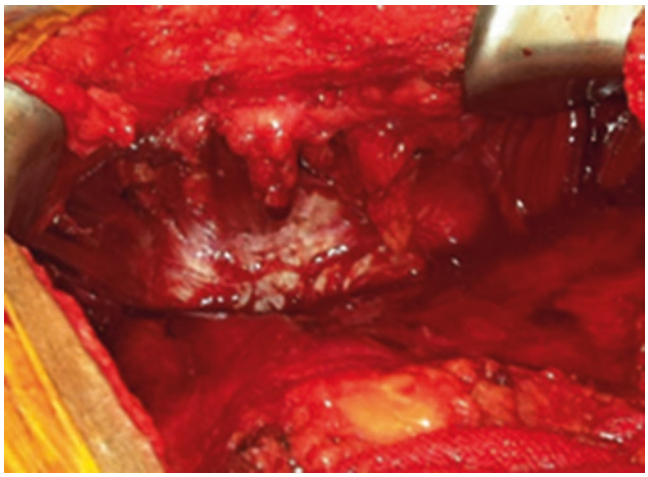

Fig. 39.3 Retro-xiphoid view following posterior rectus sheath release

completely dissected the posterior layer of the reconstruction (composed of the posterior rectus sheath, and commonly in the upper midline preperitoneal fat of the falciform ligament) is closed in the midline using absorbable suture (see Chap. 30 for additional details of open retrorectus repair). Mesh is then placed in a sublay position filling the entire retromuscular space sufficient enough to provide adequate overlap of the defect in all directions (cranial, caudal, left, and right).

Several centimeters of mesh overlap underneath the xiphoid are possible even in difficult subxiphoid hernias [11]. If wider overlap is necessary superior-laterally, the posterior rectus abdominis sheath can be divided at the costal margin to open the space between the peritoneum and the diaphragm to ensure wide overlap of the mesh in the cephalad direction [5]. Similarly, the transversus abdominis muscle can be divided at its insertion onto the posterior sheath which permits access to the retromuscular space at the costal margin permitting access to the same plane (see Chap. 30 for additional details on transversus abdominis release).

The superior portion of the mesh is secured adjacent to the xiphoid, utilizing transfascial sutures, followed by the lateral and inferior portions of the mesh. Note that the mesh should pass well beyond the xiphoid. The transfascial stitch should not be at the edge of the mesh or there will be insufficient superior overlap. Fascial closure is recommended (if possible) with one to two closed suction drains placed in the space above the mesh.

We prefer permanent synthetic mesh, generally polypropylene, for these cases and aim for a minimum of 5 cm overlap in all directions. In circumstances where the linea alba can be easily reconstructed in the midline, we prefer an intermediate weight macroporous mesh. If the rectus muscles cannot be mobilized to the midline (which is common in large subxiphoid hernias), we utilize a heavyweight mesh to reduce the risk of central mesh fracture where the mesh is bridging the fascial gap. Repair with permanent mesh is reported to yield lower recurrence rates from 0 to 32 %, compared to a recurrence rate of 43–80 % for "suture only" closures of fascial defects [7, 12, 13].

Onlay mesh placement is another option if other methods fail to achieve adequate space for mesh overlap. In these cases, the subcutaneous tissues are elevated off of the anterior rectus fascia in all directions (cranial, caudal, and lateral). The linea alba is reconstructed in the midline with suture and the mesh is placed in an onlay position extending onto the chest wall superiorly and laterally.

39.3.3 Laparoscopic Repair

The patient is placed in a supine position with arms tucked. Care must be taken when entering the abdomen due to the likelihood of adhesion formation from previous surgeries. The location and method of abdominal access is surgeon dependent. Trocars should be placed as lateral as possible to ensure adequate mesh overlap and visibility. Three to five trocars are typically required, with one trocar being 11 or 12 mm to facilitate mesh entry [11]. Our preference is to utilize only 5 mm ports laterally to reduce the risk of port-site hernia formation and to place a larger port for mesh introduction in the upper midline in a location that will ultimately be covered by the fully deployed mesh. Similar to an open procedure, sharp adhesiolysis is required. Takedown of the falciform ligament up to the level of the diaphragm is required to allow for adequate mesh overlap and to permit the mesh to lay flat against the abdominal wall (Fig. 39.4). This can be accomplished with simple cautery or an advanced

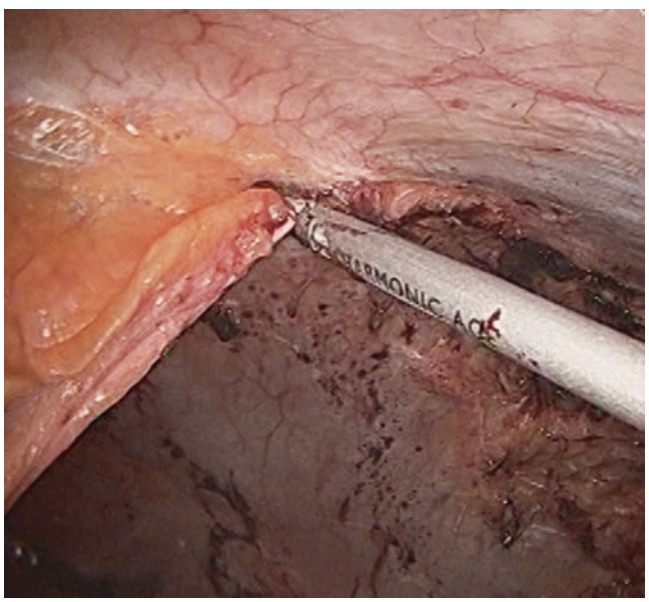

Fig. 39.4 Laparoscopic view of falciform ligament division with ultrasonic shears

energy source (such as an ultrasonic or tissue sealing device). As with other laparoscopic repairs, mesh overlap of 4–5 cm in all directions is recommended, if possible [4]. We attempt laparoscopic defect closure whenever possible (see Chap. 37 for additional details on laparoscopic defect closure). As noted for open repairs, the lateral insertion of the rectus onto the bony chest wall often prevents the ability to completely close the defect.

Four cardinal sutures are placed into the mesh which is then rolled tightly and introduced into the abdominal cavity through an 11 or 12 mm port site. Similar to the open repair, the superior-most transfascial stitch should be positioned several (4–5) centimeters below the superior edge so that it may be brought out just below the xiphoid to facilitate mesh overlap of the xiphoid [11]. When utilizing a transfascial suture method of mesh positioning, we prefer to retrieve the subxiphoid suture first as this stitch is the most critical for accurate mesh positioning and overlap. The inferior stitch is next retrieved followed by the lateral two. Alternatively, if a mesh positioning system is being utilized, care must be taken to ensure adequate superior mesh overlap before the mesh is secured to the abdominal wall.

Tacks can then be utilized to secure the mesh periphery in a standard fashion for laparoscopic hernia repair at locations below the costal margin. Mesh fixation with transfascial sutures or tacks above the costal margins is not recommended due to the risk of chronic pain (from intercostal nerve entrapment) or pericardial injury [11, 14]. Some authors recommend additional full-thickness abdominal wall stitches circumferentially every 3–6 cm to further secure the mesh [15–17].

Because the superior edge of the mesh above the costal margin and xiphoid is not fixated to the abdominal wall, there exists a possibility that this edge will fold back. This has two consequences; first, the superior mesh overlap of the hernia defect will be inadequate and second, the uncoated side of the mesh will be exposed to the viscera, which can result in dense adhesion formation. Several options exist for mitigating these risks. First, the superior flap of mesh can be held in the desired position as the abdomen is desufflated. The liver will generally abut the mesh at this location and, in a gasless abdomen, hold the mesh against the abdominal wall. Alternatively, fibrin sealant can be applied to the abdominal wall to secure the mesh in the correct position in the early postoperative period. The mesh can also be secured to the peritoneum above the costal margin with suture (performed laparoscopically or with robotic assistance). Care must be taken when suturing to secure the mesh to the peritoneum alone and not to take deeper tissue bites that may risk injury to the intercostal nerves or pericardium. Our preference is to utilize fibrant sealant for laparoscopically performed cases and to suture the mesh for robotic-assisted laparoscopic cases.

39.4 Subcostal Hernias

Subcostal hernias are often grouped under the category of subxiphoid hernias; however, they are unique in the fact they tend to occur following previous incisions that follow the trajectory of the costal margin (Kocher incision, bisubcostal incision for liver transplant or bariatric procedure) and are in some ways more akin to flank hernias. Subcostal incisions typically section muscle fibers of the rectus abdominis and oblique muscles which creates a hernia incidence rate of 6–17 % [1]. Open repair requires mesh placement in the retromuscular or preperitoneal space with as much overlap with the rib as is possible. When these hernias are large, we prefer an open approach utilizing a retromuscular approach with transversus abdominis release; however, this operation is extremely challenging in the setting of a subcostal incision [18]. For this reason, the laparoscopic approach is utilized by many surgeons. Wassenaar et al. reported a recurrence rate of 1.7 % with a laparoscopic approach utilizing intraperitoneal mesh adequately covering the margins of the hernia [19]. Regardless of the approach, subcostal hernia repair is technically difficult due to the hernias proximity to bony structures; however, similar requirements of adequate mesh overlap and fixation remain paramount. As with subcostal defects, we prefer to not fixate the mesh above the ribcage (with tacks or sutures) due to the risk of intercostal nerve or lung injury and prefer the use of tissue sealants to fixate the mesh above the ribcage. Complete primary defect closure is often not possible.

39.5 Suprapubic Hernias

Suprapubic hernias generally occur after previous low midline laparotomy or Pfannenstiel incisions. They can also occur after suprapubic catheter placement or orthopedic access to a disrupted pubic bone (Fig. 39.5) [20]. Some authors classify midline incisional hernias within 5 cm of the pubic arch as suprapubic hernias, while others have suggested incisional hernias located within 3–4 cm above the pubic arch in the midline to be true suprapubic hernias [21–23]. According to European Hernia Society guidelines, suprapubic hernias are classified as M5 zone hernias and are within 3 cm of the pubic symphysis [10]. The incidence of hernias following a Pfannenstiel incision is 0.04–2.1 % but up to 46 % follow a low midline laparotomy (Fig. 39.6) [24–27].

Because of the proximity to the urinary bladder, a three-way Foley catheter should be placed to permit urinary drainage as well as bladder distension (if necessary) during the course of the procedure. A careful review of previous operative reports is necessary to determine which planes in this region have been previously violated. Prior laparoscopic or open inguinal hernia repair may have resulted in scaring of the preperitoneal plane. Orthopedic injuries and their subse-

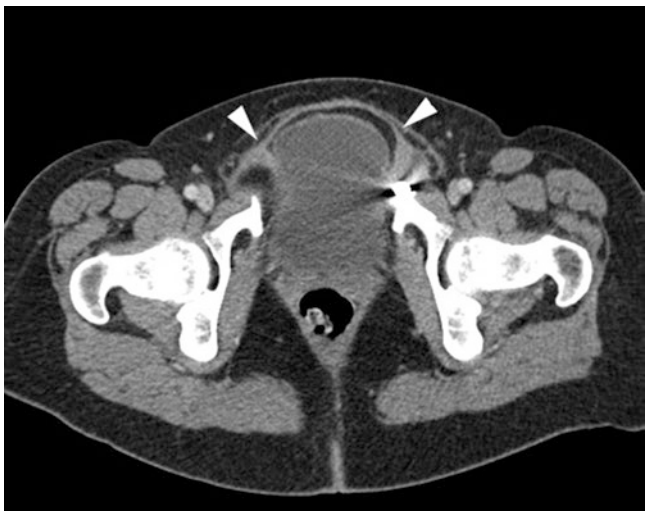

Fig. 39.5 Axial computed tomography scan of a patient with a suprapubic hernia following open repair of a pubic symphysis disruption. The medial edge of the rectus muscles are noted (*arrowheads*). The hernia contains the urinary bladder

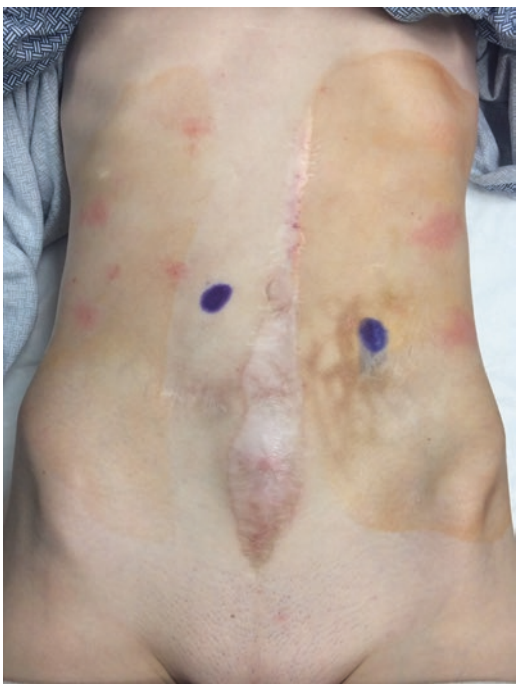

Fig. 39.6 Anterior view of a suprapubic hernia from multiple colorectal procedures for perineal Crohn's disease

quent repair can result in obliteration of the planes and in fusion of the urinary bladder to bone and surgical hardware, placing the bladder at risk for injury. Cystectomy performed for bladder cancer creates a unique set of challenges that make both open and laparoscopic repairs challenging. With this operation, all urothelial cell-bearing tissue is removed, including the posterior layers of the abdominal wall following the course of the medial umbilical ligaments. Because the peritoneum and transversalis fascia are missing, sublay repair is often not possible via open approach. Because of the exposed rectus muscle, adhesions in this area can be extremely dense, complicating both open and laparoscopic dissection.

39.5.1 Surgical Anatomy

Suprapubic hernias are generally located in the midline and cephalad to the pubic symphysis. The rectus abdominis musculature and rectus sheath insert on the pubic symphysis. Fascial reapproximation near the site of musculotendinous insertion is difficult, which creates a risk of hernia formation as well as for recurrence after repair [21]. The close proximity of the defect to bony pelvic structures, the urinary bladder and vasculature such as the epigastric and iliac arteries and veins, further complicates repair (Fig. 39.7). Mesh overlap with the pubic bone inferiorly is mandatory, and is accomplished by entering the extraperitoneal space between the pubic symphysis and the urinary bladder (space of Retzius or retropubic space). Wider overlap laterally can be achieved by entering the retroinguinal space (space of Bogros) utilizing the same methods described for laparoscopic inguinal hernia repair (see Chap. 12 for additional details about laparoscopic inguinal hernia dissection).

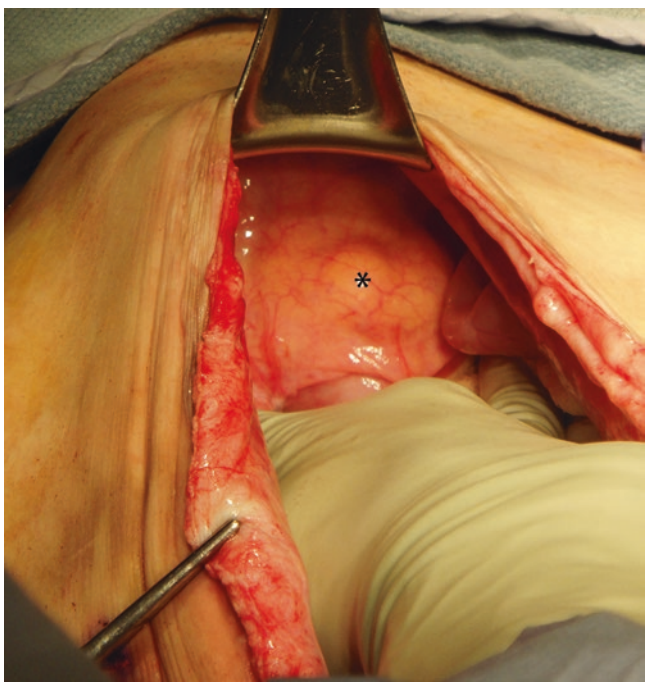

Fig. 39.7 Open view of a suprapubic hernia. The retractor is at the level of the pubic symphysis and the Foley catheter balloon can be seen within the urinary bladder (*)

39.5.2 Open Repair

The previous surgical incision can be utilized as the site of entry. Our preferred method of open repair is a retrorectus repair with mesh placed in the sublay space. Positioning the mesh here permits wide overlap with the pubic bone in most cases as well as affords lateral coverage over the myopectineal orifices bilaterally. The mesh is also protected from superficial skin infections (particularly important here due to the tendency for redundant skin and fat in an obese patient) and avoids contact with abdominal viscera (reducing the risk of subsequent adhesion formation). Lysis of adhesions must be completed in order to adequately reduce the hernia contents and to permit the posterior rectus sheath and peritoneum so slide toward the midline following dissection.

The retrorectus technique begins with incision of the posterior rectus sheath. Recall that below the arcuate line, the posterior sheath is composed of peritoneum and transversalis fascia only; there are no longer contributing fibers from the internal oblique muscle. Also, at this level, the transversus abdominis muscle is entirely lateral to the rectus muscle and will not be visible as part of the posterior sheath. As such, the posterior layer of the dissection will be thinner than when the same maneuver is performed in the upper abdomen for a subxiphoid defect. Blunt dissection extends this plane lateral to the linea semilunaris and into the space of Bogros. The dissection should extend a minimum of 5 cm cephalad from the superior edge of the fascial defect. Inferiorly the plane is confluent with the space of Retzius and dissection here should continue sufficient retropubic space has been created for at least 5 cm of mesh overlap (Fig. 39.8). After completion of the dissection, the posterior rectus sheath is closed in the midline with absorbable suture. Mesh fixation begins at the inferior portion. The mesh may be secured Cooper's ligament with suture, to the pubic bone with a bone anchor or by transfascial sutures placed just cephalad to the pubis (Fig. 39.9). The number of transfascial sutures required varies between surgeons based on the defect size and the amount of mesh overlap. Typically, one to three sutures are placed in the superior portion of the mesh with one to two on the right and left side of the mesh [11]. We place one to two drains above the mesh with removal just prior to discharge if output is minimal. Fascial closure above the mesh is recommended using slowly absorbable or permanent monofilament suture in a running or interrupted manner.

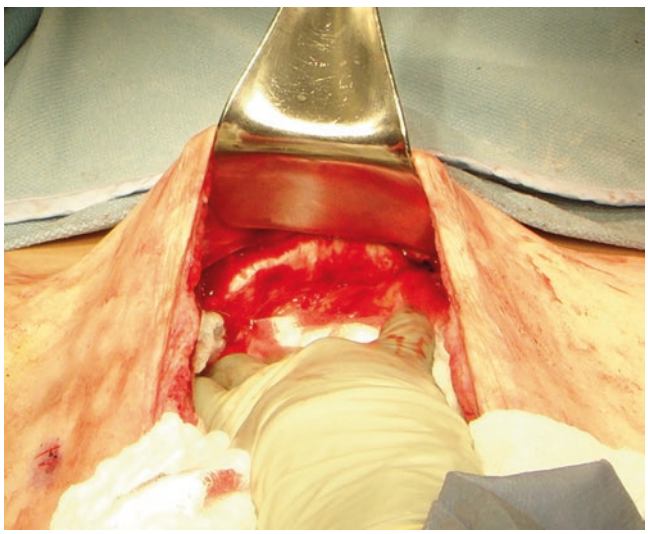

Fig. 39.8 Open retro-pubic dissection reveals a view of the pubic symphysis in the midline and Coopers ligaments bilaterally

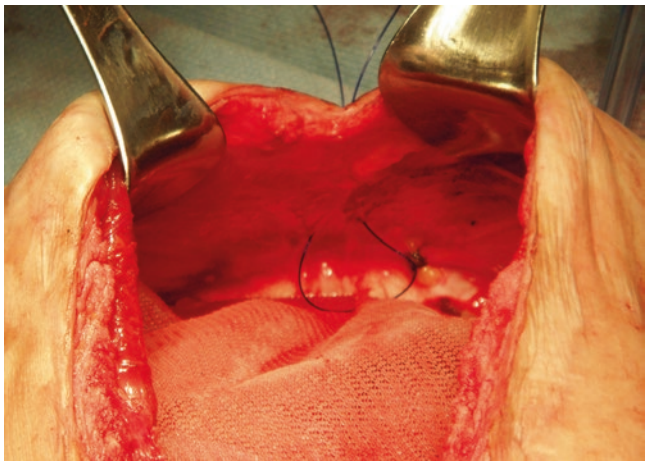

Fig. 39.9 Suprapubic mesh fixation utilizing a transfascial suture placed through the intact linea alba just above the pubic bone. Note that the stitch is located 6 cm from the edge of the mesh which extends inferior, beyond the pubic symphysis

39.5.3 Laparoscopic Repair

The patient is placed in supine position with both arms tucked. Three to five trocars are used with one being 11–12 mm in size to facilitate with intraperitoneal placement of the mesh. Ports are typically placed in the lateral quadrant furthest from the defect. Lysis of adhesions with sharp dissection is crucial with care being taken to avoid bleeding, bowel, or bladder injury. Foley catheter placement is mandatory to allow for adequate decompression and also retrograde distention to improve visualization of the bladder.

A peritoneal flap is created beginning just inferior to the umbilicus and extended inferiorly into the space of Retzius. Alternatively, the flap can begin at the inferior edge of the hernia defect (Fig. 39.10). As with open repairs, creation of the peritoneal flap will allow for inferior mobilization of the bladder and provide visualization of the pubic bone, Cooper's ligaments, the iliac vessels, and the inferior epigastric vessels (Fig. 39.11). Some authors recommend distention of the bladder with approximately 300 mL of sterile saline (with or

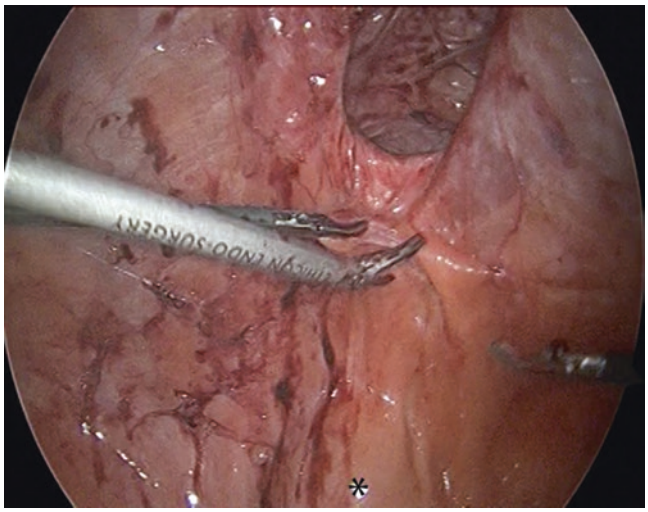

Fig. 39.10 Laparoscopic view of the inferior edge of the suprapubic defect, with a peritoneal flap beginning at this location. Note the visible bulge of the Foley catheter balloon (*)

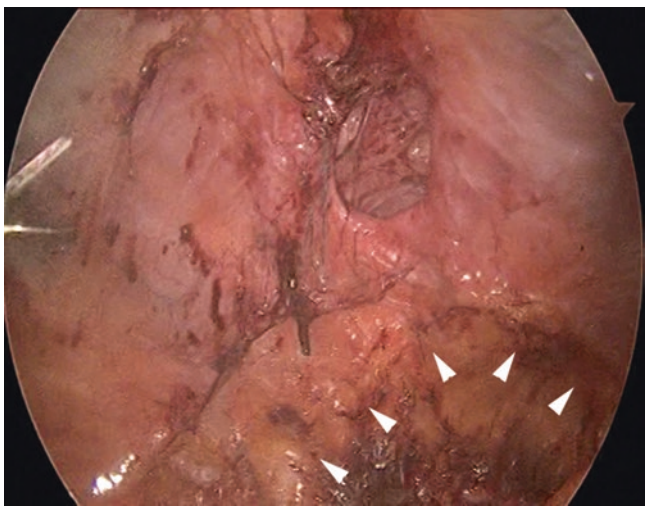

Fig. 39.11 Following peritoneal flap creation, the pubic symphysis and bilateral Coopers ligaments are visualized (*arrowheads*)

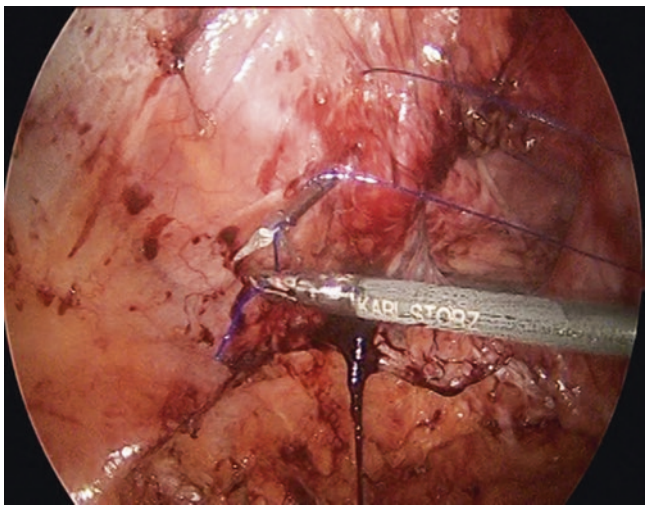

Fig. 39.12 Primary suprapubic defect closure using transfascial suture passer and permanent monofilament suture

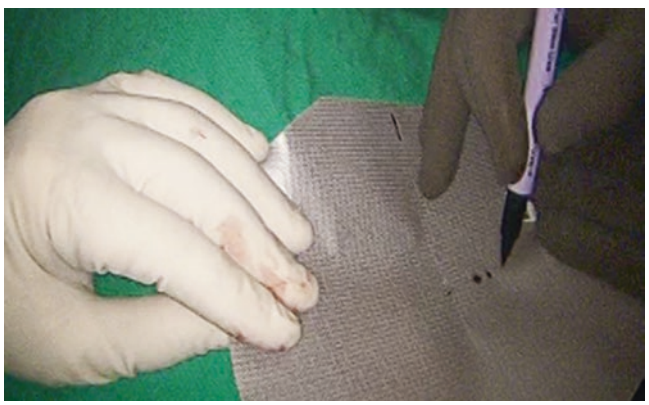

Fig. 39.13 Preparation of the laparoscopic mesh. Inferior midline marked with a straight line, location of inferior transfascial suture (7 cm from the edge of the mesh) marked with two dots

without methylene blue) during the peritoneal takedown to improve bladder mobilization and visualization, but this step is not mandatory.

Intracorporeal measurement of the defect will allow for appropriate-sized mesh placement with the desired 4–5 cm mesh overlap. Spinal needles and a ruler are adequate tools for defect measurement. When possible, we attempt laparoscopic closure of the defect utilizing a transfascial figure-of-eight suturing pattern of permanent suture (Fig. 39.12). Coated polypropylene, polyester, or ePTFE-based mesh may be used. Four sutures are typically placed on the mesh prior to insertion through an 11- or 12-mm port. The inferior-most suture is typically placed at least 5 cm away from the inferior edge of the mesh to ensure mesh overlap across the pubis (Fig. 39.13).

A transfascial suture passer is used to externalize the sutures and which are tied down to pull the mesh taught across the defect. The inferior suture should be pulled up first to ensure correct placement of the mesh (Fig. 39.14). Further fixation of the mesh with tacks should be completed with care to avoid the iliac arteries and veins (Fig. 39.15). Remaining above the iliopubic tract is necessary to avoid nerve injury. The peritoneal flap can be lifted back into position and carefully secured with tacks to avoid injury to the bladder and epigastric vessels, although this step is not mandatory (Fig. 39.16). If the mesh is not fully covered with the peritoneal flap, then the mesh selected must be approved for contact with the abdominal viscera. If a completely preperitoneal mesh position is achieved, then uncoated mesh is acceptable.

A series by Varnell et al. evaluating a trans-abdominal preperitoneal approach for suprapubic hernia repair reported a recurrence rate of 6.3 %, comparable to the literature which cites 0–5.8 % recurrence rate with all other methods [22].

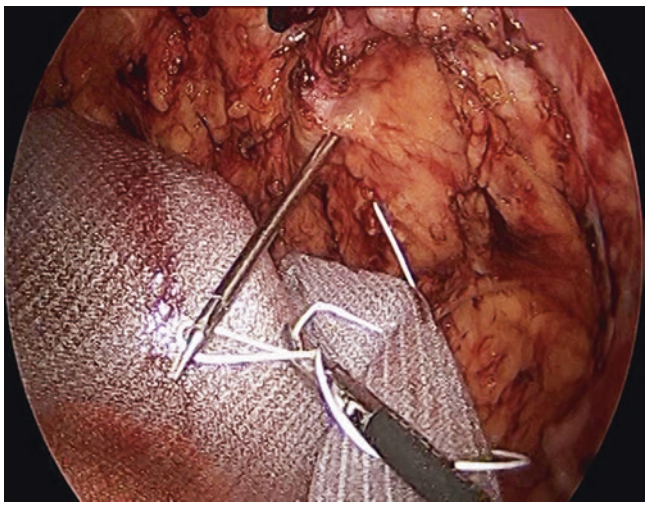

Fig. 39.14 Retrieval of the inferior transfascial suture just above the pubic symphysis

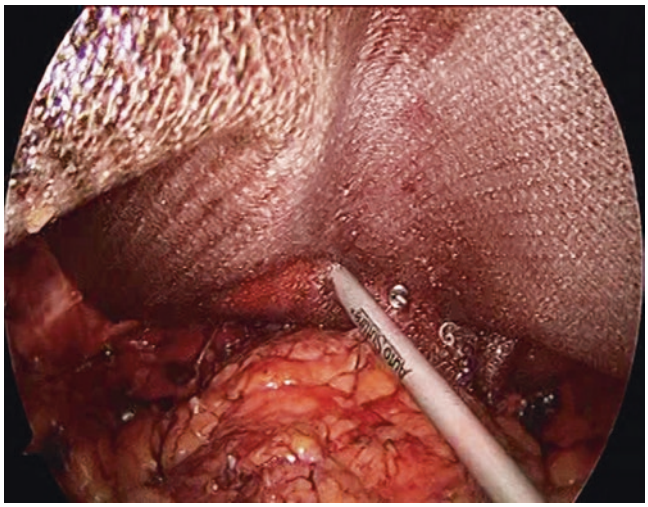

Fig. 39.15 The mesh is further secured to Cooper's ligaments bilaterally utilizing permanent laparoscopic tacks. Note that the inferior edge of the mesh passes below this point

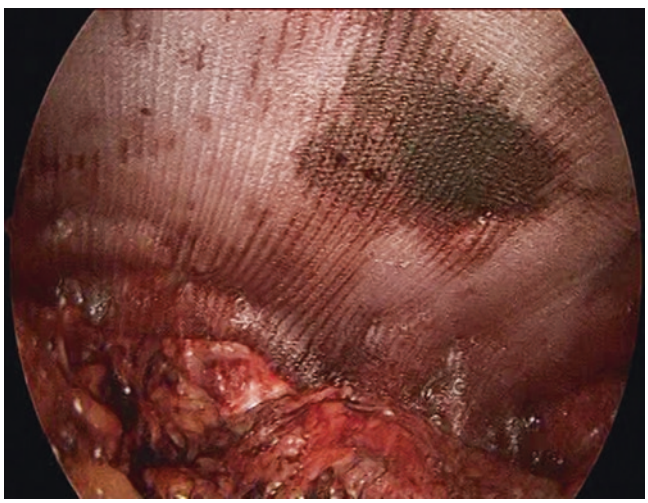

Fig. 39.16 View of the completed laparoscopic suprapubic hernia repair

39.6 Flank Hernias

Flank hernia is an all encompassing term that includes primary (congenital) defects, such as Grynfeltt or Petit hernias, and secondary (acquired) defects from trauma, retroperitoneal surgery, iliac crest bone harvest, or urologic surgery (Fig. 39.17). Several hundred primary flank hernias have been reported in the literature [28]. Secondary flank hernias have a reported incidence as high as 31 % after urologic surgery alone [29]. With a 25 % risk of incarceration and an 8 % risk of strangulation, surgical repair of flank hernias is often necessary [30]. Similar to suprapubic and subxiphoid hernias, bony structures, such as the iliac crest and the 12th rib, make repairs very complex and challenging. Numerous previous surgical approaches for flank hernia repair have included primary repair, mesh repair, tissue flap repair, and approaches from both midline and the flank [31–35]. With the fairly low incidence rate and variable surgical options, there is little consensus on the best approach to the repair of flank hernias.

39.6.1 Surgical Anatomy

The boundaries of the flank portion of the abdominal wall include the lower edge of 12th rib superiorly, the iliac crest inferiorly, the external oblique muscle laterally, and erector spinae muscle medially. Congenital defects include the inferior lumbar triangle (Petit's) and the superior lumbar triangle (Grynfeltt) (Fig. 39.18) [36].

The inferior lumbar triangle is formed by the latissimus dorsi medially, the external oblique laterally, the iliac crest inferiorly, the internal oblique muscle as the floor, and the superficial fascia as the roof. It is speculated that alterations

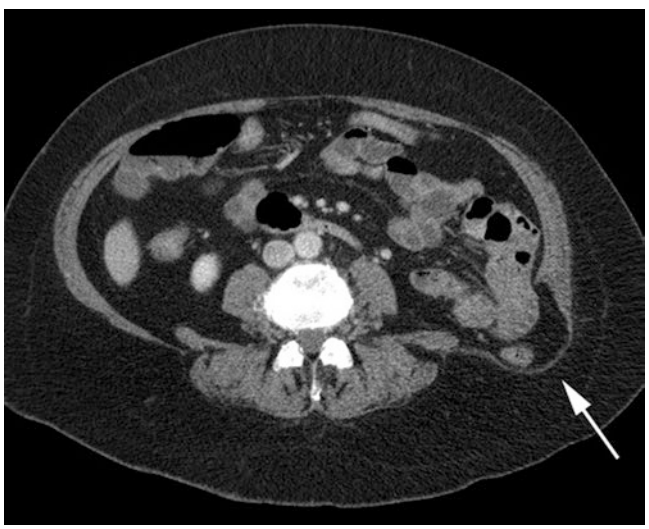

Fig. 39.17 Axial computed tomography scan of a patient with a *left* flank hernia following trauma. The hernia (*arrow*) contains the *left* (*descending*) colon and small bowel

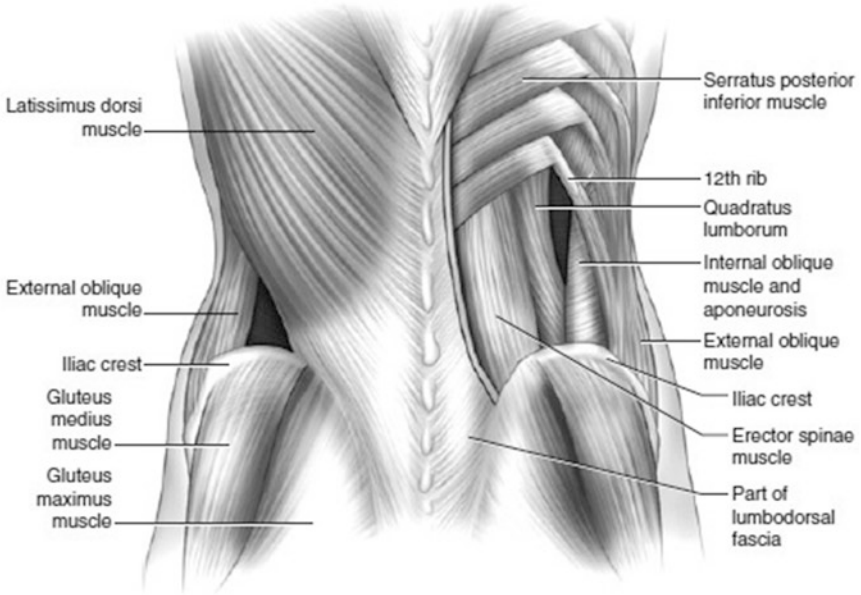

Fig. 39.18 View of the boundaries of the inferior and superior lumbar *triangles* (From Dakin GF, Kendrick ML. Challenging hernia locations: flank hernias. In: Jacob BP, Ramsaw B, editors. The SAGES manual of hernia repair. New York: Springer; 2013.)

to the origin of the external oblique muscle and a more medial lying latissimus dorsi muscle may lead to a wider triangle base and an increased risk of hernia formation [36–38].

The superior lumbar triangle is bounded by the quadratus lumborum muscle medially, laterally by the internal oblique muscle, the 12th rib superiorly, with the transversalis fascia as the floor, and external oblique muscle acting as the roof. Alteration of the anatomy of the superior triangle may increase the risk of hernia formation. Authors speculate that shorter, more obese individuals with a more horizontal 12th rib may have a larger triangle and an increased risk of hernia formation [37].

39.6.2 Open Repair

Patients are secured in the lateral decubitus position with the table broken and kidney rest up to open the space between the 10th rib and the iliac crest. For patients with combined midline and flank hernias, we prefer a midline approach. Previous incisions may be utilized to gain access. Once the hernia sac is identified, blunt dissection can be used to locate the fascial edges to permit separation of the hernia sac from surrounding abdominal wall musculature. The preperitoneal plane is entered and developed by mobilizing the retroperitoneum posteriorly to expose the psoas muscle. The preperitoneal space is the ideal location for the mesh as it allows for large overlap of the defect.

To avoid tearing the peritoneum, the dissection plane can be transitioned into the retromuscular plane (by dropping the posterior rectus sheath) just medial to linea semilunaris and carrying the dissection to the linea alba. This transition must be done with care to avoid injury to the traversing neurovascular bundles that enter the posterior rectus muscle at this location as transection of the linea semilunaris can denervate the rectus and destabilize the abdominal wall. The plane is further developed inferiorly toward Cooper's ligament and superiorly toward the diaphragm and below the costal margin as needed to ensure adequate mesh overlap (as with subcostal hernia repair). Care must be taken to not injure the ureter, gonadal vessels, and iliac vessel during dissection [39].

Any peritoneal defects may be closed with absorbable suture. Appropriately sized mesh is chosen to cover the entire retroperitoneal space from Cooper's ligament, to the psoas muscles, to above the costal margin, and finally to the midline [39]. An uncoated polypropylene mesh is used in our practice. Suture is placed on the mesh prior to placing in the retroperitoneal space. A suture passer is used to secure the mesh at the level of the psoas. The mesh is then secured medially, then inferiorly, and finally superiorly. As with other repairs, the transfascial sutures are placed remote from the edges of the mesh to allow additional overlap with the bony landmarks. Some authors secure the mesh with transfascial sutures only at 5–10 cm intervals [40]. If diminished overlap at the iliac crest is noted, mesh fixation to the iliac crest with bone anchors may be utilized [39]. Drains are left above the level of the mesh below the primary fascial closure.

39.6.3 Laparoscopic Repair

Patients are placed in a lateral decubitus position and secured in place. Three to five trocars are usually required and placed in a semicircular fashion medial to the site of herniation. One port should be an 11- or 12-mm port to facilitate placement of the mesh. Lysis of adhesions is completed using sharp dissection.

The colon should then be mobilized by taking down the line of Toldt in order to improve visualization of the hernia and to improve mesh overlap, similar to a transabdominal preperitoneal repair [11]. The defect is measured intracorporeally and a barrier-coated mesh is chosen. Four sutures are placed at the superior, inferior, right, and left middle border of the mesh and then placed through the 11- or 12-mm trocar. A suture passer is used to pull the four sutures up and the mesh is secured. Transfascial sutures, surgical glue, or bone anchors may be used for further fixation.

39.6.4 Extraperitoneal Repair

Laparoscopic extraperitoneal approach to flank hernia repair has also been described [41, 42]. An incision at the midaxillary line halfway between the 12th rib and the iliac crest is made and dissection is carried down to the peritoneum [36]. Blunt or balloon dissection is utilized to create a space for further trocar placement. The hernia contents are reduced and dissection is carried out beyond the psoas and erector spinae muscles to create a space for the mesh [36].

39.7 Additional Considerations for Atypical Hernias

39.7.1 Tissue Sealant Fixation of Mesh

Chronic postoperative pain following hernia repair has been attributed to scarring, inflammatory reactions to the mesh, and also nerve irritation by the mesh, sutures, or tacks. Glue fixation has been explored as a means of mesh fixation in order to eliminate the chronic pain attributable to sutures or tack, which may occur at a higher rate with atypical hernias. Fibrin glue consists of human fibrinogen and human thrombin that mix during application to create an adhesive property [43].

The use of glue fixation over suture or tacks has demonstrated promising results. Previous studies have demonstrated a reduction of chronic groin pain when using glue fixation for open inguinal hernia repairs without an increase in recurrence [44]. Rieder and colleagues demonstrated in an in vitro setting that tangential detachment forces of fibrin glue and polyvinylidene fluoride/polypropylene mesh were not substantially different from that of absorbable tacks and polyvinylidene fluoride/polypropylene mesh [45]. Glue fixation in the setting of atypical hernias does present unique applications. However, the evaluation of chronic pain and hernia recurrence following the use of glue fixation in atypical hernia repair is lacking.

Mesh fixation during subxiphoid hernia repairs can be challenging due to the presence of bony structures. Fixation of the mesh with sutures of tacks above the costal margin should not be performed in order to avoid chronic pain and also the risk of pericardial injury [14]. Glue fixation may provide an additional option when fixating the mesh above the costal margins and the xiphoid. The excess mesh overlying the costal margins and xiphoid bone can be affixed to the abdominal wall with tissue sealant.

Suture and tacks are currently utilized for mesh fixation during suprapubic hernia repair. Due to the concern for mesh relaxation or buckling during fascial reapproximation and removal of the pneumoperitoneum, we would recommend suture or tack fixation to the pubis and Cooper's ligament. However, glue fixation may play a role in reducing the number of sutures or tacks required to obtain adequate, and taught, mesh fixation.

Mesh fixation during flank hernia repair should also currently be performed with transfascial sutures or with tacks. Glue fixation alone has not been extensively evaluated and should be used as an adjunct to either transfascial sutures or tacks. Excess mesh overlying iliac crest can be fixated with glue.

39.7.2 Bone Anchor Fixation of Mesh

Orthopedic surgeons routinely use drill-and-insert anchors when applying autologous or prosthetic material to bone [46]. Bone anchors in the setting of abdominal wall reconstruction were first published in 1994 and their use in the setting of atypical hernias has gained interest [47].

For suprapubic hernias, the lack of fascia in the area of the pubic symphysis has previously caused some authors to evaluate the use of periosteal mesh fixation. Studies have demonstrated the superiority of bone anchors compared to simple periosteal suture fixation [48, 49]. Yee and colleagues published with experience with 30 patients undergoing laparoscopic ventral hernia repair requiring bone anchor fixation. Seventeen patients had midline or suprapubic hernias and 13 patients had flank hernias. The average length of stay was 5.2 days with a recurrence rate of 6.7 % over a mean follow-up of 13.2 months. However, it should be noted both patients with recurrences were on chronic immunosuppression and corticosteroids or renal transplantation which are a well-known cause of osteoporosis and substantial bone loss [50]. The authors criteria for utilizing bone anchors was less than 4 cm from the pubic bone to the defect in suprapubic hernias or less than 4 cm from the iliac crest in flank hernias. After laparoscopically placing and fixating the mesh with transfascial sutures, the pneumoperitoneum was released. Incisions were made over the pubic bone or iliac crest. A cordless drill was used to drill the appropriate amount of holes to house titanium bone anchors with double #2 braided polyester sutures attached to them. The pneumoperitoneum was reestablished and suture passers were used to take one suture of

each bone anchor through the mesh and back out to create a U-stitch which were then tied.

Carbonell and colleagues also published their experience with bone anchoring and repair of ten lumbar hernias. In each case, a preperitoneal plane was created to house the mesh with a 5–8 cm overlap [51]. The mesh was positioned under the iliac crest with overlap. The bone anchors were placed at the top of the inner table of the iliac crest and spaced every 15–20 mm. The attached sutures were then passed through the polypropylene mesh and tied down. The remaining mesh was fixated with transfascial 1–0 polypropylene sutures every 4–6 cm. No recurrences were noted over a mean follow-up of 40 months.

Phillips and Rosen described their bone anchoring technique used in open repair of flank hernias [39]. The mesh was initially fixed posteriorly just lateral to the psoas muscle. A surgical cordless drill was then used to pre-drill holes in the iliac crest. Mitek bone anchors (Mitek Surgical Products, Westwood, MA), which are titanium with double #2 braided polyester sutures, were placed into the pre-drilled holes. Each suture arm of the bone anchor was passed through the mesh 8–10 cm off the edge to allow adequate overlap of the iliac crest. Transfascial sutures are used to secure the remaining portions of the mesh using #1 polypropylene sutures.

More recently, Blair and colleagues published their data evaluating the use of bone anchoring in ten lumbar, seven suprapubic, and three flank hernias. An average of four anchors were used per case with no recurrences noted over a follow-up period of 24 months [52]. They suggest bone anchors should be added to any surgeon's armamentarium when performing complex suprapubic or flank hernia repairs.

39.8 Robotic Hernia Repair

An extensive literature review failed to produce any significant studies pertaining to the robotic repair of atypical hernias. Despite the dearth of information regarding the use of robotics in repair of atypical hernias, the concepts of laparoscopy can certainly be applied to robotically assisted repairs of atypical hernias. Appropriate robotic port placement should take a few points into consideration. For instance, if a defect is located in the flank, the ports should be placed on the opposite side with the robot docked on the side with the defect. Surgeons must also take into consideration the approximately 5 cm mesh overlap required for proper hernia repair and plan the distance of the robotic ports from the hernia appropriately.

The da Vinci Robot (Intuitive Surgical, Sunnyvale, CA, USA) offers the benefits of six degrees of motion, three-dimensional images, superior ergonomics, and more precise intracorporeal suturing [53]. These added degrees of freedom could provide improved retroperitoneal dissection, reduce the chance of injury, and elimination of the need for tacks and transfascial sutures, which have been associated with significant postoperative pain. Previous studies have demonstrated that transfascial sutures are more strongly associated with postoperative pain [54, 55]. Nerve entrapment or impingement is the likely cause of chronic postoperative pain.

The use of intracorporeal suturing (made easier by the use of a surgical robot) to fixate the mesh to the anterior abdominal wall eliminates the need for tacks and possibly transfascial suture placement, which in theory, could decrease the amount of postoperative pain. In locations where laparoscopic mesh fixation with tacks is generally avoided (such as above the costal margin), simple suture fixation of the mesh to the peritoneum could be accomplished robotically, offering an advantage in the repair of atypically hernias.

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Umbilical Hernias

40

Julie Holihan and Mike K. Liang

40.1 Introduction

An umbilical hernia is a fascial defect through the umbilical ring unrelated to a prior incision. Primary ventral hernias above this location are considered epigastric hernias, while hernias near this location associated with a prior incision are considered incisional hernias [1]. These definitions have substantial importance due to differences in anatomy, treatment, and outcomes (Table 40.1). Differentiating these hernias types can be complicated, in particular with supra-umbilical primary ventral hernias and incisional hernias related to prior laparoscopic surgeries or pfannenstiel incisions. In general, most supra-umbilical primary ventral hernias have features similar to and should be classified as epigastric hernias, while any peri-umbilical hernia with a prior pfannenstiel incision or nearby incision should be considered an incisional hernia.

Umbilical hernias are among the most common pathology encountered by the practicing clinician, and they are the second most common type of hernia (following inguinal hernias) to be repaired surgically. In studies of individuals among the general population, physical exam or ultrasound has identified that up to one-half of all individuals have a fascial defect of the umbilical ring [5]. What is unclear is the proportion of these patients that have or will develop clinically significant signs and symptoms. There are a myriad of potential signs and symptoms that may manifest with an umbilical hernia including worsening pain, increasing size, cosmetic disfigurement, worsening function, incarceration, and strangulation.

Umbilical hernias can be congenital or acquired. The pathophysiology of an umbilical hernia is related to a combination of mechanical deficits of the abdominal wall and/or mechanical factors impacting the abdominal wall. Mechanical deficits of the abdominal wall can be due to congenital factors (incomplete fusion of the abdominal wall), genetic etiology (described or undescribed collagen disorders), or smoking. Mechanical factors stressing the abdominal wall typically include chronic strain such as prostate disease, constipation, chronic cough, physical exertion, pregnancy, or ascites. However, the most prevalent cause of chronic strain in Westernized nations is obesity. With nearly two-thirds of individuals overweight or obese, the prevalence of clinically relevant hernias is rapidly growing.

This chapter will review management strategies, patient selection, preoperative preparation, surgical options, and outcomes of umbilical hernias among adult patients.

40.2 Elective Presentation

40.2.1 Management Strategies

Different management strategies exist for patients with ventral hernias including (1) nonoperative management except for acute presentation, (2) initial nonoperative management and preoperative optimization, (3) nonoperative management until the development of symptoms (colloquially termed "watchful waiting"), and (4) operative management (Table 40.2).

The common risks of surgery include surgical site infection, hernia recurrence, adhesions, and chronic pain, while the common risks of nonoperative management include increasing pain, increasing size, worsening abdominal function, cosmetic disfigurement, and incarceration or strangulation. Individualizing the balance between the risks and benefits of each option can help surgeons and patients identify a mutually agreeable treatment plan.

Little is known about the outcomes of nonoperative management of umbilical hernias. While the risks of emergency primary ventral hernia repair are associated with increased odds of infection, recurrence, morbidity, and mortality, the risk of acute presentation is largely unknown. In a retrospective cohort of 789 patients presenting with a

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_40

Table 40.1 Classification of ventral hernias and important anatomic, treatment, and outcome differences [2–4]

	Anatomy	Surgical repair			
		Open	Laparoscopic	Recurrence[a] (%)	SSI (%)
Primary ventral hernia	Fascial defect not associated with a prior incision	–	–	–	–
Epigastric hernia	Largely preperitoneal fat protruding through a defect in the linea alba with little to no adherence of contents to the fascial margins	Often easy to reduce the herniated preperitoneal fat and enter the preperitoneal space	Must incise and release the falciform ligament AND reduce preperitoneal fat	5–10	5–10
Umbilical hernia	Transversalis fascia, preperitoneal fat, and peritoneum may protrude through the umbilical ring and typically the layers are fused at the umbilical ring	Entering the preperitoneal space can be challenging due to fusion of layers at the umbilical ring	Must incise the peritoneum and reduce the preperionteal fat	5–10	5–10
Ventral incisional hernia	Fascial defect due to a prior incision. Fascia, muscle, preperionteal fat, and peritoneum are commonly scarred and fused within 1–2 cm of the previous incision	Layers of the abdominal wall are often heavily scarred 1–2 cm from the margins of the hernia defect and retrorectus space may be more feasible to enter than the preperitoneal space	Often challenging to excise the herniated peritoneum (i.e., hernia sac) due to the heavy scarring	24–43	10–25

[a]At 2–5 years postoperative
SSI = Surgical site infection

Table 40.2 Management strategies

Treatment category	Who	Why
1. Nonoperative management except for acute presentation	Patient at high risk for complication due to terminal comorbidities such as end-stage cardiac disease, advanced cirrhosis, or metastatic cancer	These patients are at significant perioperative risk for nonsurgical and surgical complications due to non-modifiable risk factors. The risk of complications outweighs the symptoms experienced by the patient
2. Initial nonoperative management	Patients who are symptomatic from their hernia or desire repair but have modifiable comorbidities such as smoking or poorly controlled diabetes	These patients are at increased risk for surgical complications due to modifiable comorbidities. Optimizing their medical conditions can potentially decrease the risk of complications associated with surgery
3. Nonoperative management until symptoms develop, "watchful waiting"	Patients who would be acceptable surgical candidates but demonstrate few signs or symptoms due to their hernia	These patients have minimal to no signs or symptoms. Often these patients were only diagnosed incidentally on radiographic imaging exam performed for another indication (e.g., CT scan or ultrasound). Although the risk of incarceration exists, surgery may have little to no benefit to patient quality of life. These patients can consider observing their hernia. If their signs or symptoms change, elective repair can be considered
4. Initial operative management	Patients who are acceptable surgical candidates and experience symptoms from their hernia	These patients are acceptable candidates for surgery and also have signs or symptoms that may be benefited with surgical repair

primary ventral hernia to a surgical clinic, 342 (43.2%) were treated nonoperatively [6]. The most common reasons for nonoperative management included oligosymptomatic hernias (245, 71.8%), comorbidities (42, 12.3%), and patient choice (23, 6.7%). Within the follow-up period of 31 months (interquartile range 15–48), 38 (11.1%) patients underwent surgical repair due to elective (27, 7.9%) or emergent (11, 3.2%) reasons. Common reasons for emergency repair included incarceration with or without bowel obstruction and strangulation and pain.

Although the outcomes associated with umbilical hernia repair are far superior to incisional hernia repair, careful patient selection is still warranted. The long-term risk of repair failure is high, and patients who recur following umbilical hernia repair are funneled into a vicious cycle of repeat repair, complications, recurrence, and repeat repair [7]. This vicious cycle of cost and complication can be potentially avoided by careful patient selection and preparation.

Much is known about risk factors for poor surgical outcomes, such as infections and hernia recurrence. In a recent con-

sensus statement by the Ventral Hernia Outcomes Collaborative, hernia experts recommended avoiding initial elective ventral hernia repair among current smokers (Grade A), obese (Grade A), and poorly controlled diabetic patients (Grade B) [8]. Although multiple surgical risk calculators exist to estimate complications following surgery, none have been externally validated or demonstrate strong predictive accuracy [9].

In preparation for surgery, patients with potentially modifiable risk factors should undergo preoperative optimization. This may include smoking cessation, diabetic management, or prehabilitation ("preoperative rehabilitation"). Preoperative smoking cessation has been shown to be efficacious but has limitations in effectiveness [8]. Among those able to quit smoking preoperatively for 1 month, postoperative morbidity can be reduced substantially (relative risk reduction 0.3, 95 % CI 0.2–0.6) [10, 11]. Preoperative diet modification and exercise is believed to be associated with weight loss, improved physical function, and improved glucose control. However, the effectiveness of these interventions may be limited due to poor compliance. Currently, randomized controlled trials are ongoing to assess the effectiveness of prehabilitation among patients with ventral hernias [12].

How we do it*: Currently, we recommend elective repair for all low-moderate risk patients with symptomatic umbilical hernia or umbilical hernias that are apparent on clinical examination. For patients who are current smokers, obese, or poorly controlled diabetics, we recommend quitting smoking for 1 month prior to surgery, diet and exercise for an individualized goal BMI of 30–35, and optimization of their glycosylated hemoglobin (Hemoglobin A1C) to a goal of <8.0 %.*

In the past two decades, two major advances have been made with umbilical hernia repair: the use of mesh reinforcement and laparoscopic umbilical hernia repair. Multiple randomized controlled trials have demonstrated that mesh reinforcement as compared to suture repair of umbilical hernias is associated with a substantial reduction in hernia recurrence (odd ratio 0.09, 95 % confidence interval 0.02–0.39) with a slight increase in risk of surgical site infection (odds ratio 1.29, 95 % confidence interval 0.48–3.49) [2, 13, 14]. The number needed to treat to prevent a hernia recurrence is nine, while the number needed to harm to cause a surgical site infection is 83. Based upon these calculations there is no setting in clean cases of umbilical hernia repair where mesh should not be used. Despite this existing data, nearly 50 % of all elective umbilical hernias are repaired using suture-only technique in the United States [15].

Another substantial innovation in umbilical hernia repair is laparoscopy. There are no randomized controlled trials assessing the outcomes of laparoscopic versus open umbilical hernia repair. However, in a systematic review and network meta-analysis of randomized controlled trials comparing laparoscopic versus open repair of all ventral hernias (primary and incisional), a sensitivity analysis of only primary ventral hernia repairs demonstrated that laparoscopy decreased surgical site infection (odds ratio 4.17, 95 % confidence interval 2.03–8.56) with no impact on hernia recurrence (odds ratio 0.94, 95 % confidence interval 0.46–1.98). The number needed to treat to prevent a surgical site infection is 14 while the number needed to harm to cause a single hernia recurrence is 159. However, these studies do not assess all of the potentially important factors and outcomes included in decision-making, such as patient centered outcomes (e.g., satisfaction, pain, function, and quality of life), need for general anesthesia, port site hernias, eventration/bulging, and intra-abdominal adhesions. However, based upon the existing evidence, patients at increased risk for surgical site infection should consider undergoing a laparoscopic ventral hernia repair. Existing evidence for surgical decision-making in open and laparoscopic umbilical hernia repair is summarized in Table 40.3.

How we do it*: Currently, we recommend all overweight patients, diabetic patients, patients with two or more hernias (i.e., epigastric and umbilical hernia), patients with diastasis recti, and patients with a hernia defect >2 cm to undergo a laparoscopic umbilical hernia repair. For patients who would greatly benefit from or prefer avoiding general anesthesia, an open repair is utilized. For all other patients, either treatment can be considered.*

There is little high quality data to guide choices on repair technique with umbilical hernias. Among the few existing randomized controlled trials, many have substantial design flaws including pooling incisional hernias with umbilical hernias, lack of blinding when substantial financial conflicts of interest exist, or improper randomization.

How we do it*:*

Open umbilical hernia repair (Fig. 40.1).

- With open umbilical hernia repair our preference is to make an infra-umbilical transverse incision along the Lines of Langerhans for bulges through or below the umbilicus and a transverse supra-umbilical incision for bulges just above the umbilicus (Fig. 40.1a).
- Underlying tissue is dissected down to the fascia, and the umbilical stalk is dissected free circumferentially utilizing a dissecting clamp (Fig. 40.1b). The umbilical stalk is carefully freed from the hernia sac and contents avoiding violation of both the dermis/epidermis and the peritoneum (Fig. 40.1c). Typically, the dermis will appear as glossy white tissue and start to form brown pills with cautery injury. In this setting, cautery should be shifted to the line between yellow fatty tissue and the glossy white dermis.
- The hernia sac is dissected circumferentially down to the fascia. It is a common misconception that the hernia sac can be inverted and the preperitoneal space can be entered. The layers of the abdominal wall fuse at the umbilical ring, and the fascia must be incised circumfer-

Table 40.3 Data to support operative decision-making

Repair type/operative decisions	Evidence	Grade and strength[a] of recommendation
Open umbilical hernia repair		
Incision: transverse	Limited evidence exists however, transverse and vertical incisions have similar clinical outcomes, and in efficacy trials, vertical incisions through the umbilicus may have improved cosmetic effect [16]. However, generalizability of the results and including the technical challenges to this approach remains to be assessed	Grade D Weak
Mesh location: preperitoneal	With ventral hernia repair, sublay mesh placement is associated with the lowest risk of hernia recurrence (odds ratio 0.22, 95 % CI 0.06–0.47) and surgical site infection (odds ratio 0.45, 95 % CI 0.12–1.16) compared to onlay, sublay and inlay. However, few studies exist in umbilical hernias alone. In addition, the generalizability of these recommendations and additional important outcomes (e.g., adhesions, patient centered outcomes) remain to be assessed	Grade B Moderate
Mesh type: mid-density polypropylene	Limited evidence exists, however low-density meshes have been demonstrated to have higher odds of hernia recurrence in other studies of ventral hernias and super-heavyweight meshes have been shown to be associated with chronic pain, high rates of recurrence, and increase surgical site infection [17, 18]	Grade C Moderate
Fascial closure: transverse	Limited evidence exists to support transverse as opposed to vertical closure of the umbilical fascia. Transverse closure is largely based upon historical observational studies. Randomized trials of transverse versus longitudinal laparotomy incisions demonstrate no differences [19]	Grade D Moderate
Laparoscopic umbilical hernia repair		
Ports: 25 mm lateral ports	Larger ports are at increased risk for port site hernias, particularly in patients undergoing laparoscopic ventral hernia repair	Grade A Strong
Dissection: excision of peritoneum and preperitoneal fat	Failure to excise the peritoneum and preperitoneal fat will result in tissue eventration [20]	Grade C Strong
Mesh introduction: 10 mm port through defect	Introducing mesh through a larger port can prevent damage to the mesh and the adhesions barrier and is easier for the surgeon [21]. However, these larger ports are at increased risk for ventral incisional hernia. Placing the port through the defect is safe with little risk for complication and prevents ventral incisional hernias [22]	Grade C Strong
Mesh type: coated polyester mesh	Only one randomized controlled trial exists assessing meshes in laparoscopic ventral hernia repair. This study demonstrated no differences in recurrence with polyester versus low-density mesh but slightly decrease risk of pain in the early postoperative period. These differences were no longer apparent at 6 months. The study was limited by lack of blinding [23]. In large effectiveness trials, polyester has been shown to be both safe and potentially beneficial in clean laparoscopic ventral hernia repair [24]	Grade C Weak

(continued)

Table 40.3 (continued)

Repair type/operative decisions	Evidence	Grade and strength[a] of recommendation
Primary fascial closure: bridged for small defects and closure for larger defects	Although many reports have demonstrated benefit of primary fascial closure with laparoscopic ventral hernia repair, these studies have been largely in incisional hernia repair [25]. RCT in primary hernia has demonstrated no benefit for primary ventral hernia such as umbilical hernia [26]. This, however may be related to hernia defect size as opposed to hernia type	Grade B Moderate
Fixation: double crown of permanent tacks	Permanent tack fixation has been demonstrated to improve long-term outcomes with decreased hernia recurrence rates and no difference in pain [27]. Double crown tack fixation may have benefit of less pain however may be associated with challenges of positioning the mesh [28]	Grade B Moderate

[a]GRADE = Grading of recommendations assessment, development, and evaluation [29]

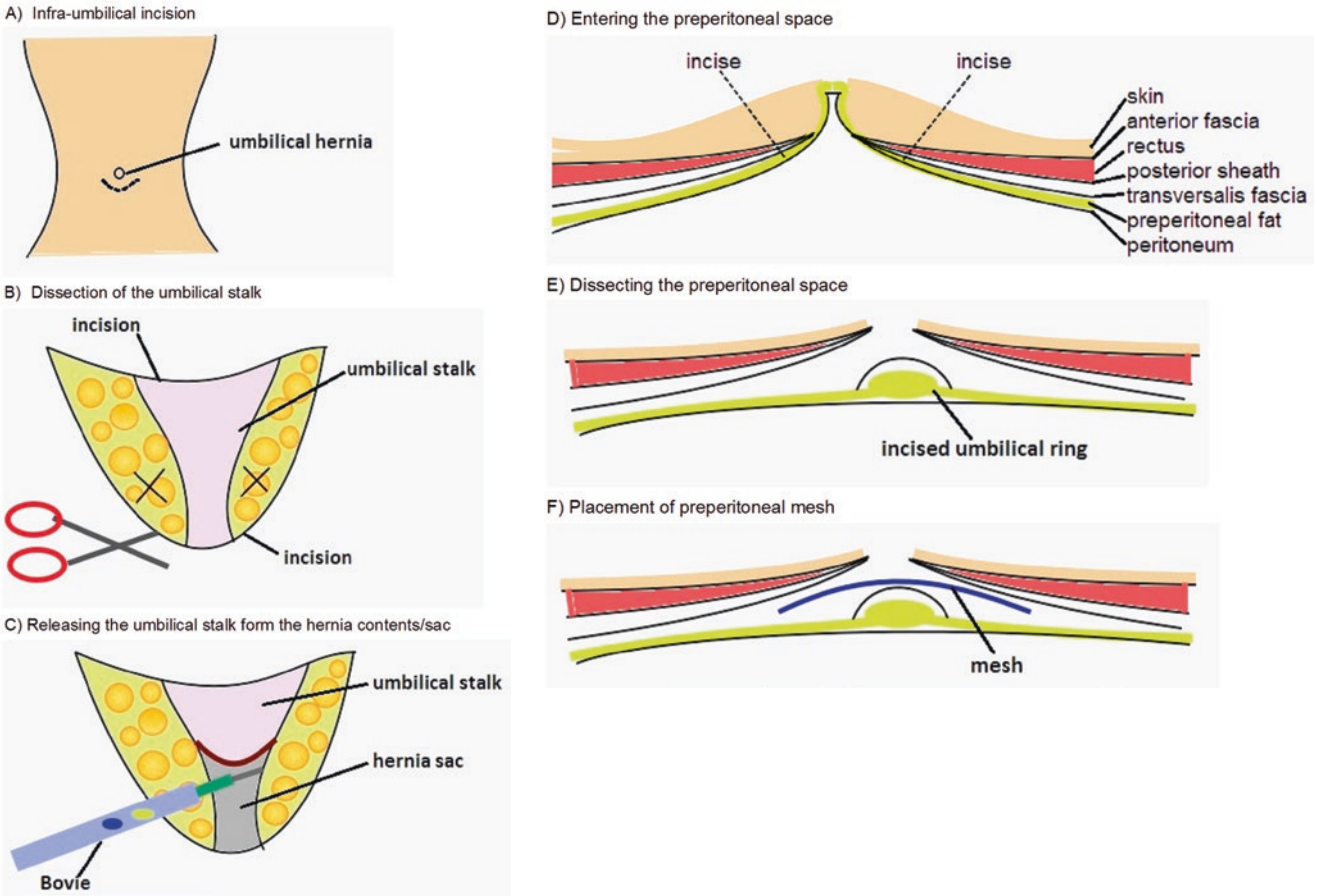

Fig. 40.1 Steps in open umbilical hernia repair. (**a**) Infra-umbilical incision; (**b**) dissection of the umbilical stalk; (**c**) releasing the umbilical stalk form the hernia contents/sac; (**d**) entering the preperitoneal space; (**e**) dissecting the preperitoneal space; and (**f**) placement of preperitoneal mesh

entially to enter into the preperitoneal space (Fig. 40.1d). Utilizing cautery, the fascia should be incised at least 2 mm from the margins of the umbilical ring but no more than 5 mm (or the retrorectus space will be entered). The freed umbilical ring is incised to split the ring of fascia and prevent a potential site for bowel incarceration (Fig. 40.1e).
- To free the preperitoneal space, gentle blunt dissection applying pressure to the posterior rectus sheath (to avoid tearing the fragile peritoneum) with small radial pushes circumferentially (Fig. 40.1f). A space of at least 3–5 cm in all directions should be developed. We utilize a mid-density polypropylene mesh placed in the preperitoneal space. The central defect can be closed with 2-0 or 0 polydioxanone sutures placed in a transverse fashion. The umbilical stalk is tacked to the closed fascial defect with two 2-0 or 0 polyglactin 910 sutures.

Laparoscopic umbilical hernia repair (Fig. 40.2).

- The abdomen is entered with placement of a 5 mm optical port placed in the left upper quadrant just lateral to Palmer's point (subcostal at the midclavicular line), and the abdomen is insufflated to 15 mmHg. Upon verification of safe port placement, an additional 5 mm port is placed along the left flank.
- Using an energy device (hook dissector with monopolar cautery), the peritoneum and preperitoneal fat is incised circumferentially 2–5 mm from the margins of the hernia defect to the posterior fascia. Preperitoneal fat and peritoneum is gently dissected free and reduced en bloc.
- A 10–12 mm port is placed through the hernia defect through a transverse infra-umbilical incision. A coated mid-density polyester mesh (coated with adhesion barrier) is introduced through the 10–12 mm port.
- For defects ≥3 cm, the fascia is closed with interrupted 0-polydioxanone sutures in a transverse fashion.
- The mesh can be held in a stable central position with a single stay suture and secured circumferentially utilizing a double crown of permanent tacks.
- The abdomen is desufflated and the umbilical stalk can be tacked to the fascia with or tied to the central stay with one or two 2-0 or 0 polyglactin 910 sutures.

40.3 Special Circumstances

40.3.1 Acute

It is well accepted that emergency umbilical hernia repair is associated with a higher rate of complications including surgical site infection, hernia recurrence, and reoperation. This may be associated with the fact that high-risk comorbid patients are less likely to undergo elective repair, and thus, are more likely to present acutely. Or it may be that acute presentation is associated with greater surgical risk due to contamination and need for a laparotomy. When risk-adjusted for patient comorbidities and contamination, there appear to be limited difference in outcomes from similarly challenging elective repair [30].

Factors associated with an increased risk for emergency repair include comorbidities such as obesity and cirrhosis as well as the physical features of a hernia. In a retrospective study of patients undergoing emergency ventral hernia repair due to potential bowel compromise (incarceration, strangulation, obstruction), randomly matched 1:3 to elective ventral hernias, comorbid patients (morbidly obese and cirrhotic) and hernia features (acute angle and hernia sac height but not hernia defect size) were correlated to emergency surgery. It is unclear if the comorbidities are associated with acute repair because patients with these diseases are less likely to undergo elective surgery or if these comorbidities actually increase the risk of incarceration. Other studies have identified that obesity and cirrhosis are highly correlated with incarceration and acute presentation [31, 32]. The traditional teaching that small hernias are more likely to incarcerate is largely due to the fact that there are more small hernias. However, the odds of a small hernia incarcerating is no different than that of a large hernia. Instead, a mushrooming hernia (acute hernia angle and tall hernia sac height) is at increased odds for emergency as opposed to elective surgery (Fig. 40.3). Among moderate risk or oligosymptomatic patients where either operative or nonoperative management may be pursued, patients with these hernia features (acute angle and tall hernia sac) may benefit from operative management.

How we do it*: During emergent umbilical hernia surgery, the primary purpose is to relieve organ ischemia and treat any ramifications of the incarceration. The patient's intraoperative hemodynamic stability, underlying acidosis, degree of contamination, underlying functional status, and long-term prognosis impact the decision to perform a suture-only repair, biologic mesh reinforcement, or synthetic mesh reinforcement. In general, we prefer to begin with a diagnostic laparoscopy. If there is no contamination, the repair will be completed utilizing a laparoscopic technique. If there is contamination, an open bowel resection will be performed. In a hemodynamically stable patient with good underlying function, estimated life expectancy >1–2 years (e.g., no metastatic cancer), and no plans for a second operation (e.g., colostomy requiring colostomy takedown), a biologic mesh repair will be performed.*

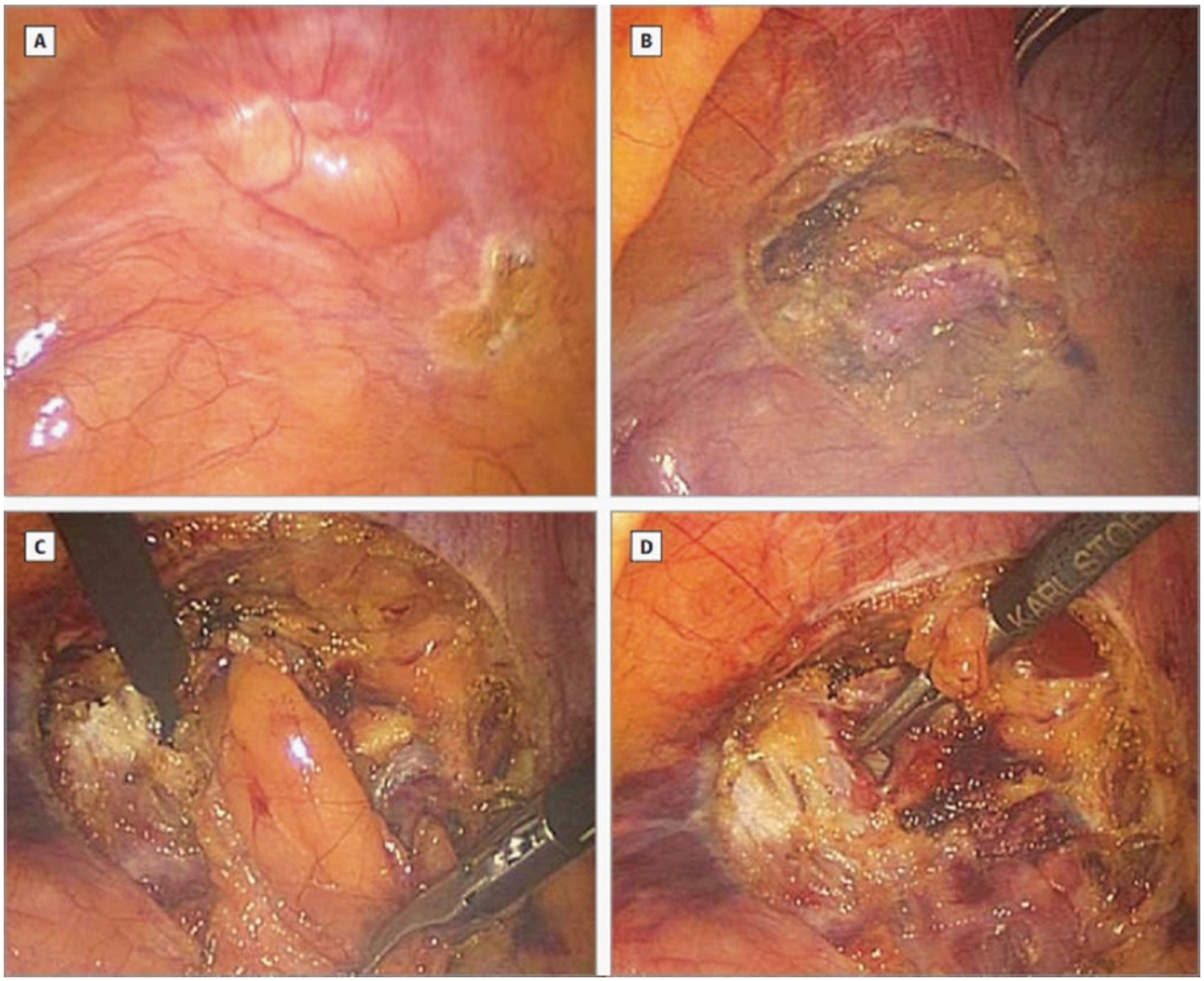

Fig. 40.2 (**a**) Primary ventral hernia; (**b**) excision of hernia sac; (**c**) excision of preperitoneal fat; and (**d**) exposure of hernia fascial edges

40.3.2 Concomitant Repair

There is little direct evidence to guide surgeons in the treatment of patients with an umbilical hernia who are undergoing a surgery for another procedure (e.g., appendectomy, cholecystectomy, or colectomy). It is unclear if patients with an umbilical hernia as compared to those without have an increased risk of developing an incisional hernia. There is data demonstrating that concomitant repair is associated with worse outcomes including increased risk of surgical site infection, hernia recurrence, and reoperation; however, among patients at high risk for developing ventral incisional hernia, prophylactic mesh placement has been demonstrated to efficacious in preventing incisional hernia [8, 33]. Currently no consensus exists to guide treatment in this setting. Surgeons report barriers to concomitant hernia repair and prophylactic mesh reinforcement including lack of support from the Centers for Medicare and Medicaid services, lack of department support, limited effectiveness data, and unclear delineation of the risks and benefits [8].

How we do it*: We describe our treatment algorithm (Fig. 40.4).*

40.3.3 Cirrhosis

Operating in patients with cirrhosis is a challenging endeavor. In particular, umbilical hernias have a complex relationship with cirrhosis. First, cirrhotics are more likely to present with an acute umbilical hernia due to incarceration, strangulation, or with a peritoneal/atmospheric fistula causing an ascitic leak. It is unclear if cirrhotics are more likely to present acutely because surgeons are less likely to repair these hernias electively or if cirrhosis increases the risk of acute presentation due to increased intra-abdominal pressure and tissue weakening. Second, portal hypertension often results

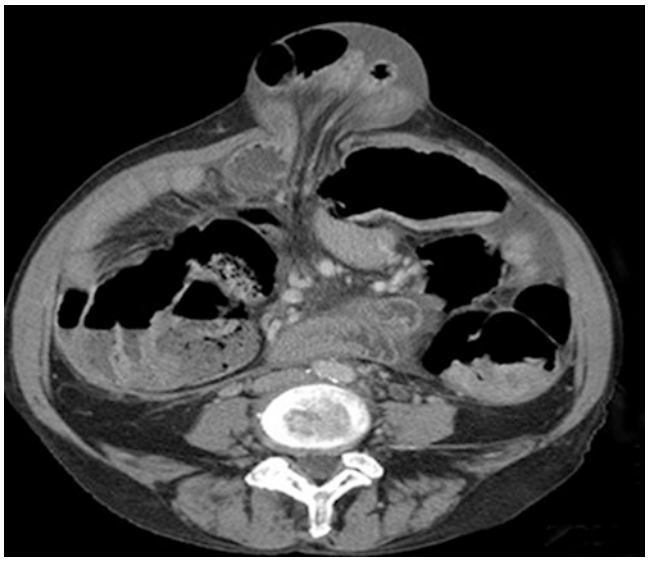

Fig. 40.3 CT scan showing "mushrooming" hernia

in hypertrophy of collateral venous circulation, and a common site of collateralization is the peri-umbilical venous system creating the "caput medusa." Incisions in this area are at high risk for violating the pressurized venous system and causing significant bleeding.

Although multiple studies have suggested that elective umbilical hernia is safe in patients with cirrhosis, all of these studies were small case series suffering from substantial selection and reporting/publication bias (i.e., poor outcomes are rarely reported as case series) [13, 34–36]. Nationwide series have demonstrated poor outcomes with elective repair of umbilical hernias among cirrhotics, and physician-reported estimate of risks and benefits more closely mirror national data as compared to overly optimistic reports of small case series [37–39].

How we do it*: We describe our treatment algorithm (Fig. 40.5).*

40.3.4 Pregnancy

Due to increased intra-abdominal pressure of pregnancy, the umbilicus will often protrude, and an umbilical hernia will become evident. It is uncommon to present with an umbilical

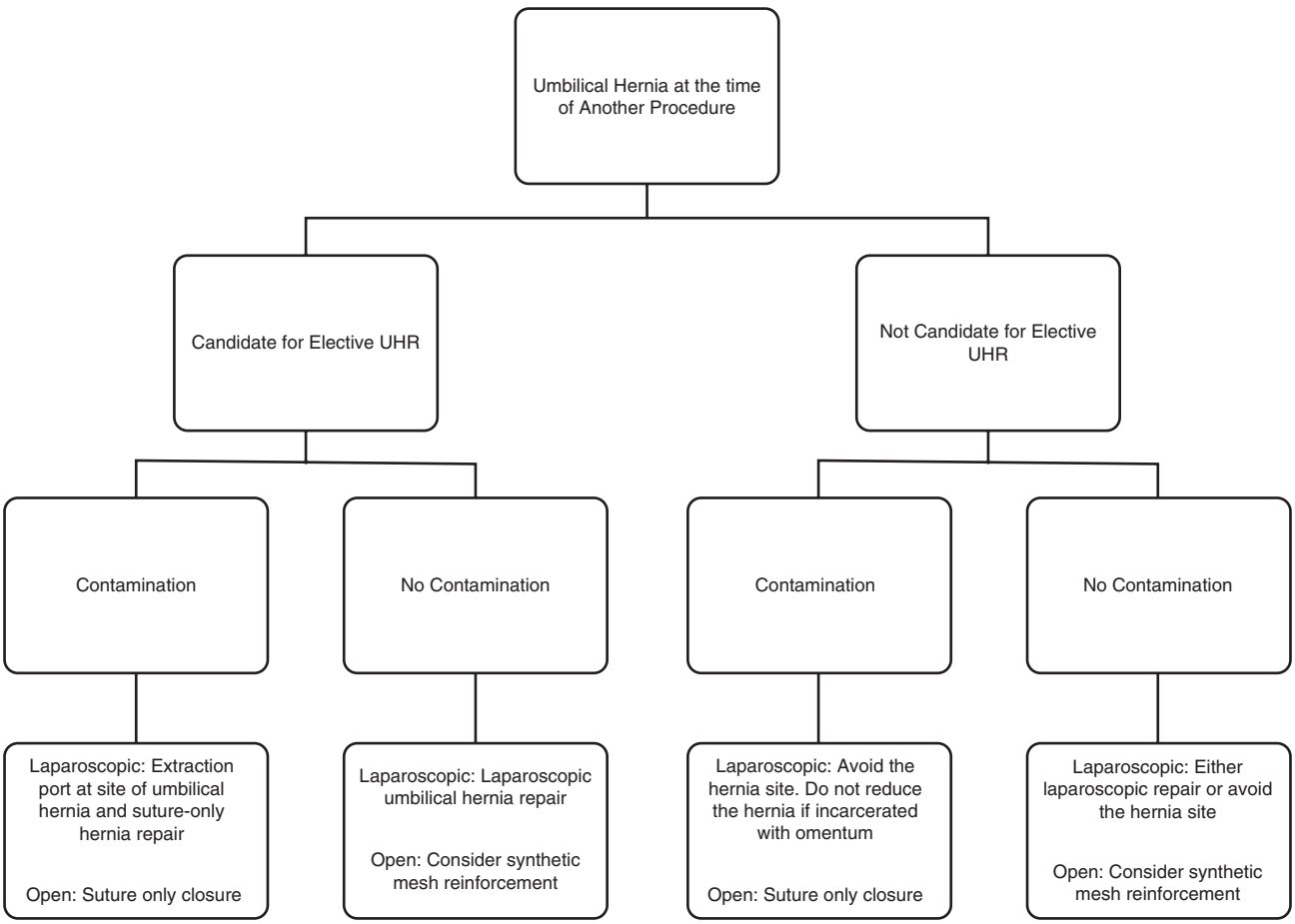

Fig. 40.4 Treatment algorithm in the approach of umbilical hernias during other procedures

hernia incarcerated with bowel during pregnancy due to the enlarged uterus. However, case reports of uterine fibroids, preperitoneal fat, omentum, and even small bowel incarcerated in ventral hernias have been reported. Umbilical hernia repair has been safely performed during pregnancy and numerous case reports of emergency surgery due to potential bowel compromise or urgent surgery due to fat incarceration and pain have been published. One must be cautious in interpreting these findings as they represent the lowest level of evidence and substantial publication bias exists (i.e., surgeons are unlikely to publish case reports with a poor outcome). An open approach may present the least amount of risk to the fetus. In all other settings, delaying any operative intervention until after pregnancy and even following breast feeding is prudent. It is unknown if the umbilical hernia can recede or if associated symptoms can regress following delivery. Plans for surgery should be based upon symptoms after pregnancy and plans for future pregnancy. There is little evidence on the impact of hernia repair on future pregnancy, and no definitive conclusions can be drawn [40, 41]. However, repair with synthetic mesh is generally considered safe and unlikely to significantly impact future pregnancy.

40.4 Future Needs

The greatest challenge with the management of umbilical hernias is a society with increasing comorbidities in Westernized communities. Obesity is an epidemic and along with persistence of smoking and growing elderly population, the prevalence of complex individuals with a clinically significant umbilical hernia will increase. Repair, whether elective or emergent, among this population is associated with a substantially increased risk of complications, triggering a vicious cycle of cost and complication: umbilical hernia repair, recurrence with a new incisional hernia, incisional

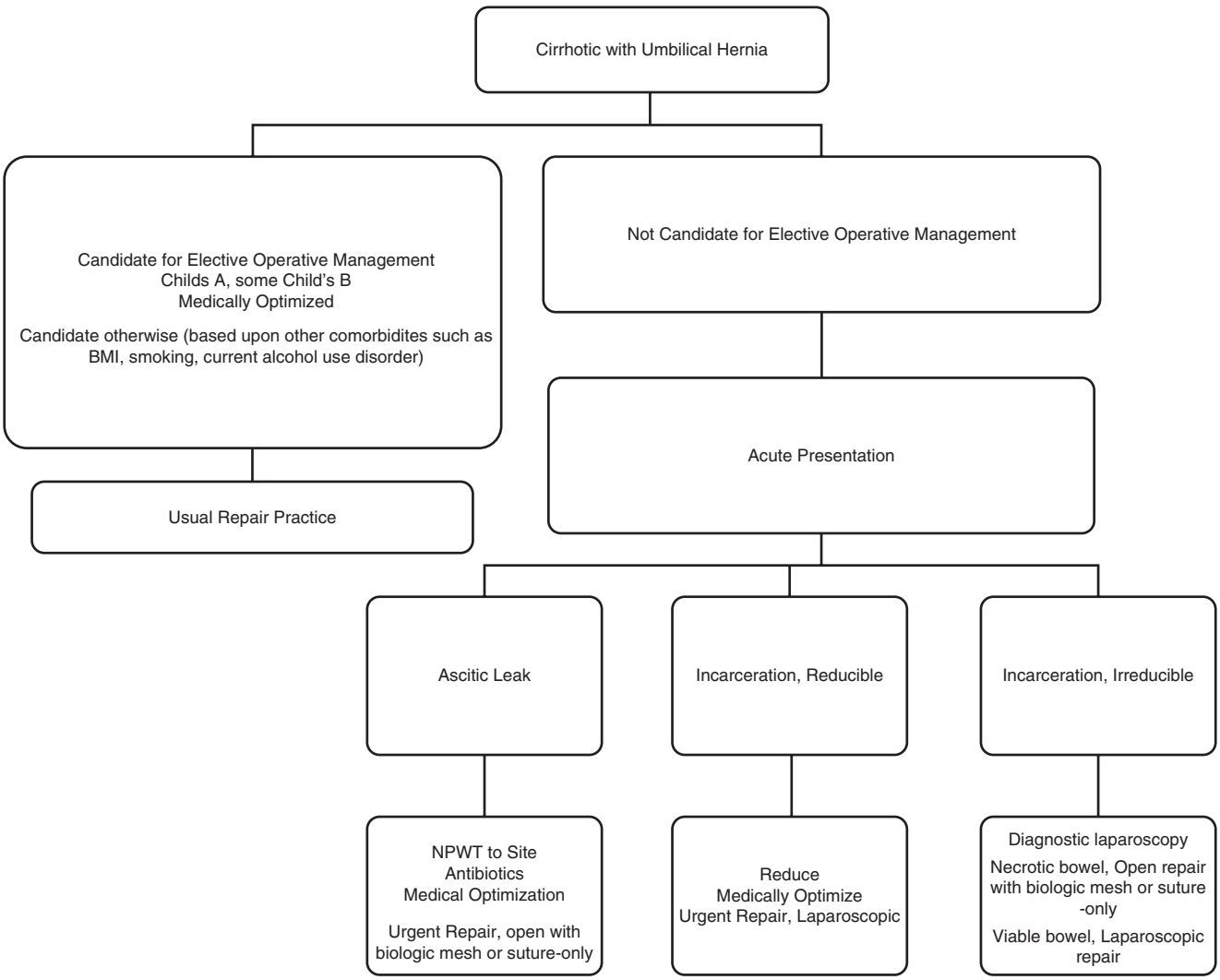

Fig. 40.5 Treatment algorithm in the approach of cirrhotic patients with umbilical hernias

hernia repair, recurrence, and so forth. The greatest priority among hernia surgeons should be the prevention and treatment of the increasingly prevalent rate of obesity in Westernized society.

There is little evidence to guide the treatment of umbilical hernias during surgery for other diseases. The risk of recurrence along with the risks and benefits of reinforced versus suture-only repairs requires more investigation. While there is an increasing body of evidence suggesting that reinforcement of surgical incisions is safe and efficacious, multiple barriers exist prevent widespread adoption of this practice.

40.5 Conclusions

Umbilical hernias are among the most common disease encountered by the practicing physician, and repair is among the top five surgeries performed by the general surgeon. Frank discussion with patients regarding the risks and benefits of treatment options along with careful preoperative preparation can help optimize outcomes of surgical management. Routine mesh reinforcement in the sublay position (preperitoneal) for open repair and mesh placed in the underlay position (intraperitoneal) for laparoscopic repair is recommended for clean cases. More evidence is needed to guide repair in contaminated cases and concomitant cases during procedures for other disease. However, the most urgent goal for hernia surgeons is the battle against burgeoning obesity epidemic.

Acknowledgments Nicole M. Hewitt for illustrations.

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Diastasis Recti

41

Maurice Y. Nahabedian

41.1 Introduction

Diastasis recti is a common condition that can manifest postpartum or following abdominal surgery. It is characterized by a widening or separation of the rectus abdominis muscles along the linea alba and in severe cases the linea semilunares as well. The differentiating feature of diastasis recti in relation to a ventral incisional hernia is that there is no fascial defect with diastasis recti. This chapter will focus on the etiology, diagnosis, and management of diastasis recti.

41.2 Anatomy

The aponeurotic layers of the anterior abdominal wall include the linea alba, anterior rectus sheath, posterior rectus sheath, and the external oblique fascia. The anterior rectus sheath and the linea alba are composed of collagen fibers arranged in an interwoven lattice [1]. The vascularity of the anterior rectus sheath and linea alba is derived from the perforating branches of the deep and superior inferior epigastric vessels as well as the superficial epigastric vessels. The loose areolar fascia over the surface of the anterior sheath and linea alba is highly vascularized. The muscular layers of the anterior abdominal wall are equally important and comprised of the paired rectus abdominis muscles as well as the paired external, internal, and transverse oblique muscles. The forces exerted by these muscles as well as intraabdominal pressure can place tension on the midline linea alba and result in separation or attenuation resulting in a diastasis recti.

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41.3 Etiology

The etiology of diastasis recti is usually the result of increased intraabdominal pressure that is typically observed with pregnancy; however, obesity and prior abdominal operations can also cause diastasis [2]. In cases of severe diastasis recti, the myofascial laxity is both vertical and horizontal and can involve the entire anterior abdominal wall [3]. In a study of 92 patients following abdominoplasty with documented diastasis recti the inter-recti distance was measured and analyzed. It was demonstrated that the distance of rectus separation was <1 in. in 7 % of patients, between 1 and 2 in. 83 %, and exceeded 2 in. in 10 % [3]. Comparisons between nulliparous women and postpartum women have demonstrated a doubling of the inter-rectus distance from approximately 0.5–1.0 to 1.2–2.3 cm using ultrasound-assisted measurements [2]. Postpartum patients demonstrated a gradual decrease in the distance over time; however, baseline values were never achieved at 6-month assessments. Postpartum patients had a reduction in abdominal strength at 6 months that was rated as 4/5, whereas nulliparous women had 5/5 strength of the trunk flexors and rotators.

41.4 Diagnosis

Diastasis recti presents as a midline bulge without a fascial defect that can occur above or below the umbilicus. It is amplified by having the patient lye flat and perform a straight leg raise (Fig. 41.1). Confirmation of rectus diastasis can be made using CT, MRI, or ultrasound but these tests are usually not necessary [4–6].

There are three classification systems that have been described for diastasis recti. The Nahas classification is based on the myofascial deformity and the etiology [7] (Table 41.1). The Rath classification is based on the level of the attenuation relative to the umbilicus and the patient age [8] (Table 41.2). The Beer classification is based on the normal width of the linea alba as determined from 150 nulliparous women [9] (Table 41.3).

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_41

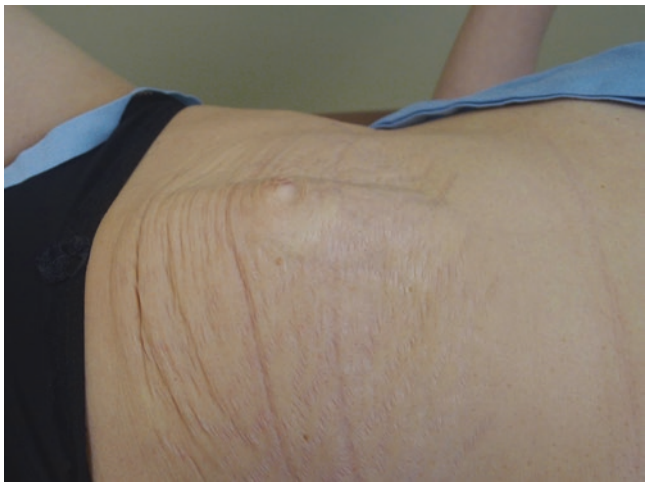

Fig. 41.1 A midline vertical bulge is demonstrated in a postpartum woman with diastasis recti

Table 41.1 The Nahas classification based on the myofascial deformity

Nahas classification		
Deformity	Etiology	Correction
Type A	Pregnancy	Anterior sheath plication
Type B	Myoaponeurotic laxity	External oblique plication
Type C	Congenital	Rectus abdominis advancement
Type D	Obesity	Anterior sheath plication and rectus abdominis advancement

Table 41.2 The Rath classification based on the level of the attenuation relative to the umbilicus and the patient age

Rath classification		
Level	Age <45 (mm)	Age >45 (mm)
Above umbilicus	10	15
At umbilicus	27	27
Below umbilicus	9	14

Table 41.3 The Beer classification based on the normal width of the linea alba

Beer classification	
Normal width of the linea alba (mm)	
Level	Width
At Xiphoid	15
3 cm above umbilicus	22
2 cm below umbilicus	16

41.5 Treatment

There are several options for management of diastasis recti ranging from exercise to simple plication of the linea alba and anterior rectus sheath to more advanced excisional techniques with or without the use of a mesh. Endoscopic and laparoscopic techniques can also be used in select situations where a small midline hernia is present as well. In many cases, an abdominoplasty is also considered to excise the redundant adipocutaneous layer.

41.5.1 Exercise

The benefit of exercise to prevent or correct diastasis recti is associated with mixed results [10]. Corrective exercise protocols include core strengthening, aerobic activity, and neuromuscular re-education. Although mild to moderate benefit has been reported based on a reduction of the inter-rectus distance, there is insufficient evidence to recommend exercise as a means of preventing or treating rectus diastasis.

41.5.2 Abdominoplasty

In most women with mild to severe diastasis recti, the overlying adipocutaneous component of the anterior abdominal wall has also become stretched and flaccid. An abdominoplasty in conjunction with a diastasis repair is typically performed in these women to further improve the abdominal contour [11–13]. The techniques for abdominoplasty are varied and can include a low transverse excision, vertical excision, or a fleur-de-lis pattern incorporating a vertical and horizontal skin excision pattern.

41.5.3 Plication of the Linea Alba

For mild to moderate diastasis recti, midline plication of the linea alba can be considered. With this technique, the attenuated linea alba is delineated and plicated using absorbable or nonabsorbable sutures. In some cases, the attenuated linea alba can be tightened using a low set cautery device to create thermal contraction. The plication is usually in two layers and includes a triangular suture technique that incorporates the lateral edges of the fascia and the midline of the posterior rectus sheath is frequently used [14]. When the linea alba is severely attenuated, it can be excised with reapproximation of the thicker edges of the anterior rectus sheath.

Studies evaluating absorbable and nonabsorbable sutures have demonstrated no significant difference in the inter-recti distance as measured by CT scan 6 months following correction [15]. In patients with significant laxity of the anterior rectus sheath, lateral plication can also be performed on both sides to further improve and tighten the abdominal contour. A two-layer repair technique is usually performed using an absorbable interrupted suture followed by a running continuous suture for further reinforcement. The length of this repair can extend from approximately 2 cm below the costal margin to approximately 2 cm above the pubic bone.

Outcomes following sheath plication for diastasis recti have been mixed. In a review of 20 women following vertical sheath plication using an absorbable suture, a 100 % recurrence was demonstrated after 1 year [16]. Reasons included a repair that was localized to the defect only, a repair that addressed only the horizontal component of the diastasis, and suture related fraying of the anterior rectus sheath due to its fragile nature. In a similar study utilizing a two-layer plication repair with nonabsorbable sutures, positive outcomes were achieved in the majority of patients [5]. Efficacy of the repair was evaluated by postoperative CT scans in 12 women at 3 weeks, 6 months, and again at a mean of 81 months postoperatively demonstrating no recurrence in any patient at all levels studied. In a comparative abdominoplasty study between parous women with a diastasis and nulliparous without a diastasis that had fascial plication with an interlocking continuous absorbable suture, the mean inter-recti distance was essentially equal at all levels studied between the two cohorts [4]. Postoperative assessment was performed via physical examination and ultrasound in all women at 12–41 months following the repair.

The type and orientation of suture material used for diastasis repairs is an important consideration. In a comparative study between absorbable sutures and nonabsorbable sutures, CT scans obtained at 3 weeks and 6 months demonstrated no significant difference [15]. In a cadaveric study that compared horizontal and vertical suture placement, a significant increase in rupture strength was noted for vertically placed sutures based on dynamometric testing [17].

41.5.4 Fascial Plication and Onlay Mesh

The use of a mesh can be considered in cases of extensive fascial laxity [11]. This is usually considered in patients with attenuation of the linea alba as well as the linea semilunares. A resorbable or non-resorbable mesh can be used and is positioned over the anterior rectus sheath following the plication. It is trimmed to fit the dimensions of the anterior abdominal wall and extends from the costal margin superiorly to the pubic region inferiorly and also extends to the anterior axillary line bilaterally. A non-resorbable mesh is usually preferred in these cases because the patients are typically healthy and at low risk for adverse outcomes. The edge and the central portion of the mesh are fixated with absorbable interrupted sutures. Abdominoplasty is performed as needed. A single closed suction drain is used. Figures 41.2, 41.3, 41.4, 41.5, 41.6, and 41.7 illustrate a patient with a severe diastasis recti managed using fascial plication and onlay mesh.

41.5.5 Retrorectus Repair with Sublay Mesh

In cases of moderate to severe diastasis recti, a retrorectus repair can be considered [18, 19]. With this technique, an abdominoplasty is almost always recommended and can be performed in two ways. The first is the low transverse excisional pattern and the second is the vertical paramedian incision extending from the xiphoid to the pubic bone. Following elevation of the adipocutaneous layer, the medial aspect of the rectus abdominis muscle is identified and the retrorectus space is entered preserving the vascularity and laterally based innervation of the rectus abdominis muscle. The rectus abdominis muscle and posterior rectus sheath are separated. The degree of redundancy of the posterior rectus sheath is approximated and then plicated along its midline using a resorbable suture in an interrupted manner. The repair can then be reinforced using a resorbable or non-resorbable mesh that is placed on the surface of the posterior rectus sheath in the retrorectus space and anchored with interrupted absorbable sutures. The umbilical stalk is passed through an opening created in the mesh. Following the posterior repair, the rectus abdominis muscles are reapproximated along the midline. The anterior rectus sheath is repaired using interrupted absorbable sutures.

Outcomes following the retrorectus repair have been demonstrated to be effective. In a review of 52 women following abdominoplasty and diastasis repair with the retrorectus approach using vicryl mesh, 100 % of patients reported high satisfaction with improvement of the abdominal contour [18]. It was postulated that posterior plication alone may not be sufficient in all cases. The use of a resorbable mesh was preferred because it effectively relieved fascial tension, was resorbed by 6 weeks, was placed in an extraperitoneal position, and did not increase the incidence of complications. In a review of 32 patients with severe diastasis recti treated with vertical abdominoplasty and retrorectus support using a midweight macroporous polypropylene mesh, no recurrent bulge or hernia was demonstrated at a mean follow-up of 1.5 years [19]. Differences in psychological outcomes in patients following diastasis repairs with anterior sheath plication or retrorectus mesh placement have not demonstrated any significant difference with improvement in both cohorts [20]. Subjective improvement in muscle strength was improved more in the retrorectus cohort compared to the suture cohort (6.9 vs. 4.5, Likert scale, 0–10, $p=0.01$).

41.6 Endoscopic/Laparoscopic

Endoscopic repair of diastasis recti can be considered in some patients [21]. The indications include midline/umbilical hernia measuring >2 cm, no prior hernia repair or laparotomy, and no need for abdominoplasty. The technique involves placing a trocar into the supra aponeurotic space and creating a dissection plane under direct vision exposing the linea alba and the anterior rectus sheath. The repair includes sheath plication and reinforcement with a synthetic mesh. A nonabsorbable barbed suture is typically used. A drain is placed and a soft compression garment is applied. Laparoscopic reinforcement can be

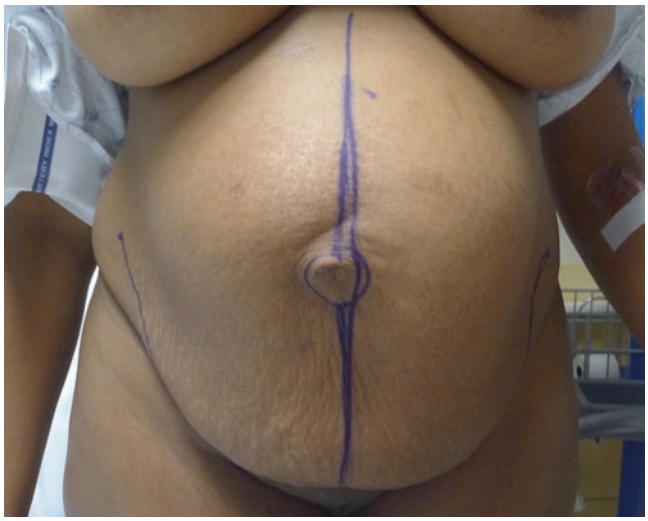

Fig. 41.2 A preoperative photograph of a woman with severe diastasis recti and an umbilical hernia is illustrated

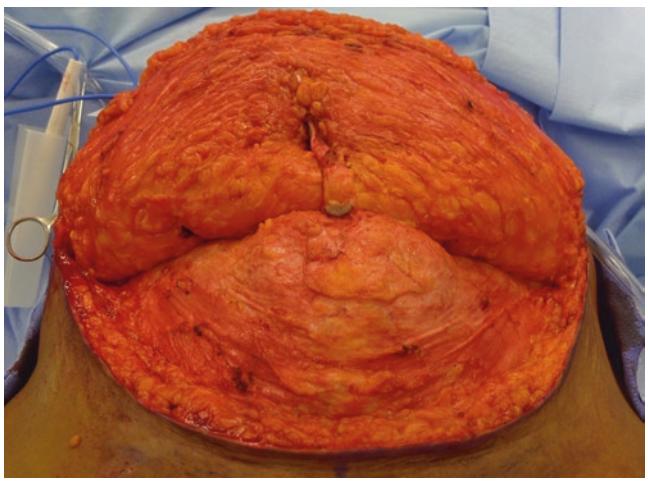

Fig. 41.3 An intraoperative image following low transverse incision and adipocutaneous elevation. The severe attenuation of the linea alba and linea semilunares is illustrated

considered in patients that have had plication of the attenuated linea alba and anterior rectus sheath. The laparoscopic placement of an intraperitoneal mesh is an alternative to onlay mesh placement [22].

41.7 Complications

Complications following rectus diastasis repair are infrequent and include infection, mesh extrusion, recurrence, nerve injury, seroma, complex scar, skin necrosis, contour abnormality, and visceral injury. Patients using tobacco products are at increased risk of delayed healing and tissue necrosis [18].

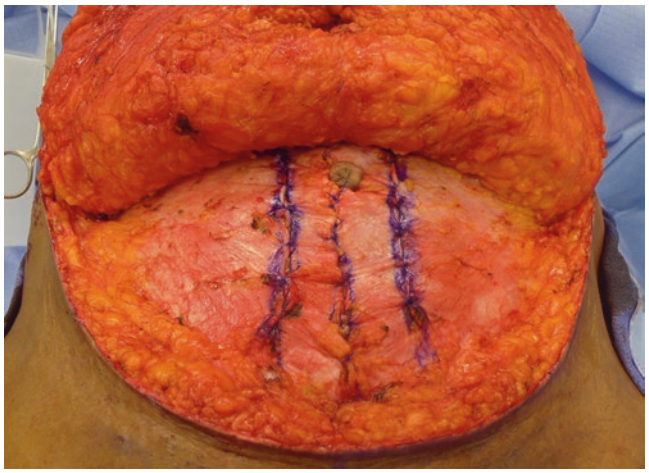

Fig. 41.4 Plication of the linea alba and the lateral anterior rectus sheath in vertical columns is completed using a nonabsorbable monofilament suture in two layers

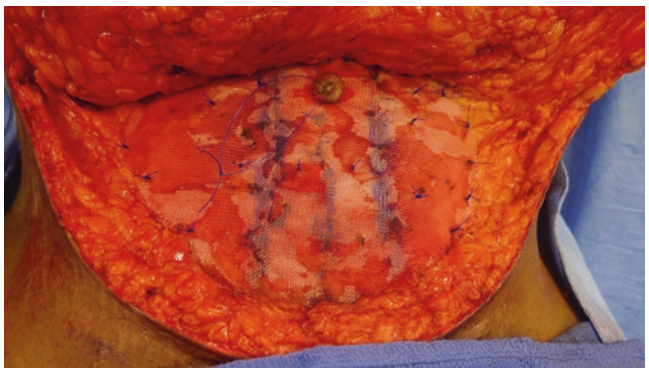

Fig. 41.5 A lightweight polypropylene only mesh is applied over the anterior rectus sheath and sutured with an absorbable monofilament suture. A temporary pull-through suture is placed on the umbilicus to facilitate exteriorization during the abdominoplasty

In a randomized controlled trial comparing outcomes and complications in women with rectus diastasis managed with layered closure of the anterior rectus sheath or retrorectus placement of synthetic mesh, superficial wound infection occurred in 24.5 % of patients of which 8.8 % were in the suture repair cohort and 15.8 % were in the retrorectus mesh cohort [20]. Postoperative pain was assessed using a visual analog scale demonstrating an improved reduction in pain in the retrorectus cohort (6.9/10) compared to the sheath plication cohort (4.8/10).

In a single study evaluating the endoscopic technique, the most frequent adverse event was a seroma (23 %) with no hernia or diastasis recurrences at 20-month follow-up [21]. The mean interrectus distance was significantly improved 1 month following the procedure with preoperative measurements ranging from 24 to 39 mm and postoperative measurements ranging from 2.1 to 2.8 mm. One- and 2-year follow-up

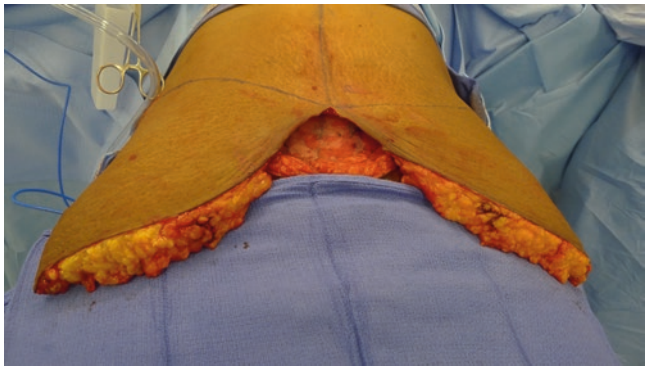

Fig. 41.6 The redundant adipocutaneous portion of the anterior abdominal wall is determined and excised

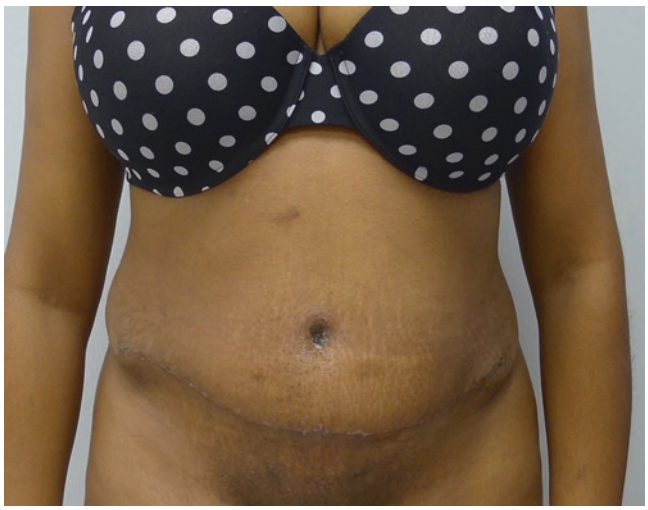

Fig. 41.7 An early postoperative photograph demonstrating significant improvement in abdominal contour with resolution of the diastasis recti

did not change from the 1-month measurements (2.5–3.7 mm). Patient satisfaction was assessed on a visual analog scale and graded with a mean score of 8.7/10.

41.8 Summary

The etiology, diagnosis, and management of diastasis recti are well understood with various management strategies available depending on the severity of the condition. Multiparous women are at highest risk for developing diastasis recti. Diagnosis is made by clinical examination and symptomology. Management options will depend on the degree of separation between the rectus abdominis muscles. Simple plication has been effective for mild to moderate diastasis. The use of resorbable or non-resorbable mesh placed as an onlay or in the retrorectus space has demonstrated success for moderate to severe diastasis.

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Evisceration and Dehiscence

42

Gabriëlle H. van Ramshorst

42.1 Introduction

Dehiscence of the abdominal wall, or *burst abdomen*, can be regarded as an acute postoperative hernia. In contrast to a superficial dehiscence of skin and/or subcutaneous tissue, a defect occurs at the level of the fascia. Its presentation can vary from a small defect in the linea alba, causing leakage of serosanguineous fluid through nearly intact skin, to a sudden burst with evisceration of abdominal contents. Dehiscence appears to occur more frequently in patients who are in poor clinical condition. A high proportion of patients who develop dehiscence, eventually develop incisional hernia. In incisional hernia, a defect of the fascia is covered by healed, intact skin. In case of elevated abdominal pressure, a bulge may be noticed as intestines, omentum, or preperitoneal tissue protrude through this defect.

42.2 Incidence and Risk Factors Relating to Dehiscence/Evisceration

In most recent studies, the incidence of dehiscence varies between 0.2 and 3.5 %. Many studies have attempted to identify risk factors for dehiscence. As many patients who develop dehiscence are in poor clinical condition, it is difficult to establish solid evidence for independent effects of individual risk factors. As an example, it is difficult to distinct the individual effects of chronic obstructive pulmonary disease, smoking, and hospital-acquired pneumonia. It has to be emphasized that data on abdominal wound dehiscence need to be interpreted with caution, as most studies were retrospective and lacked multivariate statistical analyses.

Risk factors can be attributed to the patient, type of operation, surgical technique, and postoperative period.

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42.2.1 Patient

Basic patient characteristics that have been associated with increased risk of dehiscence include male gender, advanced age, malignancy, and uremia [1–9]. These factors are beyond the influence of surgeons.

Some risk factors are clearly indicative of patients' clinical condition, and may be subject of preoperative optimalization in certain patients. These variables include, e.g., presence of ascites, chronic (obstructive) pulmonary disease, jaundice, anemia, and sepsis or systemic infections [1–4, 10–15].

A few risk factors may be influenced by patients themselves, such as nutritional status. Low levels of serum albumin and protein have been associated with dehiscence [1, 2, 4, 5, 14–16]. In a post hoc analysis of a randomized controlled trial, smoking and alcohol abuse (consumption of >4 units of alcohol per day) were identified as risk factors for abdominal wound dehiscence. However, the possible effects of surgical site infection were disregarded in multivariate analysis [17]. Smoking was also identified as a risk factor in a small case-control study, whereas two other studies could not confirm these results [18, 19, Van Ramshorst unpublished]. Alcoholism was not identified as a risk factor for abdominal wound dehiscence in two previous studies [10, 14].

The associations between superficial wound infection and the risk factors diabetes and obesity appear to be stronger than for abdominal wound dehiscence. Smith et al. identified body mass index 30–34 kg/m^2 as risk factor for abdominal wound dehiscence [20]. In spite of common belief, nor diabetes, nor obesity were independent risk factors for abdominal wound dehiscence in the majority of studies [2, 4–7, 14, 19].

42.2.2 Operation

Emergency surgery has been identified as a risk factor for abdominal wound dehiscence in many studies, but the influence of its different components on patient outcome remains

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_42

unclear [4, 5, 7, 10, 14, 21, 22]. One could hypothesize that patients who undergo emergency surgery are in worse clinical condition, more often with evidence of obstruction, with the laparotomy closed by less experienced residents and/or surgeons during late hours. Closure of the wound by a 4th year resident was cited as a risk factor for dehiscence by Webster et al. [10]. The degree of wound contamination has also been cited as a risk factor for abdominal wound dehiscence, although this association will probably be stronger for surgical site infections overall [9, 10, 21]. The same is expected to hold true for operation time and peroperative hemodynamic instability, although these can also reflect the experienced difficulty of the surgical procedure [2, 4, 10, 15, 21]. Strongly associated with contamination degree and surgical site infections is the indication for surgery. High risk procedures, compared to, e.g., diagnostic laparotomy, reportedly include large bowel, esophagus, gastroduodenal, vascular, and hernia surgery [23, 24].

42.2.3 Surgical Technique

Type of incision has been identified as a risk factor for burst abdomen in a small number of studies performed in adult patients, and is one of the few factors that can be influenced directly by the surgeon (Table 42.1). It has been hypothesized that the anatomical orientation of muscle fibers in transverse incisions prevents wound edge traction, promoting tension-free closure. From Table 42.1 can be concluded that the evidence for a preference of transverse incisions over median incisions is weak. Moreover, the choice between these two types of incisions is only relevant for a small number of surgical procedures as the proportion of laparoscopically performed abdominal procedures continues to rise. With regard to other types of incisions; Keill et al. identified the paramedian incision as a risk factor for dehiscence [3]. These results were, however, not reproduced in other studies [1, 25, 26]. No significant differences were found for subcostal, lateral paramedian, or gridiron incisions compared to transverse and/or median incisions [1, 2, 16, 27–31].

Table 42.1 Transverse vs. median incision and burst abdomen

In favor of transverse	No significant difference
Grantcharov	Brown
Halasz	Gislason
Keill	Seiler
	Proske
	Armstrong
	Stone
	Greenall
	Riou

In the past years, more studies have been published on the median incision as a risk factor for incisional hernia. Other types of incisions, such as transverse or Pfannenstiel incisions, have shown more favorable results with lower incidence of incisional hernia [32–36].

Two models were developed to predict the risk for an individual patient to develop abdominal wound dehiscence. First, Webster et al. developed a risk score based on data from Veterans Affairs Medical Centers. The population included 17,044 laparotomies, and 587 of these patients had developed abdominal wound dehiscence (3.4 %). Independent risk factors included chronic obstructive pulmonary disease, current pneumonia, emergency procedure, operative time greater than 2.5 h, PGY 4 level resident as surgeon, superficial or deep wound infection, failure to wean from ventilator, and one or more other complications. Protective factors were clean wounds and return to the operating room during admission. Data were validated in a separate cohort of laparotomy patients [10].

Second, a risk model was developed in the Netherlands based on data from an academic teaching center. For this case-control study, 363 patients with abdominal wound dehiscence and 1089 matched controls were included over a 20-year period. Major independent risk factors were advanced age, male gender, chronic pulmonary disease, ascites, jaundice, anemia, emergency surgery, type of surgery, postoperative coughing, and wound infection. The model was validated in a separate cohort of patients, again showing good predictability of the model [23]. This model was validated in a retrospective Spanish cohort by Gomez Diaz et al., showing significantly higher risk scores in patients with abdominal wound dehiscence compared to patients without abdominal wound dehiscence (mean 4.97, 95 % CI 4.15–5.79 vs. mean 3.41, 95 % CI 3.20–3.62). The value of the model for preoperative risk evaluation proved limited as the influence of, for instance, wound infection was great [37].

Kenig et al. compared both risk models in a retrospective analysis. For each case, three controls were matched on gender, diagnosis or underlying disease, and type of surgery. Patients with abdominal wound dehiscence scored significantly higher than control patients. Both models showed moderate to good predictive value, although the discriminative power of the Dutch model was hampered by the selection methods of control patients [38].

In 2015, the European Hernia Society published guidelines on the closure of abdominal wall incisions, including publications up to April 2014 [39]. Based on several meta-analyses, it was recommended to use slowly absorbable suturing material. Quickly absorbable sutures have been associated with higher rates of incisional hernia, whereas nonabsorbable sutures have been known to cause more wound pain and higher incidence of wound sinus [40].

With regard to suturing method, continuous suturing was advised since this method is significantly faster. Continuous suturing has also been associated with lower incisional hernia rates in one meta-analysis [41]. It has been hypothesized that in continuous suturing, tension can be divided better over the entire suturing thread.

In most studies on abdominal wound closure, no suture length to wound length ratio (SL:WL) were reported. This ratio has been strongly associated with the occurrence of incisional hernia [42, 43]. Israelsson et al. have performed extensive research not only on SL:WL, but also on the size of the tissue bites and stitch lengths. The small bites technique entailed taking fascia bites of 5–8 mm, whilst placing stitches every 5 mm. It was demonstrated by Millbourn et al. that adhering to "small bites" for closure of a single layer aponeurosis resulted in a significant reduction in incisional hernia rates compared to traditional large bites (5.6 vs. 18.0 %, $p<0.001$) [44]. Also, significantly fewer surgical site infections were found (5.2 vs. 10.2 %, $p=0.02$). A detailed description of the technique and advice with regard to implementation can be found elsewhere [45, 46].

These results lead to the STITCH-trial, a multicenter study in 560 patients in which the superiority of the small bites technique was confirmed, with incisional hernia rates of 13 vs. 21 % at 1 year follow-up ($p=0.0220$, covariate adjusted odds ratio 0.52, 95 % CI 0·31–0.87; $p=0.0131$) [47].

In the guidelines no recommendation could be given on the use of retention sutures due to lack of sufficient data. The available data is of poor quality and the results with regard to abdominal wound dehiscence are conflicting [3, 7, 8, 25, 48–51]. Retention sutures were widely used in the past and were known to cause pressure-related skin necrosis and pain [52].

In conclusion, the current advice of the European Hernia Society's working group for elective midline laparotomy closure is to use a slowly absorbable suture in a continuous technique in a single layer aponeurotic closure with a SL:WL of at least 4:1. An update of these guidelines, which will include the results of the STITCH-trial, is planned for 2017.

42.2.4 Postoperative Period

Surgical site infection is one of the most frequent complications of abdominal surgery and has been identified as the number one risk factor for dehiscence [1–3, 5, 7, 8, 15, 16, 21]. By release of bacterial exotoxines in the wound, collagen breakdown outweighs collagen synthesis. This causes tissue decay, resulting in dehiscence of the skin and subcutaneous tissue [53]. In patients who develop dehiscence, less granulation tissue, increase wound exudate and increased distance between wound edges were found prior to diagnosis [Van Ramshorst et al., unpublished data].

Nausea or vomiting, abdominal distension, and prolonged postoperative ileus have been identified as risk factors for abdominal wound dehiscence in some studies [5, 10, 14–16]. In other studies, no significant independent effects were found [23]. In 1976, Jenkins published a study on the influence of abdominal wound lengthening in the postoperative phase on SL:WL. As the patient's abdomen distends, so does the abdominal wound. Sutures can only elongate ("creep") to a certain extent. In case of extreme distension, SL:WL will, therefore, decrease and sutures may tear through fascia [54].

Other clinical situations of increased abdominal pressure, such as coughing as a symptom of pneumonia, have also been cited as risk factors for dehiscence [5, 10, 14–16, 23]. It seems evident that recurrent straining of the suturing thread on the abdominal wall fascia can contribute to tearing of the fascia and subsequent dehiscence with or without evisceration.

The European Hernia Society guidelines could not give any recommendation on the use of postoperative abdominal binders based on lack of evidence on the effects on incisional hernia and burst abdomen [39].

42.3 Treatment Options for Dealing with Dehiscence/Evisceration

The primary goal of treatment is definitive closure of the abdominal wall to prevent incisional hernia. It is challenging, however, to select the best treatment option for each patient. In every patient, first, underlying pathology in the form of intraabdominal abscess or anastomotic leakage should be ruled out by computed tomography or treated directly through wound exploration, depending on the clinical situation. In case of abscess formation, percutaneous drainage should be performed if possible. Second, best options are drainage through laparotomy or treatment with intravenous antibiotics alone, depending on size, position, and clinical condition. If anastomotic leakage has occurred, appropriate actions should be undertaken (for instance, repair with diverting ileostomy or colostomy) [55, 56].

42.3.1 Abdominal Wall—Should I Repair It Now?

In the event of evisceration, protruding organs should be reduced into the abdominal cavity. In some cases, such as massive bowel edema or vast adhesions, the calculated risk of morbidity or mortality is so high that patients cannot undergo general anesthesia and hence cannot undergo surgery [55].

Defects can be covered with saline-soaked gauze dressings that will require frequent dressing changes [57]. It could be considered to fixate polyglactin mesh to the skin with staples or sutures under local anesthesia. The mesh will

eventually overgrow with granulation tissue and the wound will close. This can also be an effective method for preventing bowel injury, heat and fluid loss in patients presenting with dehiscence during the night. Temporary fixation can allow for the operation to be postponed to the next day in otherwise physically stable patients without signs of sepsis.

In larger defects in "inoperable" patients, temporary fixation with polyglactin mesh to the skin, negative pressure wound therapy (with bowel protecting sheets), or "Bogota" bag application can be considered [58–63]. As soon as patients are fit to undergo general anesthesia, intraabdominal pressures have normalized and edema has disappeared, definitive measures should be undertaken to prevent fascia retraction, as this can hinder "tension-free" closure and result into incisional hernia formation with large distance between fascia edges.

42.3.2 Definitive Repair of the Fascia Defect

First, tension-free closure can sometimes be achieved by resuturing alone. Closure using suture closure alone has been reported to be possible in half of all patients, suggesting that alternative closure methods will be needed in the other half [56, 64]. Resuturing has been associated with incisional hernia rates of up to 83 % [65, 66]. There is no evidence to support the use of other techniques for resuturing than the European Guidelines for closure of the abdominal wall in patients with abdominal wound dehiscence. Resuturing alone should definitely be avoided in case of elevated intraabdominal pressure or poor condition of the fascia. As redehiscence can occur, the fascia will be damaged as it is torn by pulling sutures.

Second, if tension-free closure is not possible using suture repair, application of relaxing incisions has been described. Esmat published on the use of incisions in the transverse abdominal and internal oblique muscles (TI), additional incision in the external oblique (TIE), or combined with Scarpa's fascia (TIES). Incisional hernias were only found in patients who had undergone TIES incisions [67]. In case of active (e.g., purulent) infections, one should consider to treat the infection first with debridements and antibiotics if necessary, before performing closure with or without relaxing incisions.

Third, a two-staged repair with an absorbable mesh fixed between both fascia edges. It should be attempted to close the skin over the mesh after mobilization, if necessary. The incisional hernia that will develop can be operated in the future, if symptomatic. The latter can be a good argument for avoiding this technique, as results have been disappointing [68]. Unabsorbable meshes should not be placed definitively in direct contact with intestinal organs, as infection, fistulas, and migration of the mesh can occur [69].

Fourth, a closure technique using a combination of mesh and negative pressure wound therapy was developed in Sweden by Petersson et al. [70]. In a retrospective series of 46 consecutive patients, 23 patients were closed with suture repair, 20 by mesh repair, and 3 patients died early. Five sutured patients developed redehiscence with a 60 % mortality rate, compared to none in the mesh group. Eighteen sutured and 20 patients treated with mesh repair were invited for follow-up including physical examination after a median follow-up of 619 and 405 days, respectively. Incisional hernia rates were significantly higher in patients with suture repair compared to mesh repair (53 vs. 5 %, $p = 0.002$). Short-term morbidity was higher in the latter group (76 vs. 28 %, $p = 0.004$). In a larger cohort series on mesh-mediated fascial traction with negative pressure wound therapy from the Swedish center, 66 % of patients developed incisional hernia. The median hernia sizes were relatively small at 7.3 and 4.8 cm for symptomatic and asymptomatic patients, respectively. As these hernia sizes were much smaller than expected based on past results, the authors support the continued use of this method [71]. The technique has been adopted by other surgeons, sometimes with minor adjustments [72, 73].

The fifth option includes closure with biological meshes. A few cases or small case series have been described using porcine dermal collagen with or without negative wound pressure therapy, reporting mixed results [74–77]. A randomized international multicenter study on this topic was ended prematurely. The study included 18 patients with abdominal wound dehiscence who were closed with a biological mesh (Strattice®) as underlay or sublay, and 19 control patients who underwent primary closure with or without polyglactin mesh. The incidence of redehiscence was significantly lower in the biological mesh group (5.6 vs. 36.8 %, $p = 0.015$). (*Jeekel J, presented at congress of European Hernia Society 2014, Edinburgh*). Long-term results on, i.e., incisional hernia, are awaited.

Finally, tissue flaps have been described for delayed repair of abdominal wall defects. Usually, these repairs are conducted for complex abdominal wall defects, e.g., in presence of large defects, ostomies, or enterocutaneous fistulas. As for any hernia surgeon, seeking advice and cooperating with plastic surgeons is a necessity for treating these complex patients. Exact locations of (abdominal) scars and perforators will help the team to decide the most suitable approach.

42.4 Outcomes of Patients

The mortality rate of dehiscence varied between 4 and 35% in more recent studies. This high mortality rate has hindered long-term outcome studies. The costs associated with dehiscence are based on many factors (see Table 42.2). Some studies have attempted to calculate the extra costs associated with dehiscence.

Table 42.2 Factors influencing costs in patients with dehiscence

Type of factor	Examples
Treatment	Primary surgery
	Repeated surgery
	Wound care (time)
	Wound care (materials, gauzes, fluids)
	Negative pressure wound therapy
	Antibiotics
	Central venous access (parenteral nutrition, antibiotics, etc.)
	Dietary food/supplements
	Incisional hernia repair
	Outpatient clinic/wound nurse visits
	Abdominal binder
	Nursing home or rehabilitation institute
Travel	To/from clinic (visitors)
	To/from outpatient clinic (patient, accompanying person)
Indirect costs	Longer return to work/daily activities
	Inability to care for others

In a recent study from the USA, using data from the Nationwide Inpatient, 9.6 % higher mortality, 9.4 days longer hospitalization, and $40,323 excess hospital charges were found for patients with abdominal wound dehiscence ($n = 786$) compared to matched controls from a population of 25,636 patients [24].

In a prospective study from the Netherlands, hospital care costs for patients who were treated conservatively for abdominal wound dehiscence more than doubled the costs of control patients (€6325 vs. €14,088). For patients who needed home (wound) care after discharge, nursing costs averaged at €2.948. Almost half of patients were prescribed abdominal binders, prized between €200 and 500 each. Overall, health care costs were €10.850 higher in patients with conservatively treated abdominal wound dehiscence compared to uncomplicated control patients with €1424 spent per relaparotomy for dehiscence repair [65].

Gili-Ortiz et al. published a retrospective multicenter study from Spain, finding €14,327 higher costs per patient for 2294 patients with abdominal wound dehiscence from 323,894 admissions for abdominal surgery [78].

In comparison, repair of an "average" incisional hernia in an "average" patient was reported to cost 6451 euros in France in 2011 [79].

In general, many patients find it challenging to receive frequent wound care for, e.g., infection or dehiscence. After healing of the wound, the scars and/or incisional hernia form a daily reminder of the operation(s) and subsequent complications they suffered from. It is known from one study that patients who developed dehiscence reported significantly lower scores for SF-36 physical and mental component summaries, general health, mental health, social functioning, and change after a follow-up of 40 months. With a high incidence of incisional hernia in this group of 83 %, patients reported significantly lower cosmetic scores and total body image scores [65].

With the advancements in minimally invasive surgery and perioperative care, the incidence of dehiscence is expected to decrease over the next years. However, there will always be a need for *maximally* invasive surgery in a small subset of patients. It will be our challenge to optimize these patients as much as possible and to promote "best practice" surgical closure techniques.

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Treatment of the Open Abdomen

43

Sarah Scott Fox, Justin M. Milligan, and William F. Powers IV

43.1 Introduction

Management of the open abdomen was first documented by Ogilvie in 1940 for use in combat patients [1]. Temporary closure was performed with light canvas or strut cotton sutured to the fascia with catgut, with vaseline gauze swabs tucked under the fascia, and the abdomen was closed with sutures or strips of Elastoplast [1, 2]. He recognized that the septic abdomen should be treated like other septic wounds, with incision and drainage [2]. Studies of the open abdomen began to appear in the literature 40 years later, with high reported rates of morbidity and mortality [2]. Before 1980, patients with severe intra-abdominal trauma or sepsis were generally treated with one definitive operation, and patients died from the complications of acidosis, hypothermia, coagulopathy, and "failure to resuscitate." Patients who required re-exploration had their fascia closed and reopened at the next operation. Through the 1980s, trauma surgeons began to recognize the benefit of a staged approach, and in 1993 Rotondo coined the term "damage control laparotomy," leaving the abdomen open between explorations. The traditional approach was to manage the open abdomen as a planned ventral hernia, where a split-thickness skin graft was placed over a granulated tissue bed on the intestines, and the patient underwent definitive abdominal wall reconstruction 6–12 months after discharge. This approach was followed through the 1990s–2000s. Today, it is acceptable, and even preferred, to attempt definitive closure during the initial hospitalization [2, 3].

As the management of the open abdomen has fallen in and out of favor, the techniques for managing the critically ill trauma and general surgery patients have evolved. The literature is replete with descriptions of managing the open abdomen; however, there is currently no consensus on which techniques of temporary or definitive closure are superior.

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43.2 Definition and Indications for the Open Abdomen

The concept of re-exploration after trauma, hemorrhage, bowel ischemia, intra-abdominal sepsis, and septic shock has long been recognized in emergency general, vascular, and trauma surgery [3, 4]. The damage control laparotomy is an abbreviated laparotomy performed on a critically ill or injured patient for the purpose of controlling major hemorrhage or infectious sources, followed by stabilization in the Intensive Care Unit (ICU) [3]. In 2009, the Open Abdomen Advisory Panel (OAAP) met to develop a management paradigm for both the acute and long-term care of patients with the open abdomen based on the available evidence [3]. A proposed algorithm for managing the open abdomen is seen in Fig. 43.1.

The OAAP identified several pathways leading to the open abdomen: the development of intra-abdominal hypertension; primary or secondary abdominal compartment syndrome; or planned re-exploration [3]. Common etiologies leading to the open abdomen are shown in Box 43.1.

Regardless of the etiology of the open abdomen, all patients have an initial inflammatory response with activation of neutrophils and macrophages, pro-inflammatory cytokines and mediators that have local and systemic effects that can lead to multi-system organ failure [3]. The phases and goals of managing the open abdomen can be divided into preoperative, intraoperative, temporary abdominal closure (TAC), postoperative and re-operative (Fig. 43.2). The goals are to manage this inflammatory cascade and to close the abdomen as soon as is safe for the patient.

43.2.1 Intra-abdominal Hypertension and Abdominal Compartment Syndrome

Since 1876, when Dr. Edmund C. Wendt described the proposed relationship between reduced urinary flow in the setting of increased abdominal pressure, the notion of the

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_43

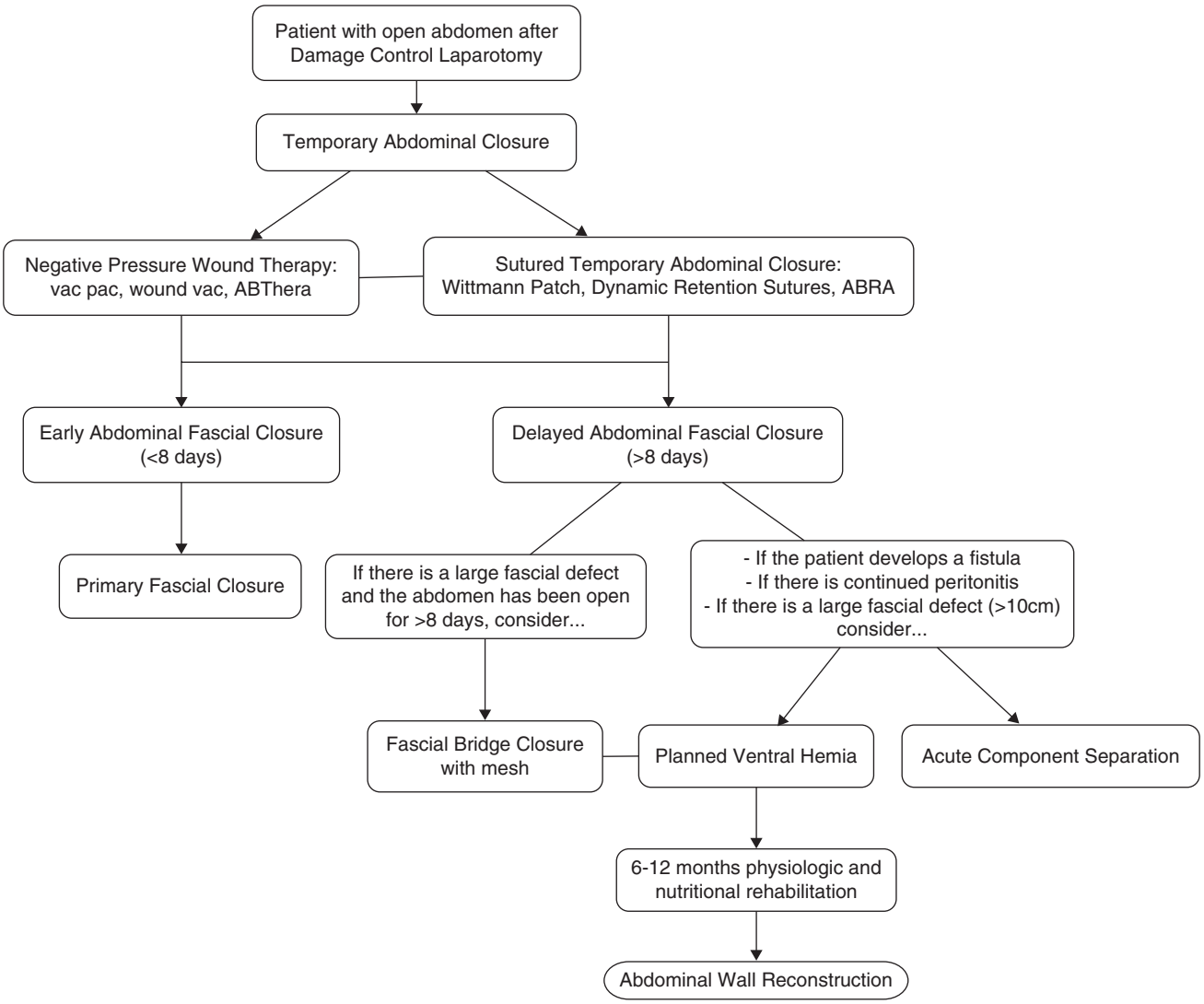

Fig. 43.1 Algorithm for managing the open abdomen [21]. Reproduced from Diaz JJ, Dutton WD, Ott MM, Cullinane DC, Alouidor R, Armen SB, Bilanuik JW, Collier BR, Gunter OL, Jawa R, Jerome R, Kerwin A, Kirby JP, Lambert AL, Riordan WP, Wohltmann CD, *Eastern association for the surgery of trauma: a review of the management of the open abdomen—part 2 "management of the open abdomen"*. Journal of Trauma, 2011. **71**(2): p. 502–512 [21], with permission of Wolters Kluwer Health Inc

Box 43.1: Common Etiologies of the Open Abdomen [3]

- Post-traumatic hemorrhage
- Non-traumatic hemorrhage (e.g., ruptured AAA)
- Sepsis
- Peritonitis
- Pancreatitis
- Resuscitative abdominal compartment syndrome (e.g., burns, trauma)
- Acute abdominal wall defect
- Gaseous distension
- Bowel ischemia with planned second look
- Post-hepatic transplant

Reproduced from Vargo D, Richardson JD, Campbell A, Chang M, Fabian T, Franz M, Kaplan M, Moore F, Reed RL, Scott B, Silverman R, *Management of the open abdomen: from initial operation to definitive closure*. American Surgeon 2009. **75**(11): p. S1-S22 [3], with permission of the Southeastern Surgical Congress.

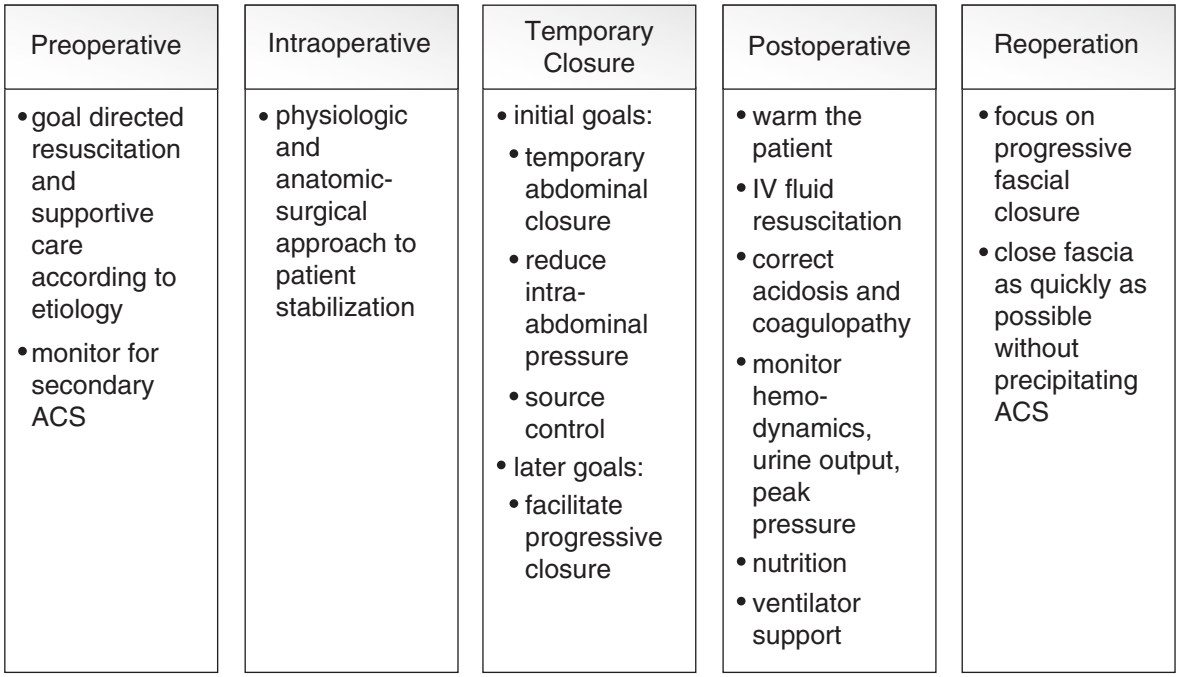

Fig. 43.2 Phases of open abdomen management [3]

Table 43.1 Definition and grading of intra-abdominal hypertension and abdominal compartment syndrome [7]

Grade	Intra-abdominal pressure (mmHg)	*Abdominal Compartment Syndrome* (ACS) is defined as a sustained IAP > 20 mmHg (with or without an APP of 60 mmHg) that is associated with new onset organ dysfunction or failure (oliguria or anuria, hypotension, increased ventilator pressures) APP = MAP – IAP
1	12–15	
2	16–20	
3	21–25	
4	>25	

IAH intra-abdominal hypertension, *ACS* abdominal compartment syndrome, *IAP* intra-abdominal pressure, *APP* abdominal perfusion pressure, *MAP* mean arterial pressure

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pervasive pathology related to intra-abdominal hypertension has been present in medicine [5]. Despite the growing concern, the surgical field continued to pride itself on closing abdomens under enormous tension late into the twentieth century. In 1981, Stone and colleagues revealed an improvement in mortality from 85 to 22 % in patients who underwent delayed abdominal closure rather than immediate closure under significant tension [6].

Although the exact definition of abdominal compartment syndrome is somewhat broad, the World Congress of Abdominal Compartment Syndrome developed a consensus statement regarding the definitions (Box 43.2, Table 43.1) and management of intra-abdominal hypertension and abdominal compartment syndrome (ACS) [7].

The development of abdominal hypertension and the associated adverse physiologic consequences that occur are largely due to the visceral and retroperitoneal edema which forms in response to hemorrhage, dead or injured tissue, or underlying inflammation or infection.

Early recognition of the development of ACS (Box 43.2) is the most critical step in the treatment of ACS, as many of the complications develop as a result of poor perfusion and subsequent reperfusion [7]. Physical exam is the most reliable early marker for identifying the development of ACS. In patients with high risk for developing intra-abdominal hypertension, serial bladder pressure measurements have been demonstrated as a reliable tool.

As intra-abdominal pressures exceed 20 mmHg, the conditions may exist for the physiologic derangements associated with ACS to occur (Table 43.1). Abdominal decompression immediately acts to lower intra-abdominal hypertension, improve abdominal perfusion pressure (APP), and improve dynamic lung compliance [8, 9]. Abdominal decompression requires an incision from the xiphoid process to the pubic symphysis, as smaller incisions may not adequately decompress the abdomen, and increase the risk for persistent or recurrent abdominal compartment syndrome. After decompression, close monitoring must continue for the

Box 43.2: Key Features of Abdominal Compartment Syndrome [7]

- Significant respiratory compromise
  - Associated with elevated inspiratory airway pressure ~35 mmH_2O
- Renal dysfunction
  - Urine output falling below 30 mL/h
- Hemodynamic instability requiring catecholamine support
- Presence of a rigid or tense abdomen strongly suggests ACS

redevelopment of ACS, which may occur due to inadequate decompression, evolving intra-abdominal pathology, or that the abdomen was closed too tightly [10]. It is essential to remember that even the "open" abdomen can develop abdominal compartment syndrome.

43.2.2 Damage Control Surgery (DCS)

Lucas and Ledgerwood pioneered the role of abdominal packing in the management of severe abdominal trauma, the associated technical difficulty in reconstructing the abdominal wall after devastating abdominal trauma in the 1970s [11, 12]. Subsequent studies in the 1980s by Feliciano and colleagues further described the life-saving role of abdominal packing and the open abdomen in patients with hemodynamic instability and difficult to control hepatic hemorrhage [13]. The term "damage control" was coined in 1993 in Rotondo and Schwab's landmark paper that demonstrated a sevenfold improvement (11–77 %) in mortality when utilizing the open abdomen in severe penetrating abdominal trauma [14]. Damage control, a naval term first used during World War II, referred to the ability of a damaged warship, to maintain function in order to facilitate a safe return to harbor. The term was carried onto the battlefield in regard to the ability to minimize hemorrhage with the fewest resources in the least amount of time possible. Damage Control surgery (DCS) refers to avoidance of definitive surgical management at the initial operation when a patient is under severe physiologic derangements. The focus of DCS is on minimizing operative time while addressing life-threatening pathology [15]. Initially utilized in the setting of catastrophic penetrating abdominal trauma, damage control surgery has been expanded to all life-threatening intra-abdominal surgical pathology. The cellular and end organ dysfunction related to these catastrophic injuries contribute to the development of the well-known "lethal triad" of acidosis, coagulopathy, and hypothermia, which once identified, will invariably result in mortality without aggressive correction. While much has changed in the management of the critically ill over the last several decades decreasing the need of the open abdomen, in the appropriate situation the well-described phases of damage control surgery remain (Table 43.2).

43.3 Temporary Abdominal Closure Techniques

The basic principles of temporary abdominal closure involve ease of re-exploration, a high rate of definitive closure, and cost-effective techniques [4]. The literature on temporary abdominal closure is heterogeneous, and many safe and effective techniques for managing the open abdomen exist. A staged laparotomy with delayed fascial closure should be considered when sepsis cannot be eliminated or controlled, there is a question of incomplete debridement of necrotic or infected tissue, there is questionable bowel viability, there is excessive visceral edema that may precipitate IAH or ACS, or if the patient's condition is critical such that resuscitation should take precedence over repairing the insult [4]. Features of the ideal temporary closure device are shown in Box 43.3. Before closing the abdomen, the patient should be stabilized and nutritionally optimized. When primary closure and re-creation of the linea alba is not possible, bridging methods should be considered [16].

43.3.1 Historical Perspective

43.3.1.1 Skin Only Closure and Loose Packing

Skin only closure is an inexpensive method of rapid closure using towel clips or running skin sutures. This method allowed easy access to the abdominal cavity for re-exploration; however, drainage was generally not possible and allowed for an unacceptable rate of recurrent abdominal compartment syndrome. There was also a high risk of evisceration, loss of domain via fascial retraction, with concordant lower closure rates (40–75 %), and high mortality (25–40 %) [17, 18].

Table 43.2 Phases of damage control surgery [30]

Phase 1	Emergent laparotomy and control of major bleeding and/or septic source, ± abdominal packing, and temporary abdominal closure
Phase 2	Transfer to intensive care unit for goal directed resuscitation to correct hypothermia, coagulopathy, and acidosis
Phase 3	Re-exploration, wash out, and staged abdominal repair

Box 43.3: Ideal Features of the Temporary Abdominal Closure Device [2, 3, 16, 17]

- Cover and contain abdominal contents, preventing evisceration
- Protect abdominal contents from injury and contamination
- Preserve integrity of the abdominal wall, preventing loss of abdominal domain and fascial retraction, while keeping the abdominal wall elastic and mobile
- Prevent adhesions between the viscera and the abdominal wall and closure material
- Prevent or treat intra-abdominal hypertension and abdominal compartment syndrome
- Be easily and rapidly performed, and provide rapid re-entry
- Prevent fistula formation
- Prevent damage to the fascia
- Help manage fluid balance, allow removal of infected fluid from peritoneal cavity, and control peritoneal effluent
- Facilitate nursing care
- Cost effective
- Allow facile and safe patient transport

Loose packing is where the abdomen is left open and the viscera are covered with standard dressings. This method of temporary closure has largely been abandoned due to early fascial retraction and high mortality [18].

43.3.1.2 Esmarch Closure

Esmarch closure was first described in trauma. Two esmarch bandages were stapled to the skin along the lateral aspects of the wound, brought together in the midline and then turned in and stapled, creating a tension free silo. An iodophore drape (e.g., Ioban™, 3M Health Care, St. Paul, MN) was then placed over the abdominal wall. This dressing, although cost effective, simple to apply, and non-traumatic to underlying bowel, did not allow for any abdominal drainage and therefore allowed for an unacceptable rate of IAH [19].

43.3.1.3 Zipper Closure

Originally described as a fast and secure method for abdominal reoperation, temporary abdominal closure was achieved using a zipper obtained at a local retailer, which was autoclaved, and attached to polypropylene mesh that was sutured to the fascia. This was covered with standard wound packing. Ultimately, medical device manufactures began production of a nylon zipper. Zipper closure allows easy re-exploration and access for repeated lavages without repetitive tissue trauma from suturing [20]. Although having largely fallen out of favor, the nylon zipper mesh is still used in the management of the open abdomen. This method may cause fascial damage, has variable closure rates (0–100 %), and carries a high mortality rate (0–60 %) [18].

43.3.2 Current Methods of Temporary Abdominal Closure

43.3.2.1 Silos, e.g., Bogota Bag

The Bogota Bag technique was first used in several institutions in Colombia in 1984 [2]. A sterile three liter urologic irrigation bag is sewn to fascia or skin, and is progressively plicated or excised to re-approximate the fascial edges [4, 18]. Closure rates are variable (17–82 %), and improve with concurrent use of negative pressure wound therapy [4, 16]. Reported mortality rates are 18–53 % [18], and advantages include low cost, rapid access, and protection of viscera from evisceration and desiccation [16]. Disadvantages are fascial trauma from suture placement, adhesion formation, inadequate control of peritoneal effluent, progressive muscular retraction, loss of domain, risk of intra-abdominal hypertension and a need to continually monitor intra-abdominal pressure [2, 16, 17].

43.3.2.2 Skin Grafting and the Planned Ventral Hernia

Through the 1990s–2000s, the open abdomen was managed as a planned ventral hernia, and a split-thickness skin graft (STSG) was placed on the granulating tissue overlying the intestines. Six to twelve months post-discharge, the patient returns for definitive abdominal wall reconstruction [3] (Fig. 43.3). Patients experience decreased quality of life and high rates of entero-atmospheric fistula. Myofascial edges retract because of lack of mechanical strain, and delayed hernia repair is made difficult by loss of domain, myofibrotic atrophy, and fibrosis. Further, the cost of care may exceed the cost of definitive closure during the index hospitalization [3, 16].

Despite these limitations, a planned ventral hernia is appropriate in certain patient populations, and a STSG may be used in conjunction with other methods such as fascial bridging (Fig. 43.1). Primary fascial closure may not be possible because of massive visceral edema, loss of domain, loss of abdominal wall tissue secondary to infection, acute respiratory distress syndrome, or extensive fusion of the viscera to the abdominal wall. The decision for a planned ventral hernia can typically be made in the first 2 weeks of the hospital course [3, 21]. The fascia should be bridged with mesh and covered with skin, either by STSG or undermining and flap mobilization [3]. The surgeon should be mindful to preserve perforators from the rectus abdominis to prevent ischemia, skin necrosis, and dehiscence when creating flaps by undermining [16].

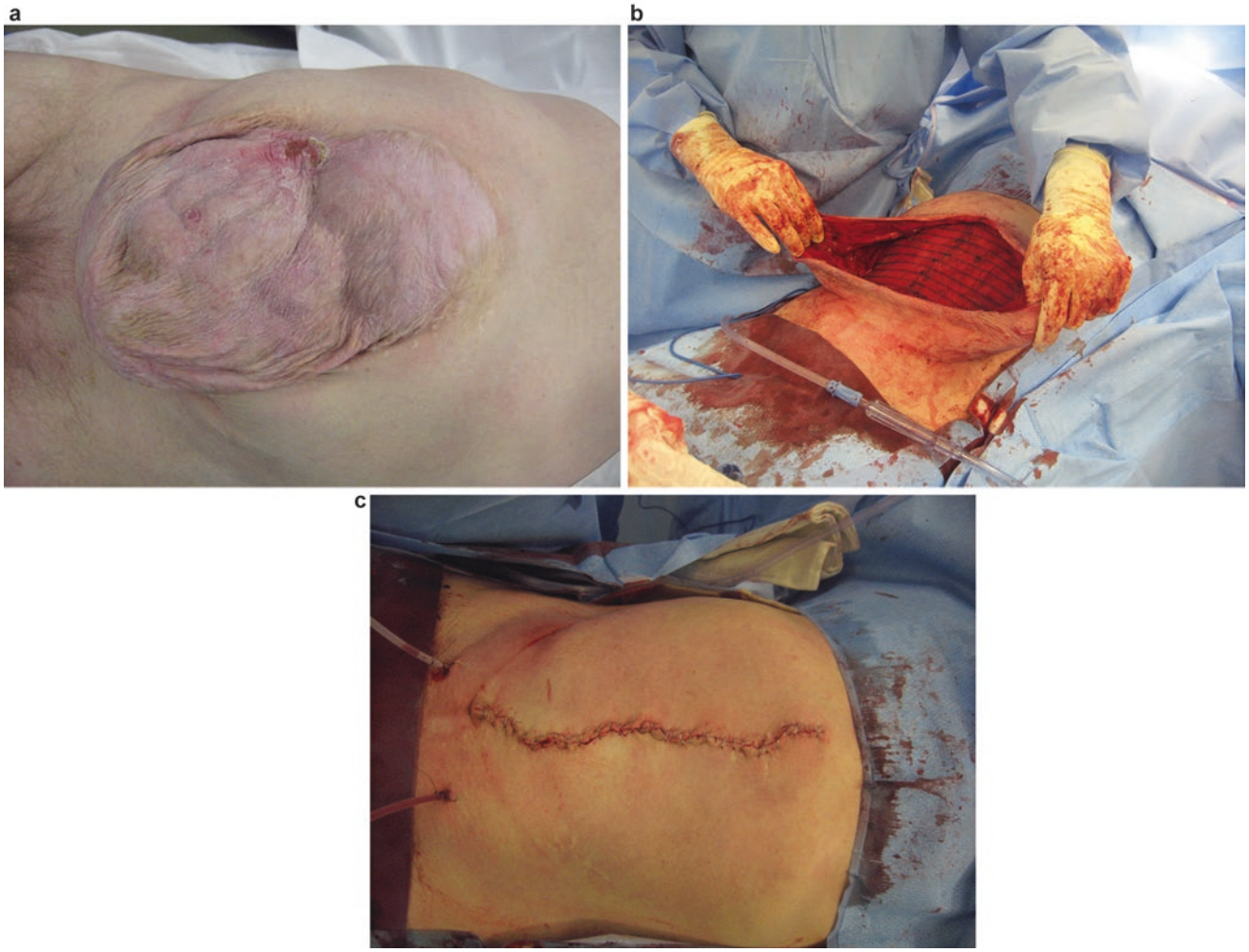

Fig. 43.3 STSG applied to an open abdomen with planned ventral hernia repair. (**a**) Healed STSG on a previous open abdomen. (**b**) Staged ventral hernia repair with mesh. (**c**) Completed ventral hernia repair

43.3.2.3 Negative Pressure Wound Therapy (NPWT)

Negative pressure wound therapy was first described by Brock in 1995 [2]. The techniques using negative pressure wound therapy provide easy access to the abdomen, low rates of morbidity and mortality, low rates of fascial retraction, and high rates of fascial closure. They provide abdominal coverage, reduce intra-abdominal pressure (though do not eliminate the risk of intra-abdominal hypertension), provide adequate control of exudates, diminish adhesion formation, and maintain traction on the fascial edges [16]. There are multiple commercially available systems: Barker Vacuum Pac™, Renasys NPWT™ (Smith & Nephew, MA, USA), Avance NPWT™ (Molnlycke, Goteborg, Sweden), ABThera™ Open Abdomen Negative Pressure Therapy System (KCI, San Antonio, TX, USA), and Vacuum-Assisted Closure™ (KCI, San Antonio TX, USA) [4, 18, 22].

The Barker Vacuum Pac™ is constructed in three layers by placing a fenestrated polyethylene sheet over the viscera and under the anterior parietal peritoneum, underneath the fascial edges. This is covered by damp surgical towels with overlying silicone drains. An adhesive iodophore-impregnated sheet (e.g., Ioban™) is placed over the dressing and skin to form an airtight seal. The drains are connected to 100–150 mmHg wall suction [2, 4, 16, 18]. This is inexpensive and controls fluid egress [2, 4]. There are reports of a 20 % fistula rate in all patients, 71 % fascial closure rate in emergency general surgery patients, and 61 % fascial closure rate in trauma patients [4].

The ABThera™ utilizes a protected polyurethane foam layer composed of six strut arms, embedded between two fenestrated sheets that are placed over the viscera and under the peritoneum. A polyurethane sponge is placed on top of the visceral protective layer and between the fascial edges and the wound is covered by an impermeable sheet to create a seal. A suction drain is applied to a pump and fluid collection system, and this applies negative pressure to keep constant tension on the fascial edges while collecting excess abdominal fluid to help resolve edema (Fig. 43.4). This system is changed every 48–72 hours. Some physi-

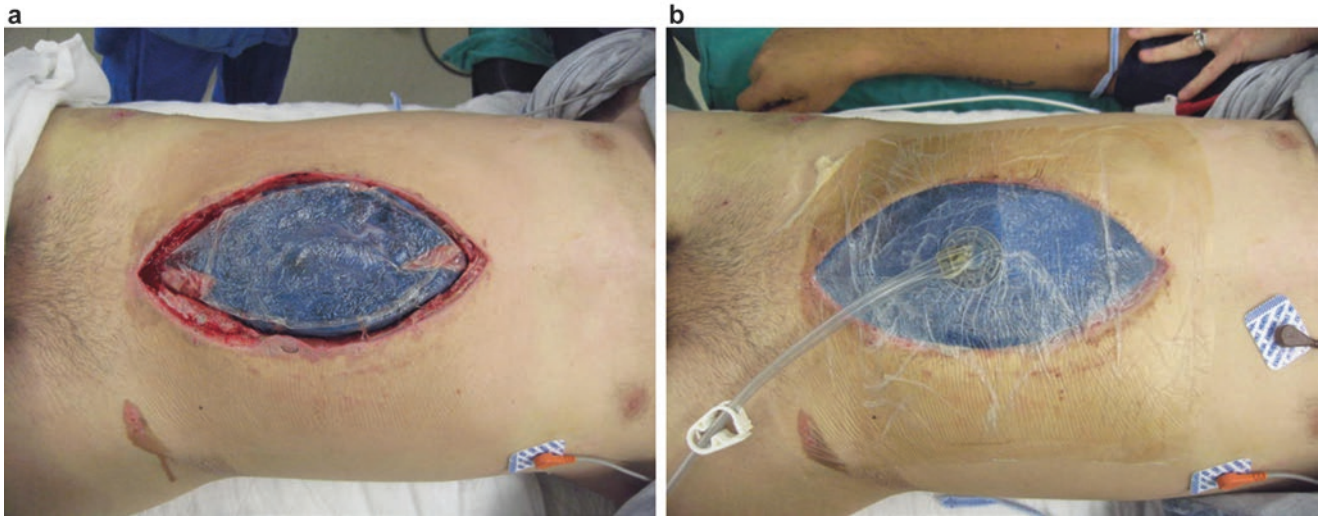

Fig. 43.4 ABThera™ placement in a patient with an open abdomen. (**a**) A visceral protective layer is placed to protect the bowel and allow for removal of accumulating fluid. (**b**) A foam layer connected to a suction device is applied to provide negative pressure for removal of intra-abdominal fluid

cians elect to close the fascial edges sequentially from the apices with each dressing change [4, 16, 18]. Overall, morbidity is low, and this system prevents fascial retraction and loss of domain [3]. Fascial closure rates of 33–100 % are described, with higher rates in trauma (86–100 %) compared to emergency general surgery patients with peritonitis (33–75 %) [21]. The system is safe to use in the open abdomen for up to 3–4 weeks, and mean time to closure in patients who are unable to undergo early fascial closure is 9 days [3, 16, 21].

When compared to the Barker Vacuum Pac™ in a bench study, the ABThera™ was found to have evenly distributed pressure across the entire foam, facilitating peritoneal fluid removal, reduction of bowel edema, and approximation of the wound. In contrast, the Barker Vacuum Pac™ pressure distribution is uneven, with higher negative pressure towards the center of the wound and lower at the periphery [17].

43.3.2.4 Artificial Burr, e.g., Wittmann™ Patch

The use of artificial burr (Velcro®-like) adhesive sheets for temporary closure was first described in 1990, and became commercially available later as the Wittmann™ Patch (Starsurgical, Burlington, WI, USA) [2]. A fenestrated adhesion-preventing barrier is placed between the bowel and parietal peritoneum extending into the lateral gutters (e.g., 1060 Steri-Drape with holes punched in the drape to allow fluid egress). The Wittmann™ Patch consists of two 40×20 cm sheets of hook and burr material, and is sewn into the fascial edges with a nonabsorbable monofilament suture, then the sheets are overlapped in the midline (Fig. 43.5). A sterile dressing is placed in the subcutaneous tissue, with an iodophore adhesive dressing placed over top. The sterile dressing may be created with Kerlix™ (Covidien, Farmington, CT, USA) and Jackson-Pratt drains connected to low wall suction covered with iodophore dressing [2, 4, 18, 23]. Alternatively, negative pressure wound vac therapy may be used over the subcutaneous defect [22], and other commercially available products can be used beneath the patch itself. This system applies tension to the midline to prevent lateral retraction of the aponeurotic edges and may undergo serial tightening [2, 4, 18, 23]. Delayed abdominal closure is achieved in 75–100 % of trauma patients and 93 % of abdominal sepsis patients. The mean time to closure is 13–15.5 days, and the system is safe to use for up to 3 weeks [21]. Low fistula rates are described. The patch may become colonized with bacteria, and there is potential for fascial trauma from the suture material that may require debridement [4].

43.3.2.5 Abdominal Reapproximation Anchor (ABRA®) System and Dynamic Retention Sutures

Negative pressure wound therapy is often used with dynamic retention sutures. Nonabsorbable horizontal sutures are placed through large-diameter catheters and through the abdominal wall on both sides. These sutures are extraperitoneal, and are placed through all layers of the abdominal wall including the skin to keep tension on the fascia [18, 22]. Serial tightening allows staged re-approximation of the fascial edges, and facilitates delayed fascial closure in 61–90 % of trauma patients [18, 21].

There is one commercially available system: ABRA® Abdominal Wall Closure System (Canica Design, Almonte, ON, CAN) [22]. The ABRA® system utilizes a variable

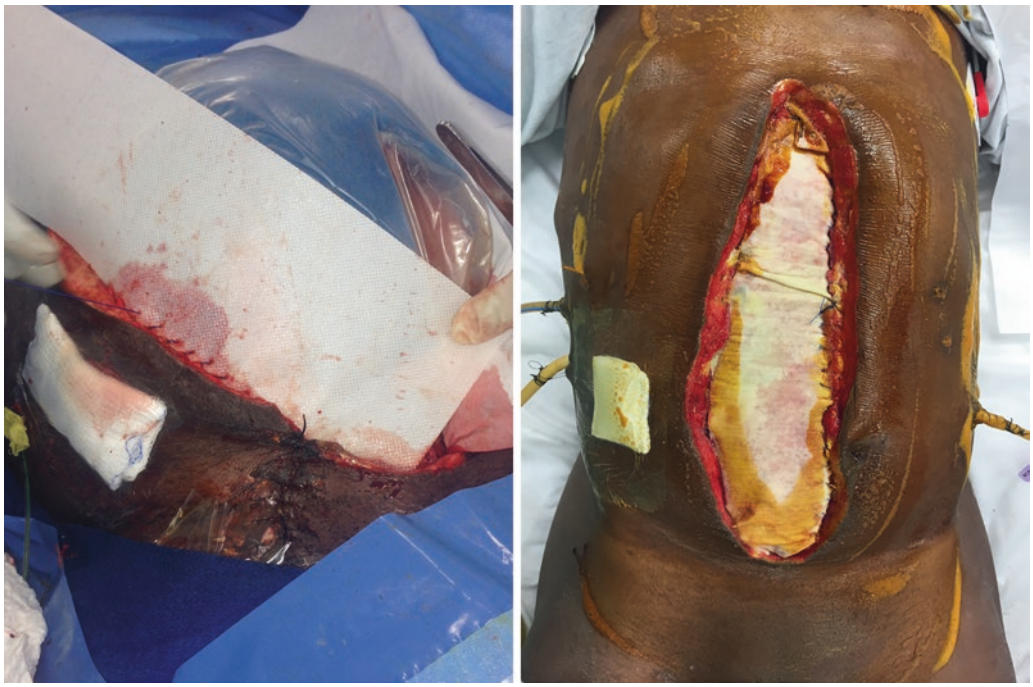

Fig. 43.5 Wittmann™ Patch sewn directly to the patient's fascia and subsequently closed in the midline

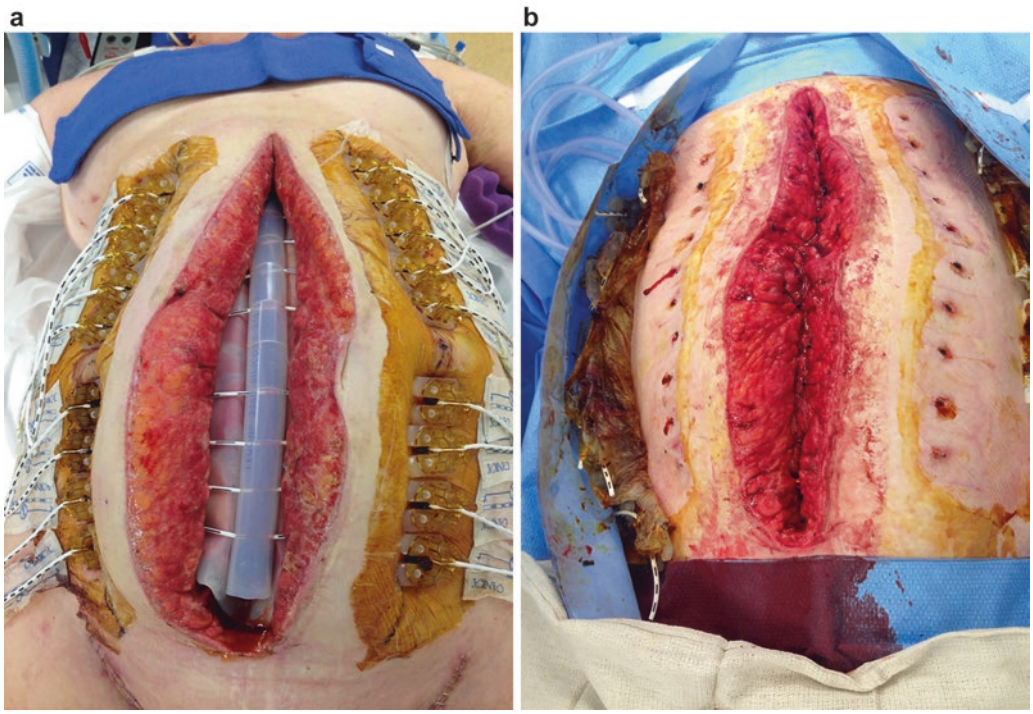

Fig. 43.6 Application of the ABRA®. (**a**) A silicone sheet has been placed over top of the bowel along with stabilizing tubing. The anchor-pulley elastomer units are placed laterally on the abdominal wall. NPWT can then be placed. (**b**) Fascial closure after sequential tightening of the ABRA® system

number of anchor-pulley elastomer units that apply closing tension to the wound. The device is applied, followed by incremental bedside re-approximation by adjusting the elastic bands [24] (Fig. 43.6). ABRA® was described by Reimer et al. who reported a delayed fascial closure rate 61 % and a 26 % hernia rate [2]. In a study by Haddock et al., primary fascial closure was attained in 83 % of patients, with incisional hernia rates of 13 and 11 % at 6 and

12 months, respectively. Patients suffering traumatic injuries had a higher likelihood of abdominal closure compared to emergency surgical patients. High Body Mass Index (BMI) was associated with lower closure rates (68 % compared to 100 % with normal BMI) [25]. Fascial closure is more likely with aggressive tightening of the elastomers to obtain primary closure by 1 week, placement of elastomers 5 cm from the wound margins to ensure adequate room for NPWT application, and an inter-anchor distance of 3 cm. Complication rates increase after day 8 of the open abdomen (fistula rate 9–21 %, hernia rate 11–29 %). This system can cause superficial skin breakdown and ulceration at the anchor sites [25].

43.3.2.6 Bridging Mesh and Planned Hernia

Mesh may be used in different phases of abdominal closure after the open abdomen: temporary abdominal closure device, fascial bridge, and to reinforce definitive fascial closure [21]. A myriad of meshes are available, and these are broadly categorized as synthetic versus biologic; synthetic mesh is further categorized as absorbable versus nonabsorbable and micro- versus macro-porous. Further discussion of mesh is beyond the scope of this chapter.

While temporary closure with mesh has largely been abandoned due to high complication rates, bridging mesh closure may be considered for delayed fascial closure in patients who cannot be closed primarily (Fig. 43.1). Patients in whom bridging mesh should be considered are those with profound visceral edema with loss of domain, fascial loss secondary to infection, or who physiologically can tolerate closure, but closure is prevented due to the visceral cocoon that occurs between postoperative day 14 and 21 [21]. A mesh is sutured between the fascial edges. As swelling subsides, the mesh may be progressively reduced in size for fascial approximation. Biologic and absorbable synthetic meshes may be left in situ, but nonabsorbable meshes must be explanted for fascial closure [26]. Subcutaneous mobilization can achieve skin closure over the mesh, or the wound may be left to heal by secondary intent with NPWT or traditional dressings. Granulated mesh may be covered by a STSG [16]. Advantages to bridging fascial mesh are easy re-exploration and coverage of abdominal contents in the temporary closure setting [4]. Disadvantages for both temporary and bridging closure include fascial damage, high fistula rates, and the potential for chronic infectious source due to mesh infection or bacterial colonization [4, 21].

The choice of mesh in the setting of the open abdomen for either temporary closure or as a bridge and planned ventral hernia repair remains a complicated issue. Nonabsorbable synthetic mesh is no longer a viable option, given the lower complication rates in using other types of mesh. Further choices regarding mesh use in this setting remain tailored to the individual patient and surgeon comfort with the particular product.

43.4 Definitive Abdominal Closure and Abdominal Wall Reconstruction

Definitive abdominal closure should be addressed once the patient is stabilized, nutritionally optimized, and fascial edges are 3–7 cm apart. After staged abdominal wall reconstruction, physicians should monitor closely for renal function, ventilator disturbance (increased peak pressure, impaired gas exchange), and increased central venous pressures that may be indicative of developing abdominal compartment syndrome (Fig. 43.1) [4].

Early fascial closure is performed within 8 days of the initial damage control laparotomy, and delayed fascial closure occurs greater than 8 days. Fascia may be reapproximated primarily, bridged with mesh, or left open as a planned ventral hernia [3]. The surgeon may consider mesh reinforcement during primary closure. However, if choosing to use reinforcing mesh, the surgeon should also consider factors such as obesity, diabetes, smoking, immunosuppressive therapy, and poor nutrition, as these increase the risk of wound and mesh complications [16].

43.4.1 Delayed Primary Fascial Closure

The open abdomen is a dynamic process that requires constant re-assessment in developing a plan that meets the patient's current needs in attempt to minimize potential complications. Historically the timing of re-exploration has ranged from 3 to 5 days after the initial procedure to allow for adequate time to return to normal physiology. As critical care has improved, re-exploration should be individually tailored in consideration of each patient's clinical course. Goals of re-exploration are to re-evaluate for contamination and hemostasis, as well as to assess the amount of inflammation present. Ample irrigation should take place in effort to decrease overall bacterial counts. Care should be taken to minimize disruption of new adhesions, weighing the risks of injury and fistula formation with need to fully evaluate the abdominal contents, especially in the presence of a new anastomosis. Only approximately 65 % of open abdomens are able to be definitively closed at the initial take back [27]. A rise in peak airway pressures of greater than 10 mmHg during abdominal wall closure after an open abdomen is generally thought to signify an excessive amount of intra-abdominal pressure and attempts therefore should be halted. The 8 day mark has been accepted as the goal point in which fascial closure should be obtained due to the marked increase of associated complications from 12 to 50 % [28].

43.4.2 Effect of Temporary Abdominal Closure Method on Fascial Closure Rate

Fascial closure rates are influenced by the temporary abdominal closure technique chosen. When analyzing temporary abdominal closure using weighted, pooled data, the highest rates of fascial closure were achieved with the Wittmann patch (90%), dynamic retention sutures (85%), and VAC therapy (60%) [18, 26]. In a recent meta-analysis, the overall weighted closure rate for non-trauma patients was 50.2% (95% CI 43.4–57.0%). The highest closure rate was seen with negative pressure wound therapy with fascial traction and dynamic retention sutures, and the lowest was seen with mesh and zipper closure. The overall weighted rate of entero-atmospheric fistula was 12.1% (95% CI 10.1–14.4%), with the highest rate after mesh and lowest after negative pressure wound therapy with fascial traction. The infected abdomen was more prone to fistula formation. The weighted mortality rate was 30% (95% CI 27.1–33.0%), and mortality was highest after loose packing and lowest with dynamic retention sutures. Table 43.3 shows the closure and complication rates of the various temporary closure systems from this meta-analysis [22]. The literature reflects lower fascial closure rates for non-trauma patients compared to trauma patients [4]. Peritonitis is an independent predictor of failure to close fascia [22].

Early fascial closure (<8 days) is possible in 63% of damage control cases during the initial re-laparotomy, and has fewer complications compared to delayed fascial closure performed after 8 days (12 vs. 52% complication rate) [21]. Delayed closure still has a high rate of success (65–100%) with appropriate temporary closure methods. Failure is associated with significant morbidity including cost, wound infection, and fistula formation. Deep space infections and intra-abdominal abscesses are independently associated with failure of closure [21].

43.4.3 Component Separation

There are descriptions of acute component separation performed during the initial hospitalization as a method for closure, with and without mesh. The external oblique and internal oblique are separated in the avascular plane, and the external oblique is divided 1–2 cm lateral to the lateral edge of the rectus sheath. The flap can be advanced as much as 10 cm to the midline. If further mobility is required, the posterior rectus fascia can be divided at the middle of muscle [16, 21]. The Open Abdomen Advisory Panel recommends against full component separation during the initial hospitalization, as Ramirez et al. described this as a secondary reconstructive option, and this eliminates it as a delayed reconstructive option [3]. Further, the patient must be stable and have good nutrition to heal from this operation, which is less likely in the acute setting [16].

A retrospective study by Frazee et al. looked at optimal timing of fascial closure in all patients with an open abdomen during the study period. Primary fascial closure was achieved in 79% of patients, and acute component separation was used in 11 of the 104 patients. Fascial closure was more likely in patients who had less than four reoperations compared to those with greater than five reoperations. Closure was more likely in patients with acute hemorrhage (85%) compared to abdominal sepsis (73%). These authors follow the OAAP recommendation for progressive fascial closure with each reoperation. If closure cannot be attained by the fourth reoperation, they advocate for acute component separation [29].

43.5 Complications

Massive abdominal trauma and abdominal catastrophes involve a high rate of associated morbidity and mortality. As such, the complications associated with the management of the open abdomen vary widely, as seen in Box 43.4. Each method of abdominal closure has risk and benefits, many of which largely depend on preexisting comorbidities, severity of injury, malnutrition, and various other confounding factors.

Surgical site infections and intra-abdominal abscesses are observed in 80% of cases in patients being managed with an open abdomen [30]. The infectious complications contribute to increased risk of fascial dehiscence and development of fistulas. Fistulas are a large source of morbidity, including protein calorie malnutrition, electrolyte disturbances, and prolonged hospitalization [21]. The challenges of the management of the intestinal fistula have been well described, and were associated with a near 100% mortality until the 1960s, when along with advancements in medicine and the advent of parenteral nutrition appropriate treatment algorithms were developed. Risk of fistulas is related to malnutrition, anastomotic leak with exposed suture lines, traumatized bowel or un-traumatized bowel that is exposed for long periods of time [21]. Intestinal fistulas that form within the laparostomy are known as entero-atmospheric fistulas (EAFs). With the advent of the open abdomen, EAFs have become increasingly encountered. EAFs are particularly problematic in that the location of the fistula along with the associated output limits the options for management of the open abdominal wound. Fistula rates in the setting of the open abdomen are highly variable: 5–75% due to heterogeneous patient population, pathophysiology, and approach to treatment [3]. Fistulas may increase ICU length of stay threefold, hospital length of stay fourfold, and hospital charges four- to fivefold [17]. EAFs are most commonly diagnosed in the first week of the management of the open abdomen. Like ECFs, it is important to categorize EAFs in terms of output (low output <200 mL/day, moderate output 200–500 mL/day, and high output >500 mL/day), but also in terms of location within the wound

Table 43.3 A comparison of temporary abdominal closure (TAC) techniques [22]

TAC technique	Description	Advantage	Disadvantage	Fascial closure[a]		Fistula formation[a]		Mortality[a]	
				%	95 % CI	%	95 % CI	%	95 % CI
NPWT	Perforated plastic sheet covers intestine, polyurethane sponge or damp surgical towels placed between fascial edges, wound covered with airtight seal and connected to a suction drain	– Low fistula rate – Cost effective – High closure rate – Low morbidity – Prevent adhesion formation – Control exudate	– Cost depending on which system used	51.5	46.6–56.3	14.6	12.1–17.6	30.0	25.6–34.8
NPWT with fascial traction	NPWT as defined above with dynamic retention sutures as defined below	– Higher closure rates than NPWT used alone	– Retention sutures may cause fascial damage	73.1	63.3–81.0	5.7	2.2–14.1	21.5	15.2–29.5
Mesh	Absorbable or nonabsorbable mesh is sutured between the fascial edges, which may be gradually tightened	– Closure – Containment of viscera	– Fascial necrosis – High fistula rate with nonabsorbable mesh – Potential for infected mesh – Lack of fluid egress	34.2	9.7–1.5	17.2	9.3–29.5	34.4	23.0–48.0
Silo closure (e.g., Bogota bag)	Sterile irrigation bag sutured between fascial edges. May be reduced in size to re-approximate fascia	– Rapid application – Low cost – Readily available – Protects viscera	– Fascial trauma – Low fascial closure rates – Inadequate peritoneal effluent control – IAH – Loss of domain	47.0	14.1–82.7	10.4	5.9–17.8	27.1	18.0–38.6
Zipper	Mesh zipper sutured between the fascial edges	– Rapid application and access – Low cost	– Skin necrosis – Fascial dehiscence – Fascial necrosis – High mortality	34.0	16.7–56.9	12.5	7.0–21.2	39.1	30.8–48.8
Dynamic retention sutures	Viscera covered with a barrier; horizontal sutures placed through large silastic catheter 4 cm from each fascial edge through the entire abdominal wall	– Low cost	– Damage to skin and fascia – High fascial closure rates – Low mortality	73.6	51.1–88.1	11.6	4.5–26.9	11.1	4.5–25.0
Loose packing	Traditional packing placed over viscera	– Low cost – Rapid application	– Low closure rates – Evisceration – High mortality	NA		15.7	7.4–30.4	40.0	25.5–56.5
Wittmann patch	Two Velcro pieces sutured to fascial edges for gradual re-approximation. May be combined with NPWT	– Low fistula rate – Low fascial necrosis – High fascial closure rate	– May be colonized with bacteria – Longer application time	119.0	NA	3.0	NA	24.0	NA

[a]Data shown reflects non-trauma patients. Fascial closure and complication rates are similar for trauma patients

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Box 43.4: Complications of the Open Abdomen and Temporary Abdominal Closure [2, 16, 17]

- Skin and fascial necrosis
- Gastrointestinal fistula
- Fluid and protein loss
- Loss of bowel function
- Loss of abdominal wall domain
- Intra-abdominal abscess
- Stoma complications
- Anastomotic breakdown
- Bowel obstruction
- Metabolic disturbances
- Decline in quality of life

(superficial or deep) [31]. In the setting of deep EAFs, intestinal contents are first released into the peritoneal cavity and are commonly associated with a septic infection, requiring operative intervention to isolate the uncontrolled leakage [32]. Superficial fistulas present within the granulating laparostomy wound primarily due to injury to an exposed intestinal loop. Unlike ECFs, in which nearly 30% will spontaneously close given appropriate management, the spontaneous resolution of EAFs is very rarely described [33, 34]. Management goals are to eliminate sepsis, to optimize nutrition (albumin >3.5 g/dL), and to delay operative repair for 3–12 months to optimize surgical success [21]. Parenteral nutrition is typically required not only in effort to decrease the fistula output, but also in effort to meet the hypercatabolic needs associated with protein losses with the open abdomen and fistula. A number of methods have been developed to assist with controlling and isolating fistula output from the healing laparostomy wound and surrounding skin. Various modifications of negative pressure wound therapy (NPWT) using items such as silicone baby pacifiers, foley catheters, barrier rings, and polyurethane film have overall been highly successful in the management of EAFs [35–37]. Although some controversy remains, the role of anti-motility and anti-secretory agents in the correct setting have a role in decreasing fistula output and decreasing time to fistula closure [35]. Prevention remains the best therapeutic strategy in the management of EAFs. In a systematic review of the literature, the weighted mortality from all techniques of temporary abdominal closure in the management of the open abdomen was 26% (95% CI 24–27%) [21].

43.6 Nutritional Considerations

The stress associated with the physiologic derangements of intra-abdominal hypertension and the severe traumatic injury requiring damage control laparotomy is very similar to any severe illness, infection, or major surgery. The hypermetabolic or catabolic phase that follows is well described with increased cardiac output and oxygen consumption, with associated gluconeogenesis, muscle proteolysis, and lipolysis. The mobilization of all the body's resources is a valuable survival mechanism to maintain organ systems and promote healing, but ultimately at the expense of deconditioning, weight loss, and malnutrition. The large wound associated with the open abdomen acts to further exacerbate the catabolic insult via protein losses which continues until the abdomen is closed [38]. Early goal directed nutrition therapy is of the utmost importance in keeping up with metabolic requirements of the open abdomen in effort to allow for optimal healing and to minimize malnutrition.

Methods and goals of nutrition support have been contested across the critical care field for some time. The options for nutrition include parenteral nutrition, enteral nutrition, or some combination of the two. The benefits of enteral nutrition are many, and have been well described including improved glucose control, improved wound healing, decreased infection risk, minimal use of vasopressors, and maintenance of the blood flow and mucosal integrity of the intestines [39]. Early enteral feeding (within 48 hours of admission) in the critically ill patient has also been demonstrated through multiple studies to decrease morbidity, improve outcomes, and may result in higher primary fascial closure and lower fistula rates [39]. The benefits of enteral nutrition are well described in reducing the severity of the stress induced cytokine cascade and subsequent inflammatory response [38].

43.7 Conclusions

Management of the patient with an open abdomen remains a complex problem facing general surgeons today. As reviewed in this chapter, there are numerous approaches to caring for these patients, but guidelines regarding specific patient populations are lacking. As the fields of trauma and critical care have advanced over the years, familiarity with the open abdomen has become more widespread. This familiarity and opportunity for study will need to extend into the pillar of emergency general surgery in the future. A recent prospective observational study of emergency general surgery patients sought to identify indications for the use of the open abdomen technique, fascial and surgical site infections, and mortality. Patients in this cohort managed with an open abdomen had an in-hospital mortality of 30% and a 6-month mortality of 36%. Interestingly, when stratified for age, octogenarians were noted to have a 64% 6-month mortality if managed with an open abdomen [40]. Studies such as this will be required to further identify the patient population in whom an open abdomen is most appropriate (e.g., young vs.

old, feculent peritonitis vs. acidosis and coagulopathy, need for second look vs. hemorrhage), what algorithms for the open abdomen lead to the highest fascial closure rates with the lowest morbidity, and the functional outcomes and quality of life associated with these patients.

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Parastomal Hernia

44

Agneta Montgomery

44.1 Introduction

An enterostomy is necessary when continuity of the gastrointestinal tract cannot be preserved for different reasons or if deviation of urine is needed using an ileal conduit. To have a stoma "per se" results in a reduced quality of life (QoL) [1]. Around 800,000 in the USA and 100,000 in the UK live with a stoma. Generalizing, it means that around 0.15 % of the western population lives with a stoma. Around half of all these patients will have a permanent stoma [2].

A parastomal hernia (PH) is the most commonly seen complication in association with a stoma and frequency is reported to vary widely between 10 and 70 % depending on technique used and time for follow-up. The incidence is estimated to be over 30 % by 12 months, 40 % by 2 years and 50 % at longer duration of follow-up. Operative factors might have an impact on function of the stoma such as leakage, prolapse of the stoma, skin erosion, swelling and pain that can all reduce QoL substantially and cause high costs for society.

The first stoma in "modern" time was performed by Allingham in 1887 operating a patient with a rectal obstruction deviating colon by fixating the mesocolon by sutures to the skin [3]. Techniques have evolved over time and today there seems to be consensus using mesh techniques for parastomal hernia repair. The introduction of a prophylactic mesh, when creating a stoma, give new hope for patients that would need a permanent stoma with the potential of improved QoL.

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44.2 Diagnose and Incidence

A parastomal hernia is an incisional hernia protruding through the trephine were the intestinal loop runs [2]. It could either be the stoma loop, another intestinal loop or the omentum that protrudes.

There is no consensus on how to define, diagnose or how to report on PH rates. Clinical examination upon Valsalva manoeuvre is one suggested method for diagnose and most commonly probably a bulging, reducible or not, is also defined as a PH. Radiologists define a herniation as any intra-abdominal content protruding beyond the peritoneum or the presence of a hernia sac.

Several classifications have been introduced, but none have been used in a clinical setting as a tool for choosing an operative technique or for measuring outcome after PH surgery. There are mainly three historical classifications (Devlin, Rubin, Moreno-Matias), based on either intraoperative findings or radiological descriptions,' that have rarely been used in scientific papers. The European Hernia Society has made a suggestion of a classification, presented in a grid format, Fig. 44.1 [4]. It was developed with the aim to be used as a standard to compare results between studies. It has not yet been validated, but used in several studies. The classification takes into account some of the important risk factors for a recurrence like hernia defect size, concomitant incisional hernia and primary or recurrent procedure.

Computed tomography (CT) in a prone position is the most commonly used investigation for PH diagnose, Fig. 44.2. A better accuracy for diagnose was demonstrated when using a supine position at CT and can be recommended especially in unclear cases [5]. Three-dimensional ultrasonography (3D) through the stoma is a promising alternative to CT scanning to distinguish a bulge from a parastomal hernia [6].

The overall incidence of parastomal hernia is approximately 50 % for an end colostomy and 30 % for an end ileostomy at 10 years [7]. The difference between an ileostomy and a colostomy is suggested to be dependent on the difference

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_44

EHS Parastomal Hernia Classification		Small ≤ 5 cm	Large >5 cm
Concomitant Incisonal Hernia	No	I	III
	Yes	II	IV
Primary ☐ Recurrence ☐			

Fig. 44.1 EHS grid for classification of parastomal hernias (Reproduced from Śmietański M, Szczepkowski M, Alexandre JA, Berger D, Bury K, Conze J, et al. European Hernia Society classification of parastomal hernias. Hernia. 2014;18(1):1–6. doi: 10.1007/s10029-013-1162-z [4])

in the size of the trephine. When comparing clinical investigation to CT investigation in 108 colostomy patients, with a follow-up of 25 months, 27 % respective 33 % were reported to have a parastomal hernia, indicating clinical diagnose to be fairly accurate [8]. In another study the prevalence of PH was 46 % in conjunction with sigmoid colostomy and 22 % at ileostomy [9]. In a register based study including almost 500 patients the risk of having a symptomatic PH 3 years after surgery was 11 % [10].

44.3 Symptoms, Patient Information and Risk Factors

A stoma per se can result in several inconveniences and psychological problems wearing certain clothes, fear of being in official places due to unexpected incidents of stoma leakage and flatulence, isolation from social networking and singles may be reluctant looking for a partner. Physical symptoms are abdominal pain, pain around the stoma area, leakage due to difficulties in fitting of the osteomy dressing, skin erosions, stoma prolapse, stoma orifices obstruction (Fig. 44.3), a siphon of the intestinal loop subcutaneously with emptying problems and a parastomal hernia, Fig. 44.4.

The parastomal hernia per se might not give any symptoms, but many patients complain on the swelling that the hernia causes resulting in an asymmetric body image. A lot of patients do not have the knowledge on the construction of the stoma. The intestinal mesentery has to accompany the intestine through the abdominal wall, taking quite some space, especially in patient with an elevated BMI. All stoma patients are entitled to have a thorough description on how the stoma is anatomically constructed and what expectations to have

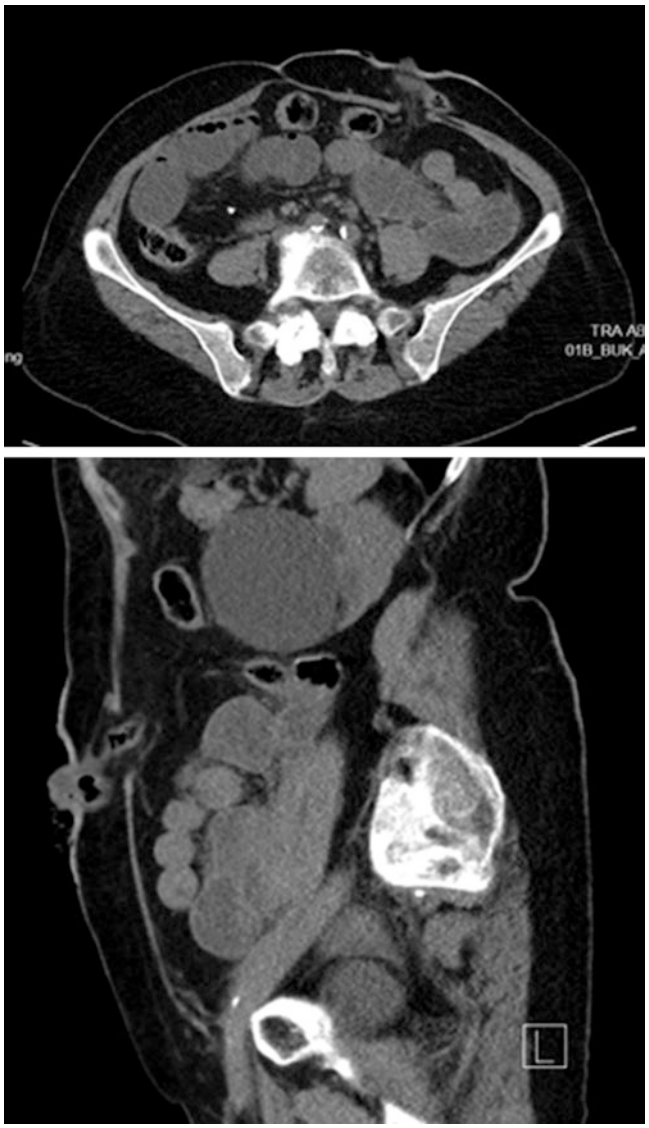

Fig. 44.2 CT scan of a patient with a colostomy that is placed well above the arcuate line, but a little bit too lateral through the rectal muscle with tendency of showing a kinked path subcutaneosly, but with a perfect size of trephine on 2.5 × 3.0 cm. No subcutaneous siphon, parastomal hernia or prolapse is seen

from the cosmetic and functional point of view, either without or with a potential complication. The patient is also entitled to have a specially trained ostomy care nurse for regular appointments and available for consultation when needed.

Risk factors to develop a parastomal hernia, when having and end-colostomy, are female gender, enlarged aperture and age, reported in a study of 108 patients [8]. Respiratory comorbidity, elevated BMI, elevated waist circumference, other associated abdominal hernias, ascites, corticosteroid use, and postoperative sepsis are risk factors reported in other studies [11]. An aperture size of <2.5 cm for a permanent stoma seems to lower the incidence of having a PH hernia reported in a CT scan study [12]. In another study the aperture size and patient age were independently predictive factors of PH development;

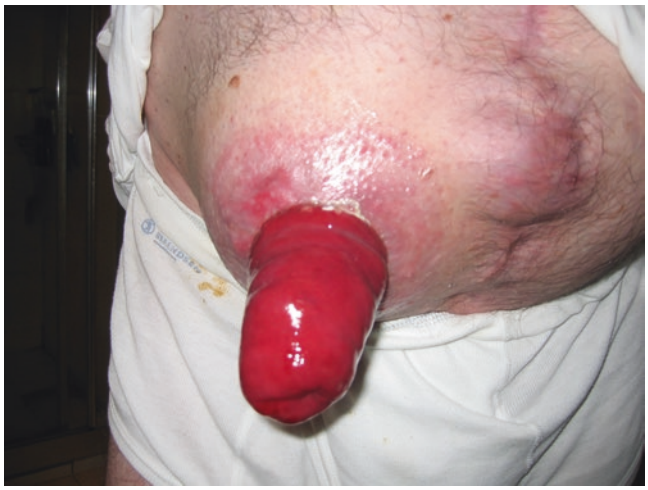

Fig. 44.3 Patient having a parastomal hernia, a stoma prolapse and an associated incisional hernia in the umbilical region at the same time

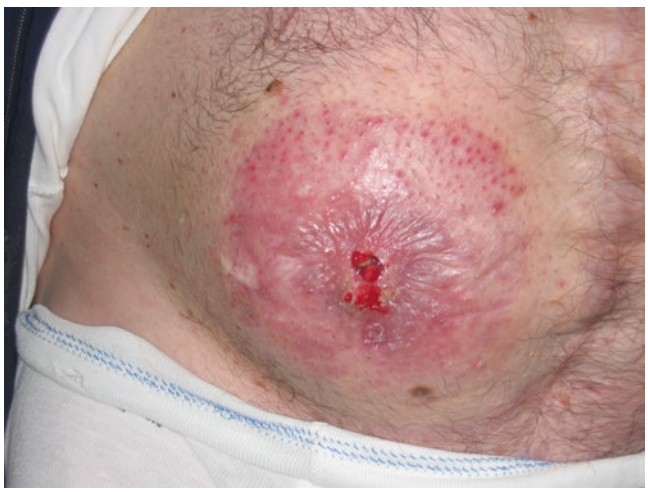

Fig. 44.4 Stricture in the stoma orifice

for every millimetre increase in aperture size, the risk of developing a hernia increased by 10 % and for every additional year of age, the risk of developing a hernia increased by 4 % [9]. In a register based study it is concluded that the emergency setting was the strongest risk factor for death [13].

The largest risk factor for having a PH is probably the surgeon crating the stoma. The surgeon should be aware of the risk factors of having a PH, were to get the most perfect location for every single patient and to use the best technique to bring the intestine out through the abdominal wall.

44.4 Quality of Life and Indications for Surgery

Patients having a stoma per se might suffer from a poor QoL that would be potentially worse when having a PH. A quality of life questionnaire was developed using 20 specific questions, each being graded on a four level scale, and summarized in as "Stoma-QoL score". This score was significantly reduced in patients having a PH compared to patient without a hernia [14].

Table 44.1 Stoma symptoms based on frequency and severity together with "acceptance in daily life" based on a Swedish enquiry study in 495 stoma patients 3 years after abdominoperineal excision for rectal cancer

	Total in % (minor/severe)
Diarrhoea	33 (29/4)
Leakage	43 (41/2)
Loud flatulence	80 (50/30)
Smelly flatulence	50 (42/8)
Skin irritation	39 (37/2)
Stoma care problems	10 (9/1)
Can live a full life	94
Feel at ease with stoma	92
Worries that something awkward may occur during sexual activity	18
Feel dirty and unclean	35
Have the leisure activities and the social life as wanted	91

Median age was 66 years (Martinez-16 [10])

An enquiry based study from the Swedish colorectal register was performed, based on 495 rectal cancer operated patient having a stoma with no PH in 89 %, with a follow-up of median 3 years after surgery [10]. Surprisingly high numbers with around 90 % report on not feeling any reduction in QoL due to their stoma. Stoma-related symptoms are reported in Table 44.1.

Surgery is of course mandatory in emergency cases with a strangulated bowel within the hernia sack. In a case series of consecutively operated PHs, 10 % were operated in an emergency setting that was associated with a high mortality rate of 29 % [15]. No mortalities were seen in elective PH repairs.

Patients having no or mild symptoms due to a PH is not recommended for operation since the risk of having a recurrence is high. In patients with old age, having a cancer recurrence or several risk factors are recommended for conservative treatment. A well-designed support belt could in some instances be recommended. In patients having poor quality of life with recurrent pain, obstruction symptoms, consistent episodes of leakage and skin problems as a cause of recurrence would be considered as indication for surgery.

44.5 How to Perform a Stoma and Stoma Types

The patients should be preoperatively marked for the ideal position on the skin that should be thoroughly discussed with the patient. Due to former scars or skin problems the most ideal place should be used. If the patient has a transverse scar from a flank or a subcostal incision, this side should be

avoided. These incisions usually result in several intercostal nerve injuries with an adjacent atrophy of the rectal muscle on the affected side. This would japerdice the support of the stoma in the abdominal wall.

The most commonly used place of a stoma is through the rectus muscle above the arcuate line in order to get as much collagen support around the trephine as possible, as shown in Fig. 44.5a. One should be aware not to harm the inferior epigastric vessels when planning the route through the rectal muscle. Full blood supply is needed for muscle strength. It could sometimes be difficult to get a straight way through all the layers of the abdominal wall; posterior and frontal rectal fascia and skin. A kinked path through the abdominal wall could cause outlet obstruction. It is wise to use clamps to medialize the fascia at the laparotomy to the midline when preparing the route through the wall. The size of the trephine for a colostomy is recommended to be <3 cm in diameter [12]. In order to hopefully reduce the chance of another intestine to pass beside the stoma intestine, or to have a subcutaneous siphon of stoma intestine, the trephine edges of fascia can be sutured to the stoma intestine. There is though no evidence to support that this would reduce the risk of having a PH hernia, but on the other had the risk of harm is low. It is also wise to pass your index finger through the stoma after finishing the operation when wound is covered. You have the possibility to redo the route if deemed necessary.

Sometimes the stoma "happens" to be placed too lateral and/or low and will end up close to the semilunar line and sometimes also below the arcuate line according to Fig. 44.5b. This localization might be suboptimal.

A stoma can also be placed through a lateral position. A Cochrane report concluded, based on >700 patients comparing stoma placement, either through or lateral to the rectus abdominis muscle, that no robust conclusions could be drawn due to poor quality of included studies. In conclusion, the Cochrane review reported neither a difference in terms of PH or stomal prolapse frequencies between the two routes [16]. Stoma formation through the rectus muscle is though the recommended method of choice. There are no evidences that alternative routes are more favourable.

Both loop and end stomas from either the small intestine or the colon are performed. The loop stoma of the terminal part of the ileum or the sigmoid colon is commonly used as a temporary stoma in an emergency setting in intestinal obstructions at different levels, anastomotic leakages or other causes of peritonitis. These are usually to be reversed within 3 months when problem is solved and patient is back in good health. In very old patients, severe comorbidities or spread cancer patients would often end up not having any reversal procedure performed. Permanent stomas are usually due to malignancy or inflammatory bowel diseases. An ileal conduit is the most commonly used diversions after radical cystectomy. It is constructed using a segment of the ilium, a short distance from the valve of Bauhini, into which the urethras are implanted. Various types of nipples have been constructed for repeated catheterization instead of having an ordinary stoma bandage [17].

44.6 Treatment Options and Outcomes

The fascial suture repair is largely abandoned due to recurrence rates exceeding 50–70 %. In a meta-analysis comparing suture repair to mesh repair resulted in a significantly increased odds ratio (OR) for a recurrence of 8.9 compared to a mesh repair [18]. A relocation of the stoma could be considered on special situations, where the abdominal wall is too damaged to be used, when repairing a recurrence of a

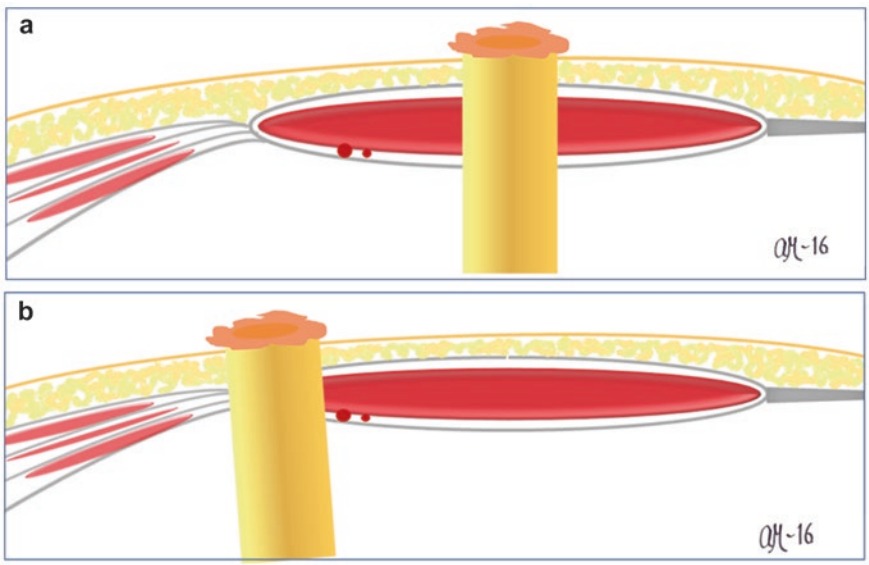

Fig. 44.5 (**a**) Ideal position of the stoma through the rectal muscle with support of both a posterior and frontal rectus sheet with a straight way through all abdominal wall layers. (**b**) Stoma in the wrong position placed in semilunar line below the arcuate line close to the epigastric vessels with the potential risk of being damaged

PH. By relocation you could lower the risk of a PH using a prophylactic mesh, but you add a laparotomy as a further risk. You also have a higher risk of having an incisional hernia at the old stoma site [11]. Fascial suture repair and relocation is generally not recommended. A mesh is generally recommended for all repairs.

Surgical techniques for parastomal hernias repair are reported by Hansson et al. [19]. Any position of the mesh in the abdominal wall seems to work quite well.

The onlay technique was first described by Rosin and Bonardi in 1977 [20]. This technique showed a surgical site infection rate of 13 % and an overall mesh infection rate of 3 % with mesh removals necessary in almost all. This technique seems to have the highest recurrence rate of mesh techniques and is seldom reported on the last years.

Retromuscular repair, usually via a laparotomy using a keyhole technique, demonstrated 4.8 % wound infections, no mesh infections and an overall recurrence rate of 6.9 % [19].

Intra-peritoneal techniques can be performed both open or laparoscopically. The open intra-peritoneal mesh repair is quite sparsely reported on since the laparoscopic technique was introduced. The Keyhole and Sugarbaker techniques are shown in Fig. 44.6a, b. The laparoscopic technique uses three to four trocars. Adhesiolysis and reduction of the hernia sac content is performed. An advantage is that the abdominal wall is expanded by gas insufflation, creating a dome that would ease the placement of the mesh with a minimum of wrinkles.

The keyhole technique uses a mesh with a circular hole (without or with a collar) with a slit so that the stoma can be surrounded, Fig. 44.6a. The mesh is fixated thoroughly to the abdominal wall. The Sugarbaker technique was first described in 1985 were the intestine is lateralized and a mesh is put intra-peritoneal covering the defect and the intestine that runs lateral in a tunnel [21]. A e-PTFE prosthesis anchored by trans-fascial sutures were used.

The laparoscopic Sugarbaker had significantly less recurrences compared to the keyhole technique (OR 2.3). The overall morbidity and mesh infection rate was 3 % and comparable between techniques [19]. The most resent meta-analysis of laparoscopic hernia repairs including 469 patients reported an overall recurrence rate of 17 % [22]. The Sugarbaker technique showed 10 % and the keyhole 30 % recurrences. Surgical site infection was seen in 3.8 %, reoperation due to obstruction in 1.7 % and other complications in 16.6 % with no difference between techniques. Six mortalities were reported on postoperatively. The Sugarbaker is the preferred technique compared to a keyhole technique for laparoscopic parastomal hernia repair.

The Sandwich technique is described and presented by Berger, the only one reporting on this technique, showing very good results [23]. A double layer of PVDF mesh was used. First a keyhole flat mesh, including a collar of mesh around the intestine passing through the abdominal wall, followed by a Sugarbaker placed second mesh. Iatrogenic bowel lesions were reported in 4 %, over all morbidity in 17 %, wound infections in 3 % and mesh infections also in 3 %. Only 2 % recurrences were reported after almost 2 years. Of the laparoscopic techniques the Sugarbaker is suggested as the preferred parastomal hernia repair in terms of recurrence.

A review, including five RTCs and seven non-randomized studies on a temporary ileostomy and colostomy after a low anterior resection for rectal cancer, comparing the postoperative complications and investigating type of stoma to be preferred [24]. A lower risk of stoma prolapse and wound

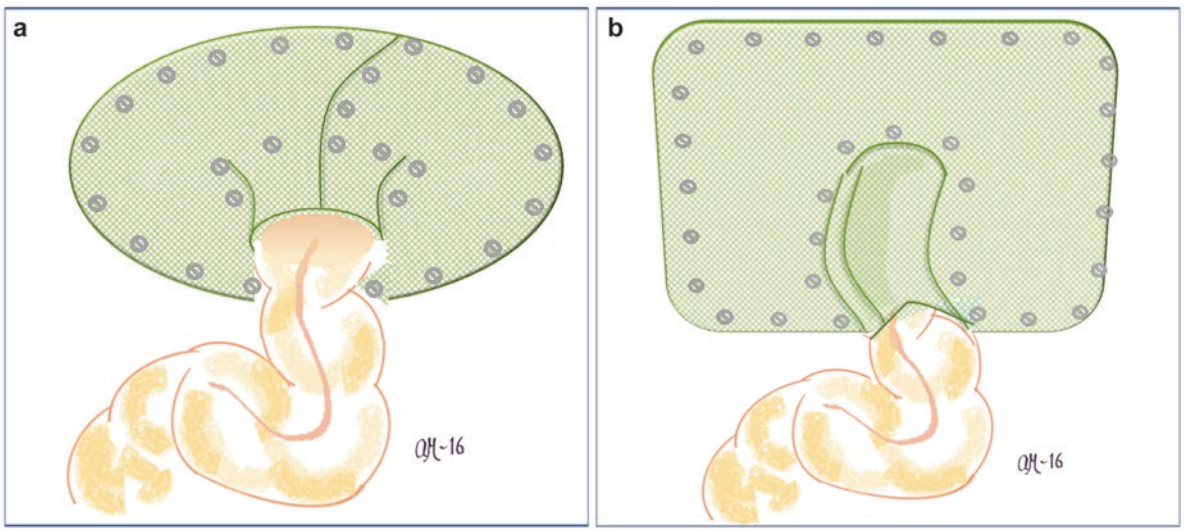

Fig. 44.6 (**a**) Principles of the keyhole technique seen from the abdominal side. (**b**) Principles of the Sugarbaker technique seen from the abdominal side

infection was seen for the temporary ileostomy. It has a minor impact on the patient's QoL compared to a colostomy and can be recommended as a temporary stoma to be used.

44.7 Mesh Types

A long list of meshes available for parastomal hernia repairs are given by Gillern et al. Polypropylene mesh is the most commonly used mesh in open surgery with good ingrowth properties [25]. A major inflammatory response is seen that could cause severe adhesions if placed intra-abdominally. Erosions into the stoma, when mesh is cut and put around the stoma, have also been reported on. Intra-abdominally the polytetrafluoroethylene (e-PTFE) composite mesh has been widely used to prevent adhesions. It was introduced already in 1993. The ingrowth capacity on the abdominal wall side is less and a thorough fixation is advocated in order not to detach and cause a recurrence. The fixation is known to cause postoperative pain that could be severe for the first days. The e-PTFE mesh is better tolerated and gives a less risk of erosion into the surrounding organs. A special polyvinylidene fluoride, PVDF [23, 26], mesh has also been lounged for both retromuscular and intra-peritoneal use for parastomal hernias. This material is more inert, with large pores, have antiadhesive properties and have a strong reinforcement capacity. It has up today no FDA approval but is widely used for incisional hernia surgery in Europe.

There are several composite meshes on the market that try to combine the properties of integration into the abdominal wall and a non-sticky side facing the intestinal side. There are several different antiadhesive coatings lounged to cover the intestinal side of the mesh, usually being low weight polypropylene or polyester.

Several meshes are specifically manufactured, with a stove-like tunnel around the stoma intestine, for either prophylaxis or treatment of a parastomal hernia. These type of meshes are designed for either intra-abdominal, retromuscular or onlay positions. A 3D funnel PVDF mesh with a preformed circular hole, with a collar that would run along with the intestine has been lounged in order to minimize the risk of a recurrence when using the keyhole technique by getting a more robust support around the trephine. The risk of having an erosion into the intestine by the mesh edge using a keyhole mesh for prophylaxis is also minimized [15].

44.8 Prevention of Parastomal Hernia

Since the recurrence rate after PH repair is high, the best strategy would be to limit the risk of having a recurrence by using a prophylactic mesh.

Prophylactic reinforcement of the stoma trephine reduces the hernia rate to approximately 15 % [12]. If having a hernia after the reinforcement it is likely to be of minor magnitude, resulting in a decrease in the rate of hernia being symptomatic and in need of surgery. If having a recurrence after an already reinforced abdominal wall it might though be a more "tricky" operation. Generally in hernia surgery a recommendation is to use an untouched area or space when dealing with a recurrence.

In a meta-analysis by Shabbir et al. comparing prophylactic mesh to no mesh, three RTCs including a total of 128 patients (mesh 64, no mesh 64) with a follow-up between 12 and 83 months were included [27]. The incidence of PH in the mesh group was 12.5 % compared with 53 % in the control group ($P < 0.0001$) diagnosed mainly on CT. A biologic mesh (Permacol) was used in ten patients with no recurrence after 6.5 months follow-up. There was no difference in mesh-related morbidity between techniques.

The frequency of PH after an ileal conduits using a prophylactic mesh has been studied in 114 patients using a large-pore, lightweight mesh. Eight patients (14 %) had a PH comparable to the results for colostomies. No associate complications were seen. RCTs are ongoing.

A prophylactic mesh has been proved to be cost effective in stage I to III rectal cancer patients, but not for stage IV [28]. A prophylactic mesh is recommended.

A prophylactic mesh is safe and is recommended to be used in the creation of both a colostomy and ileostomy/ileal conduit to reduce the frequency of PHs and thereby costs for society.

44.9 Summary

A parastomal hernia is a "complication" or rather an expected result when creating a permanent artificial route and orifice for faecal or urine deviation through the abdominal wall in patients usually suffering from a cancer or a chronic intestinal or bladder disease. Half of all stomas created are used for deviation during a limited time period, were a PH might be of less importance. For further knowledge there are two resent nice review articles by Hotouras et al. and Aquina et al. on the topic that summarizes and highlights the persisting and growing challenges of PHs that can be recommended [11, 12].

The colorectal surgeon or urologist performing the large operation removing a cancer would operate for several hours and sometime a whole day for resection. You cannot at this stage expect to always keep the full attention and energy to make a meticulous operation in creating a perfect stoma. It might be wise to bring in a "fresh" abdominal wall surgeon to perform the stoma creation, taking care of all the details and consider using a prophylactic mesh.

A parastomal hernia is the single most common complication, resulting in a further reduced QoL, in patients that already bears the burden of suffering from the primary cause of having the stoma. Let us do everything in our power to reduce this burden.

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Progressive Preoperative Pneumoperitoneum (PPP)

45

Adriana Hernández López, Estefanía J. Villalobos Rubalcava, and Adrian Murillo Zolezzi

45.1 Introduction

The functions of the abdominal wall are: visceral retention and protection, active participation in performing core movements, aids in defecation and urination, and regulation of the diaphragmatic movements for adequate pulmonary function.

During embryological development the abdominal viscera enter and expand the cavity, such that it adjusts to its newly acquired visceral content; because of its dynamic nature and constant response to change it exerts low pressure on the intra-abdominal viscera.

The capacity of the abdominal cavity varies according to the volume and content. In pregnancy or ascites, the abdominal wall gradually distends increasing the ability to contain the new content.

In giant abdominal hernias this process is reversed, as the viscera move into the peritoneal sac, the abdominal cavity shrinks, the visceral content protrudes into a "container", the peritoneal sac. In these hernias the volume of intra-abdominal viscera is reduced, and the intra-abdominal pressure adapts consequently, gradually reducing the contractility of the musculo-fascial structures, with a pronounced myofascial retraction that worsens with time [1–4].

Hernias are not only defects in the abdominal wall but are part of a whole pathological process which includes respiratory, vascular and visceral dysfunction. Moreover, they are frequently associated with obesity, chronic obstructive pulmonary disease, malnutrition, infection kidney and heart disease, which are predisposing factors for their development.

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When a patient has a giant hernia, changes in the mesentery, bowel, skin and subcutaneous tissue occur. Venous and lymphatic flow is reduced by compression from the annulus. This causes an edematous, thickened and difficult to reduce mesentery.

The loss of domain caused by the lateral fascial muscle retraction, the diaphragmatic relaxation and the frequent association between hernias, obesity and cardiorespiratory disease turns these patients into biologically and socially handicapped individuals [5–8].

45.2 Loss of Domain, Definition

Loss of Domain is defined as a large hernia, with a diameter of >10 cm or those whose contents of the hernia sack exceed the capacity of the abdominal cavity; technically it is one in which more than 50 % of the abdominal contents are located outside of the abdominal cavity. Generally they take years to form, the "giant" hernia sacs contain the viscera that can't be reduced because the abdominal cavity is no longer able to accommodate them.

Mason defined them as those in which it was not possible to reintroduce the contents of the sac into the abdomen. He estimated a volume contained in the hernia sac of over a litre or a diameter of the hernia ring exceeding 12 cm [9, 10].

Kingsnorth considers these hernias as those in which the peritoneal sac has a volume of more than 15–20 % of the natural volume of the abdominal cavity. He believes that if the ratio of the volume of the hernia sac over the volume of the abdominal cavity is less than 20 %, it is possible to perform a tension-free fascial closure.

According to Tanaka et al., the volume of the abdominal cavity is the main indicator of the loss of domain; it is easy to measure the volume of the abdominal cavity as is the volume of the herniated viscera or hernia sac. If the ratio of the volume of the sac over the volume of the abdominal cavity is greater than 25 %, it is considered a predictor for loss of domain [11–15].

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_45

45.3 Loss of Domain, Pathophysiology

Giant hernias occur through fascial defects that gradually lose their domain in the abdominal cavity, with changes that are "tolerated" because they develop gradually but will ultimately reduce the intra-abdominal pressure and the capacity of the abdominal cavity.

The complexity of these patients lies in the loss of a functional abdominal cavity. There are pathophysiological changes caused by maladjustment of multiple organ systems: increased pressure causes decreased lymphatic and venous portocaval return to the chest, there is vasodilation and venous stasis in the abdomen, pelvis and lower limbs. Because of the decreased venous and lymphatic return chronic edema occurs in the omentum, mesentery and bowel. Friction exerted by the ring on the bowel conditions inflammation that causes adhesions between loops of bowel, the sac and the hernia defect. Intra-abdominal pressure decreases as more and more bowel protrudes into the hernia sac; this causes decreased diaphragmatic excursion which lowers the strength of the diaphragm and alters ventilatory physiology generating both an inspiratory and expiratory restriction [1–4, 11, 12].

45.4 Management of the Hernia with Loss of Domain

Loss of Domain implies that the abdominal contents are permanently found in the hernia sack (a second abdominal cavity).

These hernias are a challenge for the surgeon because of the difficulty to replace the contents of the visceral sac into the abdominal cavity. As the cavity, once emptied of its contents contracts, decreases in size, and is unable to accommodate the herniated viscera.

The forced reduction with primary closure can cause a devastating increase in intra-abdominal pressure which in turn leads to a reduction in cardiac output because of a decrease in venous return (preload) and an increase in peripheral vascular resistance (afterload). There is an indirect reduction in myocardial contractility caused by a decrease in left ventricular adaptability. There is also a decrease in mesenteric and splanchnic vascular flow; kidney function deteriorates as there is decreased perfusion which leads to oliguria and azotemia; hormones such as renin, which affects the systemic blood flow, are also released which further worsen vascular dynamics [6, 9, 11, 16, 17].

The reduced thoracic volume and pressure exerted on the diaphragm reduce the vital capacity that can lead to severe respiratory failure with hypoxemia and hypercapnia which further worsens diaphragmatic excursion leading to a reduction in venous return and hypertension.

An abdominal compartment syndrome ensues, causing intestinal ischemia, respiratory distress, renal failure, skin ischemia and/or necrosis. The surgeon might face hernia repair dehiscence or altogether find himself unable to complete the repair. We must bear in mind that these patients frequently have concomitant diseases such as obesity, heart, or respiratory diseases which aggravate this situation [4, 12, 13, 18, 19].

To avoid this, it is imperative that adequate preparation be performed, favouring the gradual rehabilitation of all systems, the reintroduction of visceral content into the abdominal cavity and the reconstruction of the abdominal wall.

45.5 Hernia Surgery with Loss of Domain

The use of prosthetic material in the repair of giant hernias is associated with complications in 32 % of patients: infection, enterocutaneous fistula, ileus, intestinal perforation, chronic pain, abdominal rigidity, intestinal obstruction, foreign body sensation and seroma. The quality of life of these patients is inversely proportional to the size of the implanted mesh.

The effects of the myofascial retraction in these cases influence the complexity of the wall repair. Current options for hernia repair with closure under these conditions are: a viable tissue bridge with permanent or biological prostheses, tissue flaps with autologous fascia lata, rectus femoris or latissimus dorsi and/or the use of tissue expanders and preoperative progressive pneumoperitoneum (PPP) [4, 20].

45.6 Preoperative Progressive Pneumoperitoneum

Before the advent of anti-TB drugs, pneumoperitoneum was used as a treatment for peritoneal tuberculosis.

In 1940, Goñi Moreno in Buenos Aires, Argentina, was the first to report the use of preoperative pneumoperitoneum in giant hernia repair. Goñi Moreno's work was presented at the American College of Surgeons in 1947. The reasoning behind his idea was to allow the reintroduction of the abdominal viscera into the cavity, and their readaptation to the abdominal cavity in a progressive fashion, reducing cardiovascular and respiratory complications immediately after surgery.

The technique of preoperative progressive pneumoperitoneum described by Goñi Moreno allows a more physiological adaptation of the patient and the abdominal cavity to the reintegration of the viscera into the abdomen, which favours adequate surgical repair [1, 2, 8, 9, 12, 16].

45.7 Objectives of the PPP

It takes time to restore the abdominal capacity during the PPP. One should perform abdominal CT scan to assess the volume of the hernia. Measurements proposed by Tanaka et al. confirm the loss of domain if the volume of the sac is equal to the volume of the abdominal cavity. The tomo-

graphic measurements should be done at the level of the third lumbar vertebra, corresponding to the midpoint of the abdominal cavity [11, 21, 22].

Transoperative pneumoperitoneum has been proposed to have the same benefits of the PPP, it can reduce the degree of visceral and mesenteric edema, it promotes lysis of adhesions between the hernia ring and sac and allows easier identification of hidden defects. These benefits without a prolonged hospital stay [10], however, reduction of the herniated viscera is only "temporarily" made possible by the muscle relaxing effects of the general anaesthesia, which will afterwards return to baseline with subsequent respiratory distress. These acute changes can lead to atelectasia formation, hypovolemia, shock, thrombophlebitis and thrombo-embólicos complications [3].

The objective of the PPP is to "gradually" stretch the abdominal cavity with the concomitant increase in the length of the abdominal wall muscles. It increases intra-abdominal pressure gradually and improves diaphragmatic function, which in turn improves ventilatory dynamics.

As the intra-abdominal pressure gradually increases, there is a decrease in the thoracic compliance. The abdominal cavity progressively enlarges, and changes in the viscera allow for the uneventful reintroduction of the herniated contents during the procedure.

45.8 PPP Physiology

Patients with hernias with loss of domain have low intra-abdominal pressure. There is an imbalance between intra-abdominal and thoracic pressure as a result with a resultant weakened diaphragm, which leads to a lessened participation of it in respiratory mechanics.

PPP acts in a way similar to pregnancy or accumulation of ascitic fluid way: it expands the soft tissues of the abdominal wall without causing sudden increase in intra-abdominal pressure.

PPP causes distension of the musculo-fascial structures and increases the volume of the once retracted abdominal cavity. This happens with a subsequent elevation of the diaphragm which will resume its normal position once the pneumoperitoneum is released. Although it has been documented that the vital capacity decreases in approximately 25 % (maximum reduction) during PPP, stretching the diaphragm improves subsequent post-operative respiratory function. Pulmonary function tests performed immediately after surgery show a vital capacity of 60–75 % of pre-PPP values. This compares favourably with the 60 % reduction in vital capacity observed during a routine cholecystectomy during the first post-operative day [1, 7, 8, 19, 22].

With the elevation of the diaphragm and the lowering of the pelvic floor during the PPP there is an increase in the abdominal cavity volume. The turgidity of the herniated organs is restored reducing their volume. This relaxation of the abdominal wall promotes healing of any decubitus injury caused by the herniated viscus [5].

The gradual increase in the capacity of the abdominal cavity will allow for the intra-abdominal pressure to remain low despite the contents being reintroduced into the cavity. This results in improved diaphragmatic function and venous return, especially relevant for patients with cardiopulmonary co-morbidities who would otherwise have high risk of hemodynamic and respiratory complications.

Preparation of a patient with a giant hernia with PPP facilitates intraoperative dissection of the hernia sac and its contents due to the preoperative lysis of adhesions by the air.

The PPP acts as the conventional laparoscopic pneumoperitoneum, facilitating dissection of adhesions in an atraumatic way. Adhesions are stretched and enterolysis facilitated unless these adhesions are firm and therefore do not allow for the visceral reduction. This gradual pneumatic lysis of adhesions improves portal and mesenteric circulation and during the procedure itself will facilitate dissection and reduction of the herniated content [2, 3, 16].

It has been reported that the insufflation of air into the abdomen fills not only the cavity, but also the hernia sac. This prevents the sac from literally hanging and thereby decreases chronic edema of the mesentery and other intra-abdominal organs.

The effect of adherenciolisis explains the homogeneous distribution of air through the abdominal cavity; interestingly, air distends the abdominal cavity more than it does the hernia sac [1, 6, 9, 19].

The immediate result when performing the PPP is the distension of the hernia sac; however, over time the gradual increase in the size of the abdominal cavity will be apparent. As these changes transpire, the viscera return to the abdominal cavity, leaving the air filled sac over them and aided by gravity. This is possible to see with a plain lateral decubitus X-ray of the abdomen.

Another effect of pneumoperitoneum is increasing the length of the abdominal wall muscles. Studies have been performed utilising CT scans of the abdomen which document the effects of PPP in the size of the hernia and abdominal musculature. They confirm that the PPP causes passive stretching of the rectus abdominis muscles. Despite the longitudinal orientation of the rectus muscle the PPP increases the amplitude and length of the musculature, exerting a similar effect on the hernia ring [12, 22].

Intermittent insufflation causes stretch of the muscle fibres. Microscopic studies of muscle sections from experimental studies show muscle dilation of all layers without hypertrophy or hyperplasia. The effect is that of expansion and a reflex adaptation towards relaxation of the abdominal muscles. This expansion also causes areas of necrosis and lymphoid cell aggregates along with a reactive inflammation of the peritoneum [14].

After the second week of PPP, peritoneal irritation caused by the air insufflated into the cavity stimulates the immune system and improves leukocyte macrophage response, promoting the subsequent healing of the wounds [8, 18].

45.9 Progressive Pneumoperitoneum Preoperative Technique

PPP requires frequent insufflation of air into the abdominal cavity.

In his first case Goñi Moreno used oxygen for insufflation; he later changed to ambient air. You can use oxygen, CO_2, nitrous oxide and ambient air. However, one must remember that oxygen and CO_2 have faster absorption (four times faster) into the intraperitoneal space than ambient air [12, 17, 21].

Some authors prefer nitrous oxide because it is more readily absorbed than air; in these cases its use should be avoided by the anaesthesiologist. This is because the gas used in the respiratory cycle dissolves into the blood and quickly diffuses into the peritoneum. This can lead to a sudden increase in intra-abdominal pressure which can lead to hypovolemia, respiratory failure and death; this complication is quickly dealt with by opening the abdominal cavity [1, 3, 5, 8].

Since its original publication, multiple modifications to the technique have made it easy to perform and safe. In 1990, Caldironi proposed daily abdominal punctures with a Veress needle and use of CO_2. Initially the technique required for repeat abdominal punctures with a lumbar puncture needle (blunt tipped) gauge 16–18 performed every 24–48 h. Vascular access catheter such as the dual lumen 16 g angiocath placed percutaneously have also been used. Double lumen catheters inserted through a Veress needle has also been used, pigtail 5Fr catheters inserted under ultrasonographic or CT guided control have been used. Other techniques involve a modified Seldinger technique with the insertion at different points such as the left midclavicular line in the subcostal space, in the semilunar line, at Palmers point (intersection of the linea alba and the semilunar line), in the left iliac fossa or on a remote site from the hernia or previous scar.

The procedure is generally performed in the operating room under local anaesthesia and sedation, but can also be performed on the patient's bed under strict aseptic conditions and antisepsia [1, 2, 5, 6, 9, 11].

Once the needle is in the abdominal cavity, ambient air is passed through the needle using a 50 cm^3 syringe. The initial amount of 100 cm^3 is used to allow a small amount of distance to be introduced between the bowel and the Veress needle, thereafter catheter insertion is performed.

500–4000 cm^3 is used to inflate the cavity.

Once finished, an abdominal X-ray is performed to visualise the correct position of the catheter in the abdominal cavity and to visualise the pneumoperitoneum in the abdominal cavity.

The subsequent insufflation of the abdominal cavity can be performed as an inpatient procedure or in the physician office. Air is insufflated daily in an amount of 500–1500 cm^3 of ambient air via a syringe connected to a three-way stopcock which is connected to a mercury sphygmomanometer. Pressure should not exceed 15 mmHg during any given session [3, 8, 19, 23].

Gradual expansion of the cavity is performed, with the duration depending on hernia type and size, approximately 7–10 days in inguinal hernias, 9–28 days in ventral hernias. The total volume will range from 3800 to 5000 cm^3.

Insufflation is performed according to the patient's tolerance (besides not exceeding 15 mmHg). It is suspended when the patient manifest a feeling of fullness, pain, nausea, shortness of breath, tachycardia, hypertension, hypotension or decreased blood O_2 saturation [7, 12, 16, 19].

45.10 Preparing for PPP

1. The preparation of the patient with a hernia with loss of Domain begins with smoking cessation, respiratory therapy and placement of a belt or abdominal binder to prevent migration of air into the peritoneal sac [19].
2. DVT prophylaxis is administered daily as a single dose of low molecular weight heparin [7].
3. At the time of initial insufflation: Foley catheter placement and stomach decompression with nasogastric tube is performed.
4. Initial insufflation until the abdomen is taut is performed; PPP can reveal unknown defects [24].
5. Oral antibiotic therapy with cephalosporins or third generation fluoroquinolones is began before the start of the insufflation. A prokinetic agent like metoclopramide 10 mg every 8 h and analgesics are administered [1].

45.11 Preoperative Progressive Pneumoperitoneum Complications

PPP has a low complication rate (7 %) and is well tolerated by most patients. The discomfort associated with the procedure is epigastric pain, feeling of gastric fullness and early satiety, which decreases with administration of analgesics and prokinetic in nearly all of the patients.

Shoulder pain is the most frequent complaint in 41 % of patients with PPP, occurs early and is usually transient and moderate. It is caused by the stretching of the suspensory ligament of the liver that is not usually under tension and becomes tense when the PPP is established.

Diaphragmatic irritation or moderate wall stress may generate pain in the neck region. It is a sign to suspend insufflation.

Major complications which can occur as a product of the technique are: (a) accidental insufflation of air into the colon,

visceral perforation, peritonitis, solid organ injury, air embolism, (b) severe respiratory distress, pulmonary embolism, pneumonia, pulmonary embolism due to deep venous thrombosis, and myocardial infarction (rare complications) and (c) subcutaneous emphysema of the neck and chest and mediastinal emphysema [2, 6, 8].

Other complications include acute exacerbation of underlying lung disease, and wound hematoma.

PPP does not increase wound infection rates or other wound complications and does not affect the incidence of transoperative or post-operative complications [2, 12, 25].

An important contraindication for performing the procedure is the presence of a hernia with a small ring as this may lead to strangulation [4, 11].

45.12 Conclusions

The management of large hernias requires a multidisciplinary approach. PPP is recommended in the management of patients with giant hernias and a large volume of their viscera in the hernial sac, where it would otherwise not be possible to reintroduce the contents and make the repair, or where their reduction of the contents would lead to an abdominal compartment syndrome [6].

The PPP is used to restore the right of residence of the abdominal viscera before surgery that would otherwise be inoperable; the gradual air insufflation leads to an adjustment of intra-abdominal pressure with the progressive stretching of the abdominal fascia similar to the effects of pregnancy or the accumulation of fluid ascites [1, 26]. PPP will stretch the abdominal wall and increase the volume of the abdomen which facilitates reduction of the herniated content without ventilatory and circulatory compromise [8, 17, 19].

PPP is a simple procedure that can be performed under local anaesthesia and sedation on an outpatient basis; it is well tolerated by patients and is a safe and useful tool in the repair of giant hernias.

45.13 Clinical Case

Fifty-one-year-old female with psychomotor delay secondary to neonatal hypoxia. Forearm fracture at 46 years of age which was managed with surgery. Morbid obesity since she was 35 years of age. No previous abdominal surgery.

She began 10 years before her initial visit with progressive increase in her abdominal girth, which was accompanied by intermittent colicky abdominal pain of variable intensity which became worse after ingestion of meals and improved in the lateral decubitus position.

Weight 95 kg, 1.60 m tall, BMI 37.1.

Alert and oriented, holosystolic cardiac murmur, no aggregates heard on lung auscultation. Abdomen is large bulgy, yet soft. A very large ventral hernia with abdominal viscera is found, adequate peristalsis is heard (Figs. 45.1 and 45.2).

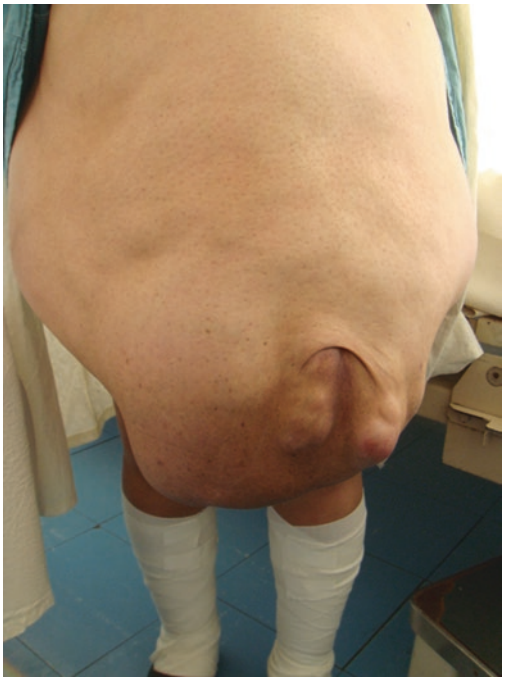

Fig. 45.1 Front view of the patient with her large abdominal wall defect (pre op)

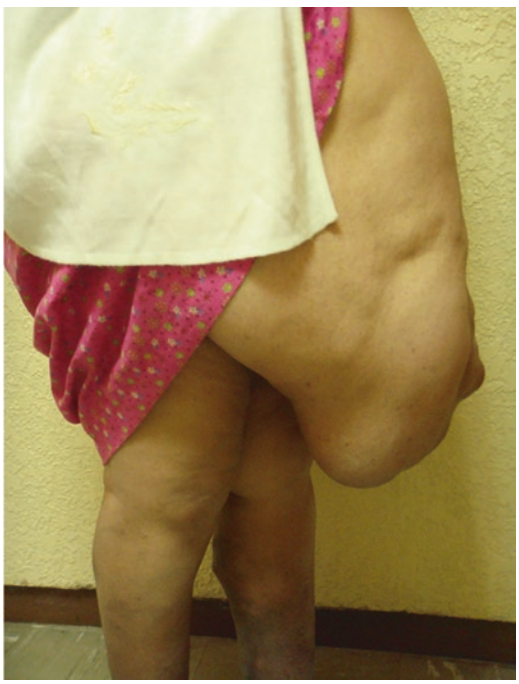

Fig. 45.2 Side view of the patient with her large abdominal wall defect (pre op)

Under sterile technique and local anaesthesia a puncture was performed using a Veress needle in the left hypochondrium, midclavicular line. A double lumen catheter was placed. Initial insufflation was performed with 2300 cm^3 of air; thereafter daily fillings with 2000 cm^3 were performed during 10 consecutive days. The second lumen of the catheter was connected to a sphygmomanometer to control insufflation pressure as described above. On her third day, she referred postprandial fullness which was not a contraindication for further insufflation (Figs. 45.3 and 45.4).

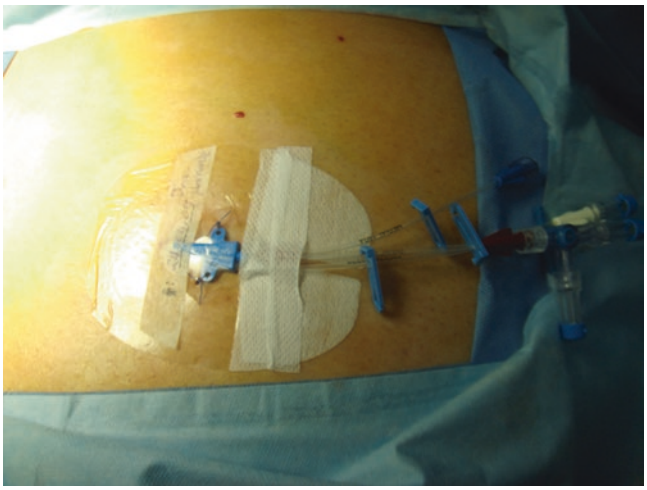

Fig. 45.3 Double lumen catheter placed in abdomen through which ambient air was insufflated

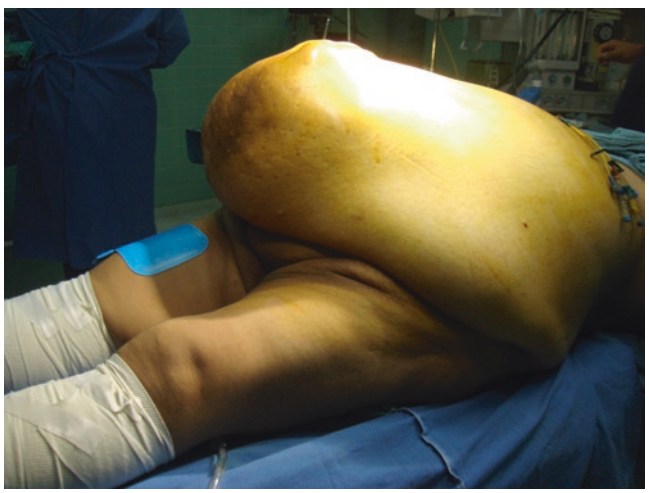

Fig. 45.4 Preoperative picture after 10 days of PPP (decubitus position)

After successful PPP, the abdominal wall reconstruction is performed using mesh and refunctionalization of the abdominal wall (Figs. 45.5 and 45.6).

Patient had an adequate post-operative course. She was discharged on her fourth post-operative day with outpatient follow-up performed thereafter (Fig. 45.7).

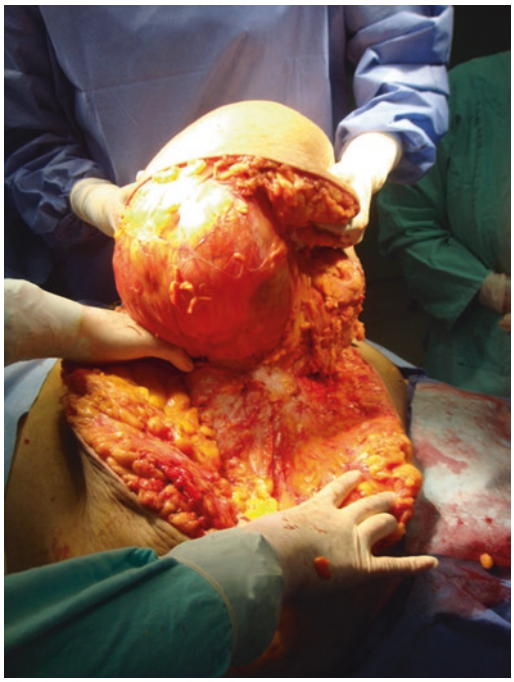

Fig. 45.5 Transoperative picture showing hernia sac and abdominal wall defect

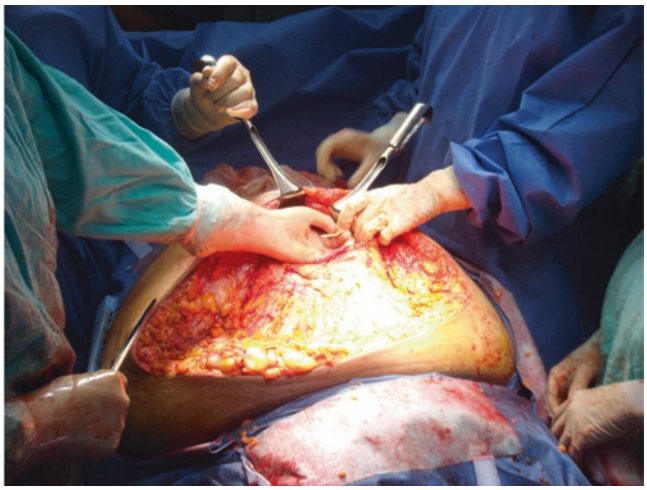

Fig. 45.6 Operative picture showing reduction of hernia

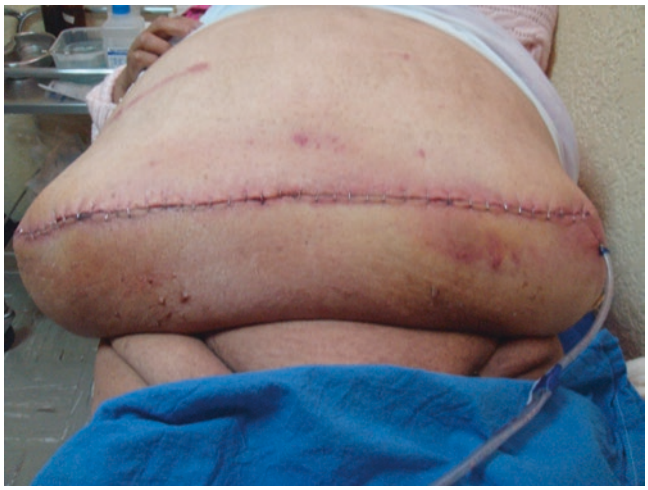

Fig. 45.7 Outpatient follow-up

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Botulinum Toxin Use in Complex Abdominal Wall Hernias

46

Benjamin Zendejas and Martin D. Zielinski

46.1 Introduction

Botulinum toxin (BTX) is a neurotoxin that is isolated and purified from Clostridium bacteria (e.g., Botulinum, Butyricum, Argentinense, Baratii) which produce eight different serotypes from A to H2. Of these serotypes, only A and B are commercially available for clinical use, with type A being the most commonly utilized [1, 2]. BTX temporarily blocks the release of peptide-rich endosomes at the presynaptic cholinergic nerve terminal. These endosomes primarily contain acetylcholine in addition to pain and inflammatory mediators such as calcitonin gene-related peptide and substance P. When the synaptic transmission of these agents is prevented, the injected skeletal muscle becomes flaccidly paralyzed with diminished pain sensation resulting in a 4- to 6-month reversible flaccid paralysis, or chemical muscle denervation [3, 4]. Though the initial response or onset of muscle weakness can be recognized within 1–2 days of administration, the maximum clinical effect or peak response shows a dose–response relationship and depends on the size of the muscle complex. For example, peak response rates for extraocular muscles are seen between 1 and 2 weeks [5], while for the abdominal wall muscles it can take up to 4 weeks [6].

The US Food and Drug Administration first approved a preparation of Botulinum toxin type A called Botox (Allergan, Inc., Irvine, CA) in 1989 for the treatment of blepharospasm and strabismus [5]. Owing to its efficacy as a neuromodulating agent and favorable safety profile, BTX has since been applied to a myriad of muscle-related pathologies, pain syndromes, and cosmetic indications.

The use of BTX in abdominal wall reconstruction of complex hernias and open abdomen management has recently gained attention. Such challenging clinical situations are associated with large fascial defects, lateral abdominal wall muscle retraction, and loss of abdominal domain [7]. Theoretically, the chemodenervation of the lateral abdominal wall musculature with BTX should result in improved abdominal wall compliance, decreased lateral abdominal wall retraction with less midline tension, and pain modulating benefits, all enticing properties with potential applications in abdominal wall reconstruction settings.

This chapter will review the rationale and evidence that supports the use of BTX in complex abdominal wall hernias, describe the technical aspects of its use, proposed indications, and provide insights into its future role in this setting.

46.2 Rationale and Evidence for the Use of Botulinum Toxin in Complex Hernias

46.2.1 Preclinical Studies

The role of contraction of the lateral abdominal wall muscles in the formation of midline hernia after laparotomy was tested in a rat model by Lien et al. [8]. Three groups, with six rats each, were subject to sham (control—no laparotomy), saline (placebo), or BTX injection of the abdominal wall prior to laparotomy closure. At 2 weeks, their abdominal walls were examined and the BTX group had weaker musculature but with significantly fewer and smaller hernias than the saline group.

Similarly, in a rat model, Cakmak et al. [9] evaluated the effect of BTX chemodenervation of the lateral abdominal musculature on intraabdominal pressure. On day 1 of the experiment, infusion catheters and pressure transducers were inserted into the abdomen of 15 rats, 5 of which received saline injections of the abdominal wall and 10 received BTX. Saline solution was infused to reach a preset intraabdominal pressure of 6 mmHg on day 1 and day 3. Electromyographic (EMG) tests of the lateral abdominal

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_46

wall musculature were performed to evaluate muscle contractile strength and respiratory rates were monitored to assess the impact on respiratory function. At day 3, results showed a statistically significant 20 % increase in intraabdominal volume for the same unit of intraabdominal pressure in the BTX group, compared with no increase in volume in the saline group. EMG activity confirmed effective muscle paralysis in the BTX group. Respiratory rates did not differ between groups.

Rodriguez-Ruiz et al. [10] evaluate abdominal wall tension and compliance in a ventral hernia rat model. Fourteen rats underwent planned ventral hernias and were randomized to receive either saline or BTX at 3 weeks. Hernia defects, abdominal wall tension, and compliance were measured at 2 weeks postinjections. Hernia defects were not statistically significantly different. Rats in the BTX group, however, demonstrated significantly less abdominal wall tension and twice as much abdominal wall compliance when compared to the placebo group.

46.2.2 Clinical Observations

Ibarra-Hurtado et al. [6] examined the role of BTX in the treatment of large complex hernias after open abdomen management. In their prospective cohort study, two patients were injected with BTX and followed with computed tomography scans weekly to determine the point at which maximal hernia defect reduction was achieved. Subsequently, ten additional patients were scanned before the injections and 4 weeks after. In the two patients that were imaged weekly, results showed a 50 % reduction in transverse hernia diameter at week 3 after injection, with no further reduction in size afterwards. In the ten patients that were scanned at week 4 postinjection, results showed a mean reduction in hernia diameter of 5.2 ± 3.2 cm from preinjection values. All patients underwent abdominal wall reconstruction. Postoperative complications were within expected range, with none attributable to BTX use, and with no documented recurrences at 9 months of follow-up.

Our group's first venture with BTX for abdominal wall pathology began with a patient who had undergone an uneventful laparoscopic ventral hernia repair [11]. At 3 weeks postoperatively, she had persistent abdominal wall pain and muscle spasms. Physical exam and imaging studies revealed no cause for her pain. She initially underwent trigger point injections with local anesthetic, which improved some of her discomfort but spasms persisted. BTX injections were tried and were successful at persistently relieving her symptoms.

With such experience, our group began to use BTX in the preoperative setting for select ventral hernia cases to optimize postoperative pain control and to explore its potential role in decreasing hernia recurrence. We retrospectively analyzed this initial experience with a case–control study design [12]. Twenty-two patients with BTX injections were matched to 66 concurrent controls. Results showed that despite similar multimodality treatment of postoperative pain, patients who underwent BTX injections required significantly less opioid analgesia and reported less pain. Other outcomes such as hospital length of stay or hernia recurrence were equivalent.

Additionally, our group has explored the use of BTX to improve the rates of fascial closure in the open abdomen setting. First, we studied a prospective cohort of 18 patients who were injected with BTX within the first few days of their abdomen being left open (half within the first day) [13]. With this approach, most patients (83 %) achieved successful delayed fascial closure. Such preliminary data led our group to carry out a multi-institutional, prospective, placebo-controlled, randomized trial to test the efficacy of BTX in achieving superior rates of fascial closure in the open abdomen setting [14]. Forty-six patients were randomized, no significant differences between groups existed at baseline. Injections were performed on average 1.8 ± 2.8 days from damage control laparotomy. Results showed that the 10-day probability of fascial closure was equivalent for the BTX (96 %) and placebo groups (93 %). Complications, length of hospital stay, and other clinical outcomes, such as pain surrogates (morphine equivalents), were also equivalent. Given the higher than expected rates of fascial closure seen, a statistical type II error could have occurred.

Farooque et al. [15] investigated the effect of BTX on lateral abdominal wall muscle thickness and length in eight patients with complex abdominal wall hernias. Their results suggest that 2 weeks after BTX injections, the lateral abdominal wall muscles elongated (mean length gain of 2.8 cm per side, range 0.8–6.0 cm) and became thinner (mean decrease of 6.3 mm, range 0.4–13.5 mm). All cases underwent successful hernia repair without documented early recurrences.

Chavez-Tostado et al. [16] reported their experience with BTX in the management of giant incisional hernias, where a cohort of 14 patients (mean hernia diameter of 15 cm, and hernia area of 282 cm^2) underwent preoperative BTX injections and reimaging at 4 weeks postinjection. Results show a reduction in the hernia diameter in roughly half of the patients, with a non-statistically significant decrease in mean hernia area from baseline of 34 cm^2. In the majority of the patients, midline fascial approximation was achieved. At 15 months of follow-up no recurrences have been noted.

The use of BTX to prevent abdominal compartment syndrome after the repair of a large Morgagni hernia in an adult patient is described by Barber Millet et al. [17]. The patient's abdominal domain prior to BTX administration was 5035 cm^3 (cc), which expanded to 6900 cm^3 at 3 weeks post-BTX injection, corresponding to a 37 % increase in abdominal domain. The patient proceeded to have an uneventful operation and recovery.

Similarly, Ibarra-Hurtado [18] describes the use of BTX in the treatment of a patient with large bilateral inguinoscrotal herniae. Given preoperative concerns for loss of abdominal domain, he was injected with BTX which resulted in a 26 % gain of intraabdominal volume at 1 month postinjection. The patient underwent successful repair of his herniae without complications.

46.3 Technique

We recommend BTX injections be performed in a setting where conscious sedation can be administered. BTX (300 units, Botox®, Allergan) is reconstituted in 150 cm^3 of injectable 0.9 % sodium chloride solution (final concentration 2 units/cm^3). Two syringes are labeled and loaded onto a three-way stopcock, one with the BTX solution and the other with injectable NaCl. There are six injection sites on the patient's abdominal wall: right/left subcostal; right/left anterior axillary; right/left lower quadrants (Fig. 46.1). An 18-gauge spinal needle attached to a three-way stopcock via 9-in. extension tubing is advanced under ultrasonographic (US) guidance into the external oblique, internal oblique, and transversus abdominis muscles at each of the six injection sites. For ease of tissue layer identification, the initial injection is into the transversus abdominis layer first with subsequent injections into the remaining muscle bellies as the needle is withdrawn. Aliquots of 1–2 mL of injectable NaCl is injected into each layer to ensure appropriate needle placement. Injection of 8.3 cm^3 (16.6 units) of the BTX solution for each muscle is then performed at each of the six injection sites (25 cm^3/50 units per injection site). One must ensure that injections are as lateral as possible given that the obliques are most muscular at their lateral portions. This can be challenging with the caudad and cephalad injection points given the prominence of the antero-superior iliac spine and the lower ribs. Likewise, it is important to achieve and visualize the diffusion of the BTX bolus cephalad to the ribs as the external oblique attaches 5–7 cm cephalad to the costal margin.

Ibarra-Hurtado et al. [6] have used an alternative BTX dose and injection sites. They dilute 500 units of BTX (Dysport®, Galderma) in 5 mL of 0.9 % saline solution (100 units/1 mL). Injections of 0.5 mL are performed at five sites (50 units/0.5 mL per injection site) between the external and internal oblique muscles through a 25 Fr subdural blockage needle under ultrasonographic guidance. Injection sites are: two sites at the middle axillary line between costal margin and iliac crest level, and three sites between anterior axillary line and middle clavicular line between costal margin and iliac crest level, with similar sites on the opposite site. The above regimens have not been compared against each other to determine if one is superior to the other. Our group prefers to dilute the BTX into a greater volume of fluid to better diffuse it through the entire length of the abdominal wall with fewer injection sites to decrease the risk of injection site complication.

46.4 Safety and Adverse Effect Profile

BTX has been used extensively in the clinical setting for more than 30 years in a variety of conditions. No serious adverse events have been reported, and most mild adverse effects described (e.g., focal weakness) are attributable to its mechanism of action [19].

Given that the abdominal wall muscles function as accessory or secondary breathing muscles, theoretical concern could

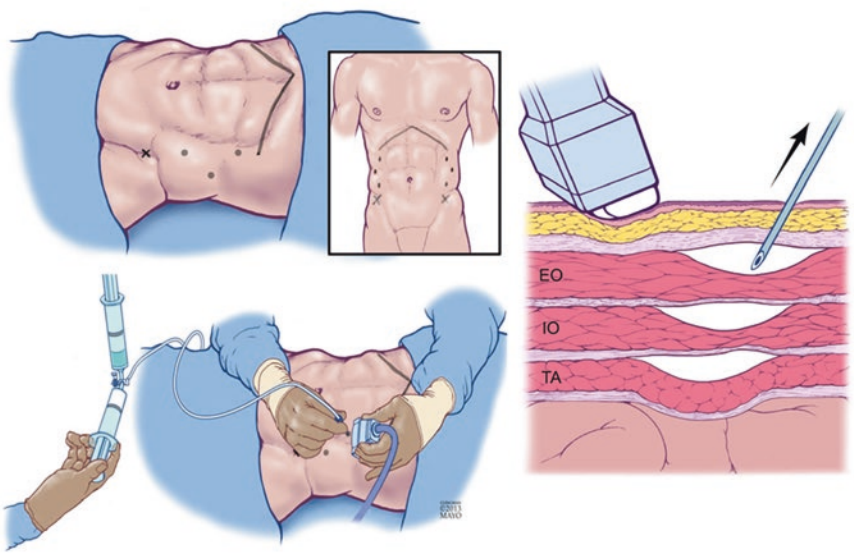

Fig. 46.1 There are six injection sites on the patient's abdominal wall: *right/left* subcostal; *right/left* anterior axillary; *right/left* lower quadrants

exist about the clinical effects of paralyzing these muscles and the effect this may have on respiratory function. In a healthy adult with no underlying respiratory issues, such loss of accessory respiratory muscles should not pose a substantial concern, but in a critically ill patient (such as those after damage control laparotomy), or in patients with compromised baseline lung function, caution should be taken when considering BTX chemodenervation of the abdominal wall. Though the clinical use of BTX in these at-risk populations has been limited, no clinically meaningful adverse effects have been reported.

Injection site complications such as bleeding or infection remain a possibility, though in practice none have been reported, careful attention to sterile technique, avoidance of injections in sites of skin breakdown or active infection, and the use of ultrasound guidance should greatly reduce these risks.

Farooque et al. [15] reported that some patients subjectively described "bloatedness" as the abdominal wall muscles lengthened and relaxed. Few patients also subjectively reported a weaker cough and sneeze. This was aided by the use of an abdominal binder to provide support. All patients return to their normal daily activities prior to surgery. Similar to findings by Farooque et al. [15], our patient population has also anecdotally reported transient "bloatedness" as one of their more common subjective complaints.

46.5 Proposed Indications

From the available published data presented above, we propose that BTX be considered as one more tool available for the management of patients with complex abdominal wall hernias in the following situations:

(a) Patients with intractable postoperative abdominal wall pain or spasms. Consideration could be given to preoperative administration in patients with known poor pain tolerance or with significant allergies or contraindication to other pain control alternatives.
(b) Anticipated greater than expected difficulty to achieve fascial closure in the open abdomen setting after damage control laparotomy.
(c) Patients with complex abdominal wall or diaphragmatic hernias that are associated with either loss of abdominal domain and/or there is greater than average risk for postoperative abdominal compartment syndrome.

Based on the peak response rate of BTX for the abdominal wall musculature [6], patients should ideally be injected approximately 4 weeks prior to their hernia repair to obtain the maximal benefit from the chemodenervation. In the setting of an open abdomen after damage control laparotomy, patients should be injected as soon as possible after hemodynamic stability has been ensured.

We emphasize that the abovementioned proposed indications are based on results from a handful of studies with few patients and low level of quality evidence. BTX chemodenervation of the lateral abdominal wall muscle should be seen as one more tool in the toolbox of the hernia surgeon for the challenging complex hernia repair patient.

46.6 Future Directions

The use of BTX in the complex hernia patient is only in its infancy. Many questions remained unanswered. In addition to clarifying which patient population benefits the most from this tool, issues surrounding the optimal timing of administration, dosage, and method of injection remain to be clarified.

Further research should examine the cost-effectiveness of BTX in comparison with other methods of abdominal wall expansion pain such as progressive preoperative pneumoperitoneum or tissue expanders [20]. From a postoperative pain control standpoint, comparisons are needed to determine the role that BTX has with respect to alternatives such as transversus abdominous pre-peritoneal plane blocks with bupivacaine [21, 22].

Cakmak et al. [9] suggest that neonates born with gastroschisis or congenital diaphragmatic hernias could benefit from BTX chemodenervation of the abdominal wall. The resulting increase in abdominal wall compliance could allow for shorter times to fascial closure in gastroschisis, or in less intraabdominal hypertension or compartment syndrome issues in the early postoperative period after the repair of large diaphragmatic hernias. Further research should examine the safety of the administration of BTX in the neonatal population.

46.7 Conclusions

The use of botulinum toxin A for chemodenervation of the lateral abdominal wall in the treatment of complex abdominal wall hernias appears promising but further research is needed to clarify the patient population that benefits the most. Several decades of BTX clinical use in a myriad of settings support its safety. No clinically meaningful adverse events have been reported with regard to the application of BTX to the lateral abdominal wall. Caution should be undertaken prior to its widespread implementation as its incremental benefit to other abdominal wall reconstruction adjuncts has not been studied. As of now, we suggest that this technique be viewed as one more tool available in the hernia repair armamentarium.

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Hernia Repair in Undeserved Areas

47

David L. Sanders, Maarten Simons, and Pär Norden

47.1 Epidemiology

There are very few studies that accurately detail the epidemiology of inguinal hernias (IHs), in the economically developed world let alone in undeserved areas. IH incidence—measure of probability of IH occurrence in a population within a specified time—is difficult to firmly establish although it seems unlikely that incidence varies much between countries [1–6]. In contradistinction, IH prevalence—population proportion with IH at a given time—appears to be significantly higher in countries with poor healthcare access. The assumption is that most cases go untreated in resource-poor settings. The discrepancy in incidence versus repair rate results in high prevalence. This in turn has a huge economic impact on countries least able to shoulder that burden [7].

A 1996 UK study found a lifetime risk of inguinal hernia repair of 27 % for men and 3 % for women, an immense inguinal hernia disease burden [8]. Data from sub-Saharan Africa paints a very different clinical picture. A 1978 study of rural Ghanaian men estimated that 7.7 % had an inguinal hernia [9]. However, a 1969 study showed that the prevalence of IH was as high as 30 % on Pemba Island in East Africa [10].

A prospective cohort study compared inguinal hernias in Ghana and the UK and revealed that two-thirds of Ghanaian hernias extended into the scrotum. This was the case in only 7 % of UK inguinal hernias [11]. The majority of these were long-standing right-sided indirect hernias. Ghanaian subjects had an average age of 34 years versus 62 years in the UK cohort.

Inguinal hernias, occurring in the young, have a major impact on fragile economies. In the Ghanaian study, 64 % of subjects experienced daily activity limitations and 16.3 % of these individuals were unable to work.

A truly startling percentage of IH repairs are done on an emergent basis in sub-Saharan Africa—65 % in Ghana, 76 % in Uganda, 33 % in Sierra Leone, and 25 % in Nigeria [3, 12–15]. In contrast, 5 % of IH repairs are performed emergently in Sweden [16]. The consequences of this are dire. A 2007 Nigerian study reported that 20 % of emergent IH repair patients died [17].

In 2012, data from the National Health and Nutrition Examination Survey prospective cohort study of inguinal hernias were used to estimate IH disease burden in Ghana [2]. Per this approach, the inguinal hernia prevalence in the Ghanaian general population is 3.15 % (range 2.79–3.5 %). The number of symptomatic hernias was estimated at 530,082 (range 469,501–588,980). The annual incidence of symptomatic hernias was 210 per 100,000 individuals (range 186/100,000–233/100,000). It was concluded that at the estimated Ghanaian IH repair rate of 30 per 100,000, a backlog of one million hernias needing repair develops each decade. The cost of repairing all symptomatic hernias in Ghana was estimated to be 53 million USD. Hernia elimination over a 10-year period would cost 106 million USD. Nearly five million disability-adjust life years (DALYs) would be saved by the repair of prevalent cases of symptomatic hernia in Ghana. These findings are supported by another study which estimated the unmet burden of inguinal hernias in sub-Saharan Africa [18]. This study reported that the average district hospital performs 30 hernia repairs per 100,000 individuals per year (95 % CI: 18–41), leaving an unmet need of 175 per 100,000 annually.

The same model was used to estimate Tanzanian IH prevalence [1]. The prevalence of IH in Tanzanian adults was 5.36 % while an estimated 12 % of men had hernias. This equates to 683,904 Tanzanian adults with symptomatic IH. The annual incidence of IH in Tanzanian adults was 163

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_47

per 100,000 people. At Tanzania's current hernia-repair rate, a nearly one million hernia-in-need-of-repair backlog will develop over 10 years. Repair of the prevalent symptomatic hernias in Tanzania would save 4.4 million DALYs.

A 2012 study using data from the 2010 Global Burden of Disease (GBD) database quantified the burden of digestive diseases avertable by surgical care at first-level hospitals in low- and middle-income countries (LMICs) [5]. The study calculated the potential decrease in digestive disease burden if quality surgical services were universally available and accessible at first-level hospitals. It concluded that 74 % of the burden of inguinal/femoral hernias in East Europe and Central Asia was avertable.

These disparities in surgical coverage highlight issues possibly amenable to rapid improvement. In East Europe and Central Asia, for example, the excess hernia burden can likely be addressed with few additional resources. Other regions may require a comprehensive reordering of priorities and resources to address their IH burden.

In conclusion, the incidence of inguinal hernia patients in low resource settings is unacceptably high.

47.2 Operative Technique

In undeserved areas, where out-of-pocket expenditures are significant, families often cope by borrowing money or selling assets to pay for surgery. Most inguinal hernias in these settings are still repaired with the Bassini method (and many modifications) because of the high cost of mesh and the lack of training in mesh repair [3, 19–21].

Occasional exceptions have been reported. A study from Nigeria found that mesh repair was well accepted with few complications at 1-year follow-up [22]. Similarly, in rural Ghana and Uganda, mesh repair has been successfully used without significant complications [23, 24]. In India, mesh repair seems to be more common (or perhaps more commonly written about) than in other undeserved areas [25]. Laparoscopy has been introduced in India as well [26]. Nevertheless, mesh cost remains prohibitive in most undeserved areas.

Most people with inguinal hernias live in low resource settings. Many operative innovations such as laparo-endoscopic and mesh cannot be widely used in these undeserved due to cost. Solutions that provide cheaper alternatives and do not compromise the safety and effectiveness of mesh repair are needed.

47.2.1 The Use of Low-Cost Mesh

In most resource-poor countries, sutured repair—with significantly inferior results compared with mesh—is common, since commercial mesh is either unavailable or unaffordable [8, 27].

The hernia healthcare industry has developed over 200 mesh types with costs ranging from 40 to 6000 USD per piece [28]. The most commonly used macroporous polymers are polypropylene and polyester. Meshes differ marginally in their ultrastructure, filament type/construction, pore size, weight/density, tensile strength, and elasticity [28]. Commercial hernia meshes are class II medical devices and are required to undergo the Food and Drug Administration (FDA) pre-market notification process in the United States or the Medicines and Healthcare products Regulatory Agency (MHRA) or other authority approval in the UK and Europe prior to market release [29]. Clearly these approved meshes are suitable for use in undeserved but are generally unaffordable there and therefore not used.

The use of mosquito net as an alternative to commercial prosthetics was pioneered in India [30]. The first multicenter trial was performed there, using indigenous autoclaved and sterilized mosquito net mesh composed of polyethylene and polypropylene (Bangalore Mono Filaments, Bangalore, India).

The study reported a 6.9 % incidence of complications, comparable to complications seen with Prolene mesh, only one recurrence (0.27 %) and no adverse mesh reactions at up to 5-years of follow-up. More recently, a number of studies in developing countries have examined hernia repair with locally available mosquito net of various types [25, 31–37]. Mosquito nets vary in construction, but most commonly consist of cotton, polyethylene, nylon, and polyester polymers [38].

Net pore size must be less than 1.2 mm to stop mosquitoes. However many nets use a pore size of 0.6 mm in order to stop other biting insects [38]. Several studies have demonstrated that mosquito net can be implanted with low complication rates, but using the general term mosquito net to describe all meshes has potential problems.

There are legitimate concerns about infection risk, foreign body reaction, the effectiveness of sterilization procedures in low resource settings, and the safe use of locally sourced and prepared mosquito net for implantation.

A 2013 study compared the characteristics of a widely used mosquito net to other FDA- and MHRA-approved commercial meshes [39]. The tested mosquito net was a low-density polyethylene homo-polymer (LDPE), knitted from monofilament fibers, the mean pore diameter was 1.9 mm, with a 91.2 % porosity, 53.7 g/m^2 mean mesh weight, and linear mass density of 152 denier, comparable to the "large pore" (class I) commercial meshes. The bursting force for polyethylene mosquito net was greater than that for UltraPro and Vypro (43.0 vs. 35.5 and 27.2 N/cm, respectively). The mosquito net exhibited less anisotropy when compared with commercial meshes.

A randomized trial of nylon mosquito net versus commercial mesh in 40 IH patients from Burkina Faso found no difference in short-term, 30-day follow-up, outcomes [36].

A 10-year retrospective analysis was done of consecutive patients who underwent a total of 651 IH LDPE net repairs and were followed up for a mean of 15 months. Thirty-two patients

were lost to follow-up. Six superficial surgical site infections occurred (0.9 %), as did one seroma (0.1 %), and two hematomas (0.3 %). Two patients reported chronic pain (0.3 %). No recurrences or mesh rejections were reported. The LDPE net was less than 0.03 % the cost of commercial mesh [25].

When mosquito net is used, tension-free IH repair is approximately one-third the cost of repair with a conventional alternative [34, 40, 41]. This finding is supported by a meta-analysis, which also found no increase in septic complications or recurrences [42].

A recently published RCT comparing LDPE mesh with commercial mesh including 302 male patients concluded that there was no significant difference in recurrence or complication rates [24].

Net steam sterilization at 121 °C has been recommended but long-term follow-up data confirming sterility is lacking. Most of the currently used LDPE net is sterilized with ethylene oxide [23].

Cost-effectiveness analyses have estimated the overall cost associated with mesh repair to be 12.88 USD per DALY averted (assuming 120.02 USD/hernia repair and 9.3 DALYs averted/person) [7, 40]. Based on this figure, hernia repair using low-cost mesh is a more cost-effective intervention than oral dehydration or at-home HIV/AIDS treatment with antiretroviral therapy [43].

Before universal acceptance of mosquito net for IH repair can be achieved however, careful audit and follow-up studies are required, which may be difficult to do in undeserved areas.

47.2.2 Logistics and Education

The challenge for hernia surgery in undeserved areas is to integrate the organizational structure of surgical care into the larger healthcare system [4]. The healthcare systems in low- to middle-income settings have variations in the range of services offered between hospitals in the same country [44]. The most important factor to account for is hospital functioning. Studies have shown that properly functioning small hospitals and health centers in rural areas can deliver effective basic low-cost surgical services [45, 46]. However, many of them suffer from a lack of trained staff, equipment, and integration of service delivery [47]. A well-functioning hospital offering a narrow range of vital surgical services can be part of an integrated model of healthcare delivery. Integration aims to improve the service in relation to efficiency and quality, thereby maximizing use of resources and opportunities [48]. The benefit of integration has been demonstrated in several settings [49].

Health practitioners should have appropriate surgical and anesthetic equipment and supplies. It is important for hospitals to be able to administer appropriate anesthesia, whether local (LA), spinal, general (GA) or with tracheal intubation [46].

A meta-analysis demonstrated a striking disparity between anesthesia-related mortality in LRSs when compared with high-income countries [50]. Factors contributing to this disparity included: few qualified anesthetists, lack of appropriate training, limited supplies for safe patient monitoring, and limited supplies for the safe administration of anesthesia [51].

Adequate surgical training of practitioners and the use of LA permit the vast majority of IH repairs to be done in undeserved areas. Studies have shown that IH repairs with LA allow return to normal activity a day earlier than GA, important in LRSs [52]. Local anesthesia costs significantly less than spinal anesthesia and GA, another advantage in undeserved areas [44].

Given these limitations and the inherently higher risk of GA, it is recommended that groin hernia repairs in LRSs be performed under LA.

Several strategies can be used to overcome the logistical challenge of cost. Surgical instrument packs and other materials can be bought at a discount from nonprofit organizations. Healthcare facilities and manufacturers can donate these materials close to their expiration dates [53]. If medical personnel and equipment are in short supply, short-term surgical missions by charitable organization can help reinforce the existing infrastructure. Sanitary mobile surgical platforms can be used in environments lacking modern sterile facilities. While short-term surgical missions have been promoted as a method of alleviating disease burden, the best way for charitable organizations to support surgical care in undeserved areas is through partnerships with local hernia societies and health practitioners [54]. Teaching and training local teams should be performed next to alleviate the waiting list. A partnership of this type is occurring presently in Ghana with Operation Hernia http://www.operationhernia.org.uk/ and Hernia International http://herniainternational.org.uk. The effectiveness should particularly be evaluated in respect to the retention of surgical skills of the newly trained staff, to improvements in outcomes, and to the retention, in-country, of local healthcare providers [54].

A sustainable model to improve hernia surgery in undeserved areas requires a national commitment to providing access to surgical services, especially in rural areas, and to adequately training practitioners. Safe, effective, accessible, and cost-effective surgical services must be available to meet needs in underserved areas [55].

A lack of skilled healthcare personnel exacerbates this access problem. In sub-Saharan Africa, for example, most surgical and anesthesia services are provided by general physicians or nonphysician clinicians rather than specialists. Strategies to provide education, training, and resources and reorder priorities are necessary.

Many surgical skill educational programs exist but are not especially focused on hernia surgery. It is known that continuing education improves patient safety. A conceptual hernia surgery education program could focus on three groups of surgeons.

- Surgeons needing focused training and skill development
  - Hernia societies can create a hernia surgery certificate program whereby surgeons receive a certificate of completion/competence after finishing a supervised course of study and demonstrate competent performance of a series of IH repair skills.
- Healthcare provider continuous education and skills training
  - Open to surgeons and all others involved in IH patient care activities
  - May involve periodic visits from referral hospital personnel, telemedicine, review of educational materials
  - On-site support and training in hernia surgery by surgeon specialists from referral hospitals to outlying facilities
- Operators/surgeons in outlying hospitals
  - Can be visited on a rotating or as-needed basis by hernia specialists in a series of "surgical camps"

Few studies have evaluated the impact of short international training trips on the practice of local physicians following training trip participation. One study conducted in Ghana and Liberia reported on a 2-day surgical training course on tension-free mesh repair performed in a resource-limited setting. It also looked at the course's impact on local surgical practice. It concluded that a brief training course can significantly improve local practice. Operation Hernia is a UK-registered charity initiative involving the EHS and the Plymouth-Takoradi (Ghana) Hospital, which trains, and teaches hernia surgery, in Africa. It sends volunteer teams to work alongside African surgeons, training them in local anesthetic administration and guiding/mentoring during hernia operations. Teams operate on a large volume of cases in a short time, often in two theatres simultaneously [4, 56].

When deciding which surgical services to offer facility capabilities and infrastructure must be considered. A well-equipped facility is necessary to support a strong education program in undeserved areas. According to the WHO Safe Surgery Initiative, operating theatres must be of adequate size, have appropriate lighting and have dependable electricity and water at a minimum [55].

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Social Media and Education in Hernia Repair

48

Erin R. Bresnahan, Desmond T.K. Huynh, and Brian Jacob

48.1 Introduction

The International Hernia Collaboration (IHC) is currently a private vetted-membership Facebook™ group of surgeons, healthcare providers, and industry representatives who are passionately interested in the repair of hernia and optimizing outcomes. The first 3 years have taught us clearly that by embracing closed Facebook™ groups as collaborative forums designed to provide quality improvement, we can more effectively and transparently obtain immediate global feedback that will improve both patient outcomes and the quality of care that surgeons provide to their patients. Groups like this one will help disrupt and evolve the current standards being used today to provide ongoing healthcare education and quality improvement.

48.2 Social Media: Background

Social media can be defined as any online venue which allows communication amongst groups of individuals through the use of text, images, audio, video, or live broadcasting. Another name commonly used is "user generated content" (UGC), which on social media is easily created, disseminated, and accessed by members of the group. A 2014 study by the Pew Research Center showed that 74% of all online adults used some social networking platform [1]. The most popular of these platforms is Facebook™, with 1.59 billion monthly active users [1].

The Facebook™ platform is continuously evolving, and adoption of Facebook™ "pages" has been used by businesses for years. In healthcare, the networking function of Facebook™ has already been employed by academic and private practices to connect with patients to augment consultation and collaboration, aid in patient education, increase visibility of particular diseases, and publicize new research findings and best-practice guidelines [2]. Similarly, it has been harnessed by major medical journals to increase awareness of their publications. More recently, Facebook "groups," which enable a community of users to privatize content, have been growing in popularity.

Groups provide a number of features that facilitate discussion amongst members, ranging from the standard text, image, and video posts to group polls, file sharing, and sharing of events. Additionally, a group's contents may be privatized by restricting access to the group; the content of these "closed" groups is accessible only by members who must first be approved by a group administrator. Facebook™ groups are an ideal forum for medical discussion because of these features and the fact that many physicians are already using the platform on a daily basis. Research on the use of Facebook™ groups for medical education has been mostly qualitative and focused on students' or physicians' perceptions, describing the patterns and modes of use, and online professionalism. There is an emphasis in the literature on the need for more rigorously controlled studies to demonstrate a proven effect of Facebook usage on improved clinical or educational outcomes.

While some may critique the use of social media by physicians [3], when used professionally it has been suggested to be a powerful tool. A number of studies cite positive physician and student experiences with Facebook™ as a learning tool, but often with open Facebook™ groups or pages used mostly for disseminating information [4–9]. Here we will describe the experience of "The International Hernia Collaboration," a closed Facebook™ group dedicated to the discussion of specific patient cases in a protected environment, which may serve as a model to explore the benefits of social media in the medical community.

48.3 International Hernia Collaboration

The International Hernia Collaboration was established in December 2012 by Dr. Brian P. Jacob of New York City, as a community of hernia surgeons around the world. The goal of

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_48

the group was to facilitate discussion about all things related to hernias; to enable physicians to ask for advice, discuss risks and benefits of different strategies and practices, debate the merits of new findings in the field, and disseminate information instantaneously to the global hernia surgery community. As a closed group, only vetted and approved members have access to create and view this content. Additionally, posts are required to have any identifying information removed unless the patient has given express permission for their information to be shared with the forum. Posts that are unprofessional or that violate USA Health Insurance Portability and Accountability Act (HIPAA) compliance laws are deleted.

As of March 2016, membership has grown to 2105 members, with users being a mix of attending physicians, residents, medical students, and industry members. At any given day, there are over 300 surgeons in the vetting queue process, and an average of four to six new requests to join arrive daily. The administration is selective to admissions, the goal being to optimize the quality and value of the discussions. The members represent over 63 different countries, with the vast majority of users being concentrated in the USA. There remains a noticeable limited growth in many European countries, with faster adoption in South America, Latin America, and Australia. Over the past year, there has been an average of 124 posts per month, and 25 comments per post. There are a total of over 3500 posts in the forum, which can currently be searched through with keywords by group members. Engagement is high, with 95.7 % of posts being responded to, and both membership and group engagement have drastically increased since the creation of the group, as seen in Figs. 48.1 and 48.2.

Figure 48.3 shows the distribution of post types since the IHC's creation. Patient case presentations make up the majority of posts in the group, with a focus on preoperative, intraoperative, and postoperative decision-making. The format typically includes the history of present illness for a patient with a hernia or hernia-related complication, and an accompanying image modality when appropriate. The multimedia capabilities of the Facebook™ platform enable doctors to upload many types of medical imaging (CT scan, PET, MRI), photographs (of hernias, wounds, explanted meshes), and videos of the operative procedure. Most recently, live broadcasting capabilities were launched, opening a whole new paradigm of sharing capabilities from mobile devices. Posts are typically formulated by asking the group "what would you do" (#WWYD) in a given case. The physicians posting these cases will ask for input about surgical management, approach, technique, selection of materials, consideration of comorbidities and past surgical history, or management of postoperative complication. Additionally, some patient case presentations or videos are posted retrospectively, either for educational purposes or to ask for critiques. The group will offer suggestions for how they would handle the case, supporting their opinions with personal experience and references to literature (Fig. 48.4). Several topics in particular regularly arise in the setting of new posts and continued discussion of previous cases: postherniorrhaphy inguinodynia, the operational caveats associated with obesity, wound infection management, and the merits of the robotic platform for repairs are among a few.

General questions not related to a specific patient case are also common, for example, an inquiry about the group's experience with a particular mesh, optimal set up of laparoscopic or robotic ports, billing code confusions, how to negotiate with insurance companies, and more. Purely educational posts are also common—often, members sharing recently published literature or articles in the field and starting a critique of the works and analysis of the benefits of the research for physicians and patients. There are also recurring informational series posted to share expertise on various matters and encourage learning through discussion and observation. One such initiative, "Tips for TEPs," is posted regularly by Dr. Jorge Daes of Columbia as a compilation of recommendations associated with how to best perform the TEP technique, along with videos demonstrating surgical maneuvers physicians have had success with and notes about what to avoid.

> TIPs for TEPs part 6- Special Edition
> Mesh use and Fixation: a Collaborative
> We are pleased to present our first IHC collaborative video to our members. Prominent members of IHC joined efforts to present different ways to place and fix meshes during hernia repair. Maestro ******* will share his vast experience on fibrin sealants and an interesting historic perspective. IHC founder ********** will discuss his experience and publications on the use of the self-gripping mesh. World renowned surgeon ********** will share his 15-year experience (more than 2000 cases) with the use of cyanoacrylates. I will share some of our tips on the introduction, unfurling and positioning of meshes as well as details on safe tack fixation and the option of not fixing meshes.—2/1/15, 27 likes, 37 comments

An additional series, "Every step of the way," is a variation on an educational case presentation in which the clinical picture and management is presented one step at a time. Members are able to discuss and debate what should be done and ask questions about each step before what was done next is shown. These posts follow the patients from preoperative decision-making, through their operation, to postoperative management of any complications, and long-term follow-up with assessment of outcomes. Rather than giving a summary of what was done, this allows physicians and residents to think and work through the steps themselves as they would in an actual clinical scenario, facilitating more active learning.

This Facebook™ group is a model for how social media can be used as a valuable tool in continuing medical education, particularly by enabling interactive learning in real time and providing access to experiences of experts in multiple

Fig. 48.1 Number of active IHC members per month. An active member is defined as one who has posted, commented, or liked a post

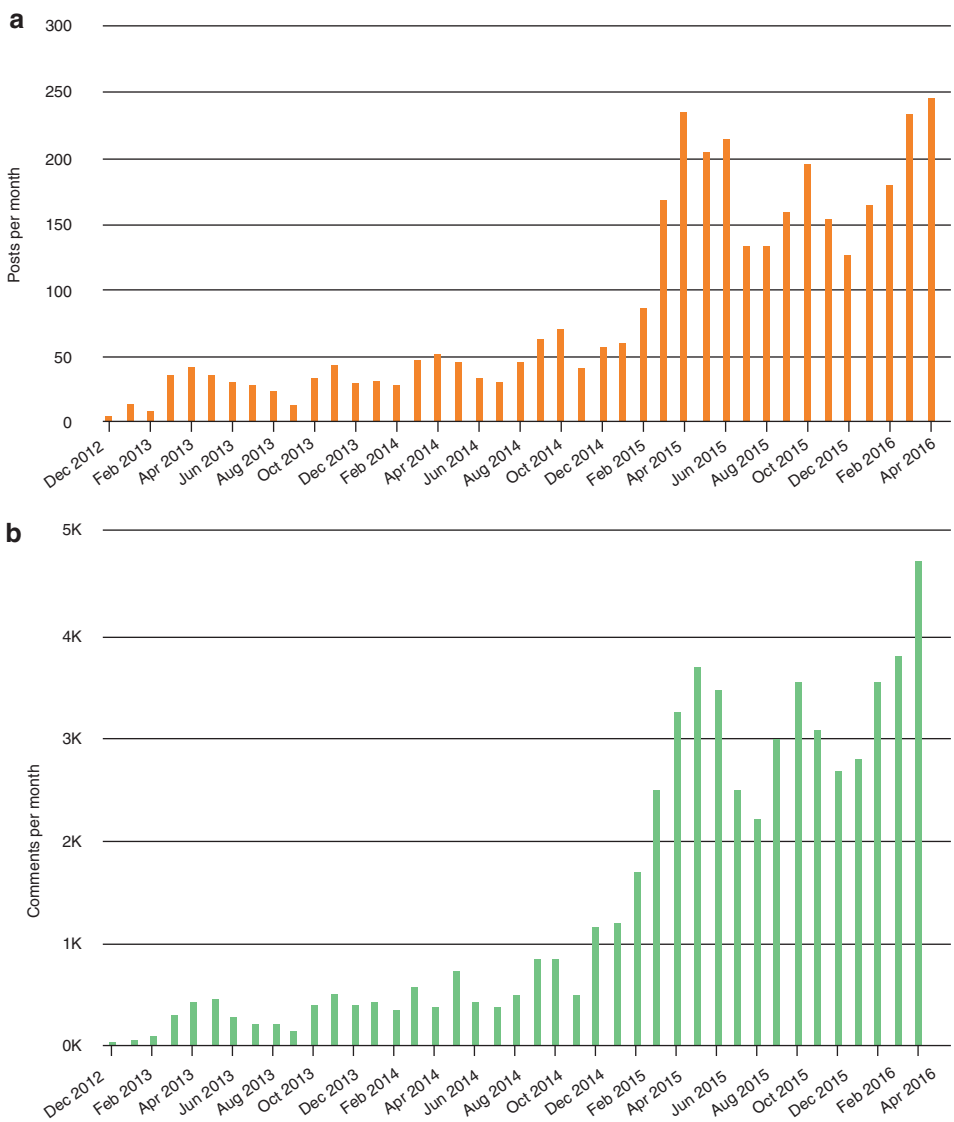


Fig. 48.2 (**a**) Number of IHC posts by month. (**b**) Number of IHC comments by month

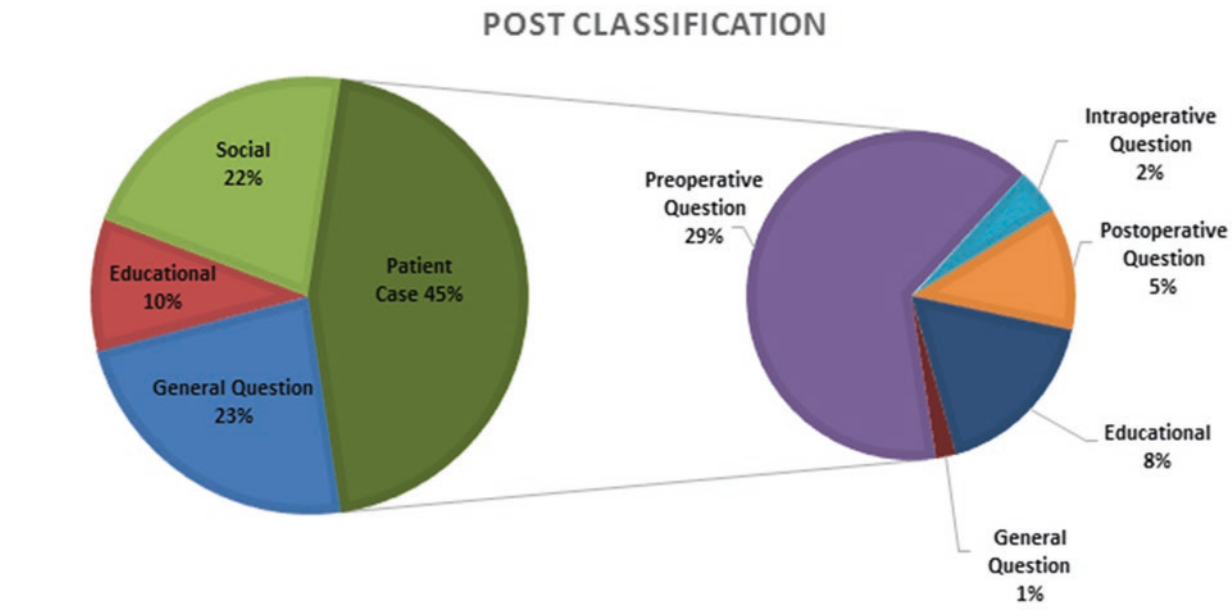


Fig. 48.3 IHC Post classifications (cases, educational, informational, social)

Fig. 48.4 Example of patient case presentation from the IHC

subspecialties. The forum has direct applicability to clinical practice and patient outcome improvement, and the opportunity for feedback. It also promotes awareness of differing resources and practices around the world, the enhancement of research potential, and interdisciplinary collaboration.

48.4 Interactive Learning

Many investigations into ways to improve continuing medical education (CME) courses highlight moving away from a lecture-based framework and fostering a more interactive and collaborative learning environment. The social aspects of learning and the improved cognitive processing which is known to occur when knowledge is imparted in a more social context are becoming more widely discussed in the age of social media and increasing global interconnectivity [10]. Some of the top critiques physicians have for CME programs are that they lack interactivity and that the material being taught is inapplicable to their clinical practice [11].

A qualitative study looking at the European Workshop of Advanced Plastic Surgery (EWAPS), a forum that meets yearly for the discussion of new developments in their field and continuing education, investigated factors which might contribute to improving CME program effectiveness [10]. EWAPS meetings are closed, meaning that only members could attend, and physicians had to be invited by the board to become a member. Members came from different countries and had varying levels of experience in plastic surgery. Interviews with participants revealed that the environment of trusted colleagues whom they got to know year after year through the forum enabled them to feel more comfortable having an open discussion where people were willing to expose their weaknesses with the understanding that they would not be judged, but rather given advice to improve. Also cited by the participants as a positive, learning-promoting aspect of the EWAPS meetings was the format of presentations in which speakers gave a prompting presentation of no more than 3 min, with a 12-min discussion following [10]. The emphasis on interactive processing of information and collaborative dissection of meaning engaged participants, keeping their interest and attention.

The International Hernia Collaboration, and similar closed-group forums for physicians, enables a continuous interactive environment in which this type of learning can take place. Numerous physicians who use the site frequently have referred to the other members as their "IHC family," and note feeling very comfortable sharing difficulties they encounter in their practice without fear of critique. Many physicians have begun to post videos of their operations, including those which may have resulted in a recurrence or other complication, asking for feedback and critique from more senior members; one member posted the following:

> I have been part of IHC now for the past 6 months. This site is a goldmine of information, in this short time I have learned a tremendous amount from my peers. Here is a recent lap bilateral inguinal hernia case in a 65 year-old male, the video is 13 minutes and double speed. Perhaps at their convenience … others can give me a "no holding back" critique. As I reviewed this video myself I wonder now if I should be using larger meshes-this is a 10 × 15 cm implants, I also would like to know if you feel like I have developed appropriate critical view. I guess one of the topics to discuss is when do you stop or know that the critical dissection is complete. I sincerely appreciate the time you take to review this. Thank you.—12/13/15, 87 responses

The nature of the majority of posts establishes an environment focused on case-based and problem-based learning, in which discussion is emphasized above all else. The posts which are educational or designed to transmit knowledge or experience, rather than ask a question, are usually followed by a critical reflection on the imparted wisdom, making the transmission of knowledge less similar to "lecture"-style instruction methods, and more encompassing of self-directed and peer-based learning.

48.5 Access to Collective Experience in Real Time

When physicians have questions or a difficult case, they usually consult information in medical resources—textbooks, literature reviews, sources like UpToDate™. This lacks the benefit of being interactive; one cannot ask specific questions in which the source will take into account all the specific parameters of the case at the same time. The IHC connects users with thousands of physicians around the world who may have many more years of experience with particular techniques, chronic groin pain, postoperative infection management, etc. Drawing on the experience of others who have logged similar cases focuses the discussion on the evidence most relevant to the case. Members who practice in rural settings or areas where physician resources are more limited have spoken out about how helpful the group has been to them.

The "real-time" aspect of the forum can be understood with an example of a case which was presented around 8:30 PM asking for immediate responses to help out with a hernia patient who presented to the emergency room. This generated numerous responses the same day, which the physician was able to incorporate into her intraoperative decision-making process. Instantaneous access to a huge knowledge base at all hours of the day enables physicians to connect with valuable resources when they might have otherwise had few to turn to for rapid answers to questions. This is particularly salient in light of patients with rare conditions or situations. Although a given physician may only have seen one or two cases in their lifetime of a given rare condition, the collective experience of many can be used to generate a

foundation for recognizing and successfully managing those cases when they do show up.

Many physicians in the forum have noted they made significant changes to their standard practices due to concepts they learned from discussions in the group. Additionally, some have described their practice changes as a conglomerate of the input of multiple colleagues' tips and techniques; as one member posted,

> Let me present a case my partner ******* and I did today as an example of how the IHC has influenced our practice. 45 y/o male large midline incisional hernia and hernia at colostomy site in L mid quadrant. 25 × 34 cm defect, Open bilateral TAR from well above costal margin to coopers, taking down and using hernia sac as part of the posterior closure, lateral to medial dissection in TAR plane (Thanks ******), incorporate interrupted permanent sutures in posterior fascia and anterior fascia and skin and suture giant mesh together (Thanks *******,******, *****, and ********). Glue for mesh (thanks *****). Thanks ********* for the IHC. Pictures to follow.—1/23/15, 51 comments

48.6 Research and Quality Improvement Potential

The IHC can also be used to help promote quality and research initiatives across hospital, state, and national boundaries to generate more generalizable and strong conclusions. The American Hernia Society Quality Collaborative (AHSQC) program was advertised to members through the forum, and there were a number of posts in which members praised the program and detailed their positive experience with it. Multiple members stated that they joined this quality initiative mainly due to the fact that their peers on the forum recommended it and convinced them of the need and benefit. Usage of the forum to bring physicians together to collaborate on a study will vastly increase the quality of conclusions that can be made from research.

Additionally, physicians are able to disseminate relevant findings more easily to a wide audience, either after or before publication. The authors can be quickly and directly asked questions about their work, with a much more interactive and transparent experience than the current formal journal submission review process. More can be discovered about the strengths and weaknesses of a study, as well as how to design future research, through an open discussion.

48.7 Interdisciplinary Collaboration

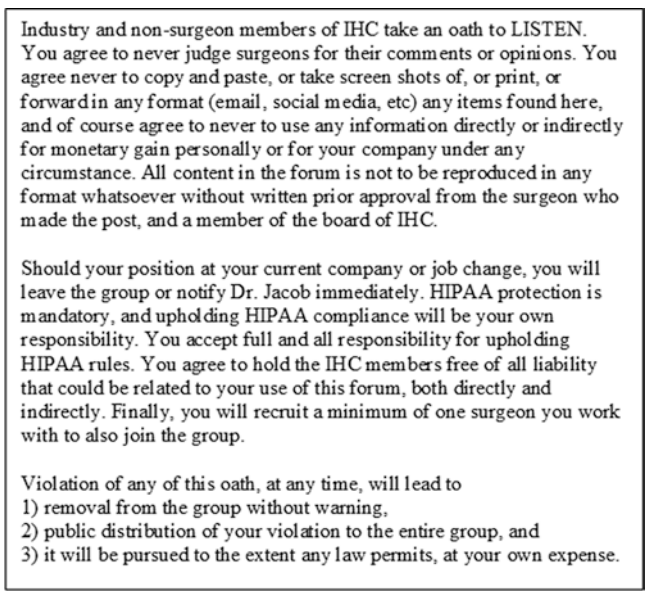
In addition to providing a route for increased research development, Facebook™ forums can provide interdisciplinary connections between physicians and industry members. Collaboration with industry in terms of the group was somewhat controversial—an agreement was made that industry members would only be able to join the group if a physician member "vouched" for them, and they signed the "IHC Oath" (Fig. 48.5). Their status as an industry employee must be clearly stated on their profile, and they are not permitted to comment in a discussion unless their opinion is specifically asked for. This allows the industry to collect valuable data about unmet demands, as well as how to change their current products to better suit the needs of the field.

One post stated:

> With some heavy hitters (expert surgeons and management) at Intuitive HQ discussing many issues. What changes would you like to see i.e. training pathway, company approach, mentorship, instrumentation etc.?—6/29/15, 33 comments

In the comments, physicians were able to voice their opinions about what was needed in the emerging field of robotic hernia surgery:

> 1) ensure a culture of safety that pervades all they do and say. In other words, always have the patients best interest at heart even if it means not using the robot. 2) provide and support unbiased, evidence-based education not only for surgeons with immediate ROI but for fellows and residents as well. Invest in education for the future. 3) marketing is important from a corporate standpoint, but perhaps there is a way to ensure that marketing is evidence-based and the evidence is what is highlighted.
> Manufacture cheaper robots for third world countries
> Set aside money for competitive investigator-initiated research grants so we can study robotics techniques and outcomes.
> Having said that, mentorship is something intuitive has struggled with. With robotics emerging at society level (CRSA, SRS, etc.) and other educational FB groups (Robotics Surgery Collaboration), this challenge is beginning to be addressed.
> I do robotics but time on the robot is restricted and until it becomes a tool that can be accessed as easily as a retractor, it



Industry and non-surgeon members of IHC take an oath to LISTEN. You agree to never judge surgeons for their comments or opinions. You agree never to copy and paste, or take screen shots of, or print, or forward in any format (email, social media, etc) any items found here, and of course agree to never to use any information directly or indirectly for monetary gain personally or for your company under any circumstance. All content in the forum is not to be reproduced in any format whatsoever without written prior approval from the surgeon who made the post, and a member of the board of IHC.

Should your position at your current company or job change, you will leave the group or notify Dr. Jacob immediately. HIPAA protection is mandatory, and upholding HIPAA compliance will be your own responsibility. You accept full and all responsibility for upholding HIPAA rules. You agree to hold the IHC members free of all liability that could be related to your use of this forum, both directly and indirectly. Finally, you will recruit a minimum of one surgeon you work with to also join the group.

Violation of any of this oath, at any time, will lead to
1) removal from the group without warning,
2) public distribution of your violation to the entire group, and
3) it will be pursued to the extent any law permits, at your own expense.

Fig. 48.5 IHC Oath for industry/non-surgeon personnel who wish to join the forum

> will be slow to be accepted and used. I am a devotee but the struggle for access is tiring.
> Mentorship is the way to move forward. I think the company have quality accessible surgeons who are willing to teach. Should be regionalized with the epicenters mentoring in their region. Then eventually have local guy at each hospital. Once taught and through their learning curve, partners can teach each other. Etc, etc. This can be done with industry (mesh, robot) working with societies (SAGES, ACS, IHC, CRSA). I agree with ********* that it needs to be done safely and MIS surgeons should be targeted first who will more quickly adopt this MIS approach. No reason industry and societies can't work together for the greater good.

Seeing the failure and success stories of different products will enable those in industry to make changes and improve. Assessment of physician attitudes towards new technology or materials, techniques, etc. through discussions on the forum, rather than the formal surveys which are often employed, could bring out broader opinions than those offered in multiple choice, preselected answer choices. A discussion about the pros and cons of a new technology or product—more like a focus group—can generate both qualitative data and quantitative data. The distribution of opinions (i.e., mostly positive or mostly negative) can be analyzed across different regions, different hospital/patient population types, physician age or experience level, etc. Additionally one can gain insight into why a particular technology is not being adopted in a certain location—i.e., hospital policy, physician reluctance, lack of advertising or awareness, etc.—without the time and money required for focus groups.

In addition to enabling collaboration with medical industry members, the IHC has enabled discussion of translational research through consultation between surgeons and basic scientists. In a recent post, members gave feedback to a bioengineer testing physical properties of meshes as to what studies would be of the most help to their field:

> I am a bioengineer at **********. We have developed a new biomechanical test method for hernia grafts that we think is more clinically-relevant than the conventional tests. In essence, we test the grafts as sutured patch-shaped constructs (as opposed to clamped specimens) to model in vivo loading. We found that the graft-fixation method and test mode (ball-burst or planar-biaxial) affect graft biomechanics. I now have a summer student and I am planning to have him test a few more meshes to generate some comparative data that would be of potential interest to hernia surgeons. I'd to get a feel from this group what meshes (synthetic and biologic) would you want to know more about. Thank you!—6/12/15, 13 comments

48.8 Conclusion

Social media is a rapidly growing means of networking and communication amongst medical professionals, and has potential as a forum for discussion, transmission of knowledge, and continuing medical education. The International Hernia Collaboration Facebook™ Group has revolutionized the way surgeons collaborate globally. By embracing social media as a collaborative forum designed to provide quality improvement, surgeons are more effectively and transparently obtaining immediate global feedback that in turn is improving both patient outcomes and the quality of care that surgeons provide to their patients. We have witnessed the beginning of the disruption and evolution of the current standards being used today to provide ongoing healthcare education and quality improvement. Dozens of new medical and surgical Facebook™ groups and other social media collaboratives have since begun and continue to grow. Just scratching the surface, collaboration and education through user generated social media sites is just the beginning of a paradigm shift in ongoing quality improvement efforts.

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Robotic Ventral Hernia Repair

49

Jeremy A. Warren and A.M. Carbonell

49.1 Introduction

The optimal surgical approach for the repair of ventral incisional hernias remains a subject of considerable debate. Use of a minimally invasive or open approach, combined with a variety of mesh choices, positions in the abdominal wall, and fixation constructs, produces numerous options for repair and makes direct comparisons impossible. The Rives-Stoppa technique is widely considered the gold standard for open VHR, and is our preferred open technique. This is performed by incising the posterior rectus sheath in order to enter the retrorectus plane, dissecting the posterior rectus fascia from the overlying muscle laterally until the semilunar line is reached, followed by complete closure of the posterior fascia, placement of mesh behind the rectus muscle over the closed posterior fascia, and reapproximation of the anterior fascia. Advantages of this approach include placement of mesh in a well-vascularized, contained compartment separate from the viscera, and restoration of native functional anatomy. However, wound morbidity remains problematic, and mesh selection varies widely. While wound complications are significantly decreased with laparoscopy, this approach requires intraperitoneal placement of mesh, and is limited in its ability to restore the functional anatomy of the abdominal wall. The long-term outcomes of intraperitoneal mesh are poorly studied. Despite multiple available barrier coatings designed to prevent adhesions, subsequent abdominal operations are necessary in up to 25 % of patients, and the presence of intraperitoneal mesh increases the complexity of those operations and creates a higher risk of secondary mesh complications. Reoperation is associated with longer operative times, potential for secondary mesh infection, and incidence of enterotomy or unplanned bowel resection in as many as 20 % of cases [1–4]. Our technique for robotic retromuscular VHR (rRMVHR) utilizes the robotic platform to replicate the open retromuscular hernia repair with a minimally invasive approach, conferring the benefits of both the traditional Rives-Stoppa repair with those of laparoscopy, while minimizing the negatives of each approach [5].

49.2 Overview of Current Literature

The use of the robot for ventral hernia repair was first reported in 2003. Ballantyne reported two patients with small defects repaired telerobotically using a standard intraperitoneal placement of mesh [6]. Using a porcine model, Schluender also described the technique for intraperitoneal mesh repair, focusing on intracorporeal suturing of the mesh to the abdominal wall as a means of potentially reducing postoperative pain associated with traditional tacking devices and transfascial sutures used to secure mesh during laparoscopic VHR [7]. There has been very limited adoption of this technique since these initial descriptions, however, with only a handful of small case series published. The first series reporting outcomes of rVHR included 11 patients repaired with intraperitoneal mesh placement and exclusive intracorporeal suturing of the mesh [8]. Three complications occurred (27 %), including a trocar site hernia, postoperative ileus, and unrecognized enterotomy. In 2012, Allison et al. reported a series of 13 patients with a similar technique, with routine closure of the hernia defect intracorporeally followed by intraperitoneal mesh placement [9]. One patient developed a recurrence, one had postoperative urinary retention, and two had prolonged hospitalizations for pain control. The largest series published to date reports a hybrid laparoscopic-robotic approach comparing 67 patients repaired using a totally laparoscopic approach to 67 patients whose hernia defect was closed robotically. In all cases, mesh was placed

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_49

intraperitoneally and secured with tacks, followed by either transabdominal sutures in the laparoscopic non-closure group, or with intracorporeally placed sutures to the abdominal wall in the robotic group. Overall, there was no difference between groups other than longer operative time required for defect closure, though there was a trend toward lower complications and recurrences when robotic defect closure was performed [10]. Robotic preperitoneal repair was performed in three patients reported by Sugiyama et al. with no complications in short term follow-up [11]. Finally, Abdallah et al. reported the first use of the robot to perform a retromuscular hernia repair in five patients with small hernia defects associated with diastasis rectus. This approach involved a suprapubic docking position and transabdominal trocar placement, with dissection of the posterior rectus sheath from the overlying rectus muscle, similar to the Rives-Stoppa repair [12]. The report of this novel approach, which allows replication of an open retromuscular VHR with a minimally invasive approach, had a significant impact on the development of our current technique.

49.3 Patient Selection

Though literature is currently sparse on robotic hernia repair, the well-recognized benefits of minimally invasive surgery in patients at high risk for wound complications, such as the morbidly obese, smokers, and diabetics, are applicable to rVHR. There are limitations to this approach, however. Patients with poor skin and soft tissue integrity, such as those with a prior skin graft, a widened scar from previous wound complications, chronic wounds, or poor cosmesis will likely still require an open repair. Defect size and the compliance of the abdominal wall, best assessed by physical exam, are important to determine if the defect can be closed robotically. The largest total defect closed in our series was 20 cm, which involved both a midline and lateral hernia defect; the largest single defect closed was 15 cm. Defects larger than 8 cm require a double-dock approach with bilateral transversus abdominis release (TAR) as described below. For smaller defects, typically less than 5 cm, a single-dock preperitoneal approach is preferred, as there is less tension on the defect closure and myofascial release is not usually required. Mid-sized defects, typically up to 8 cm, are approached with a single-dock retromuscular technique. This avoids an unnecessary TAR for a small to moderate sized defect, but still affords a myofascial release to more easily reapproximate the anterior fascial defect. These are very general guidelines, and the ultimate decision on which approach will be used is typically made in the operating room after initial abdominal insufflation, when the true extent of the hernia defect can be assessed.

49.4 Surgical Technique

As with any novel surgical technique, ours has evolved with increased experience. Given the heterogeneous morphology of hernias, one approach does not necessarily fit every hernia. Defect size, location, and patient body habitus all play a role in the setup and execution of robotic hernia repair. Our initial experience emulated the setup described by Abdallah, docking the robot in the upper or lower midline to approach hernias in the opposite extreme of the abdomen. In order to apply this approach to infraumbilical defects, a lateral dock was necessary. However, management of the dissected posterior sheath flaps, docking from both sides of the abdomen separately, and working against the tension of pneumoperitoneum were barriers to broader applicability of the robot to VHR. To address these differences in hernia characteristics and the technical difficulties encountered, our technique has progressed to include four separate approaches, each tailored to the patient and hernia characteristics, and each adhering to the same principles of the Rives-Stoppa retromuscular hernia repair.

49.5 Double-Dock Approach

The patient is placed in a supine position with arms out. The operative table is flexed slightly to open the angle between the iliac crest and costal margin, and positioned at approximately 45° from anesthesia to allow the robot access to the left side of the patient for docking (Fig. 49.1). Intraperitoneal access is obtained using a 5 mm optical viewing trocar at the right subcostal space. Pneumoperitoneum is established at 15 mmHg of carbon dioxide (CO_2) and a long 12 mm optical trocar is placed midway between the costal margin and iliac crest as laterally as possible, typically along the mid-axillary line. A balloon tipped trocar is useful to avoid retraction of the trocar into the abdominal wall or subcutaneous space. Two long 8 × 160 mm robotic trocars are placed at the costal margin and over the iliac crest, the subcostal one typically replacing the initial optical entry 5 mm trocar (Fig. 49.2a). The longer 160 mm trocars are used regardless of the size of the patient, as this provides additional clearance of the robotic arms away from the patient, and allows greater flexibility for advancing the robotic instruments into the extremes of the abdominal cavity. The robot is docked with the center column of the patient cart aligned with the hip or upper thigh (Fig. 49.2b, c). This allows more space between the robot and the patient arm for the bedside assistant.

After completing any necessary adhesiolysis, the retromuscular dissection is initiated by incising the posterior rectus sheath about 5 mm lateral to the linea alba, typically

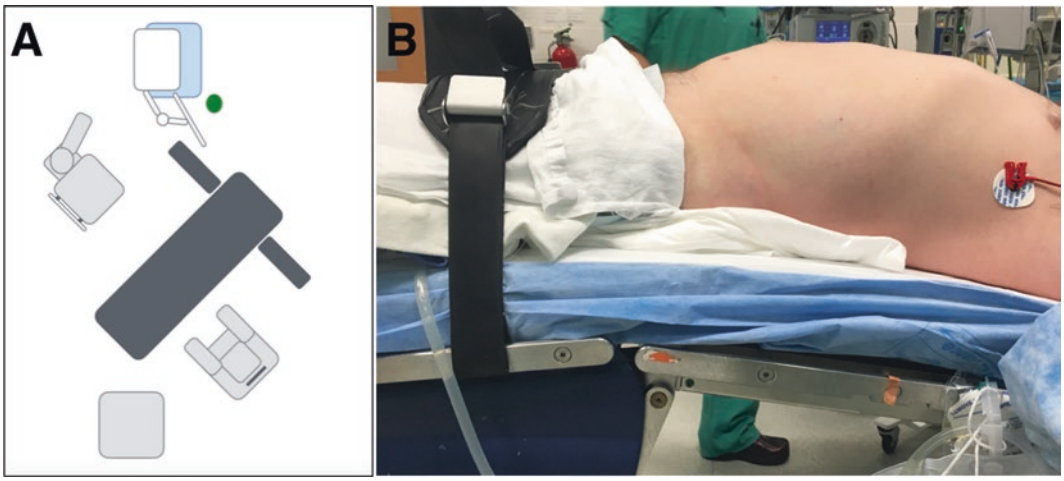

Fig. 49.1 Operative setup for rVHR. (**a**) Operative table turned 45° from anesthesia cart, with laparoscopic tower on the patients' *right*, the robotic patient cart on the patients' *left*, and robotic vision cart at the *feet*. (**b**) Bed flexes to open angle between costal margin and iliac crest

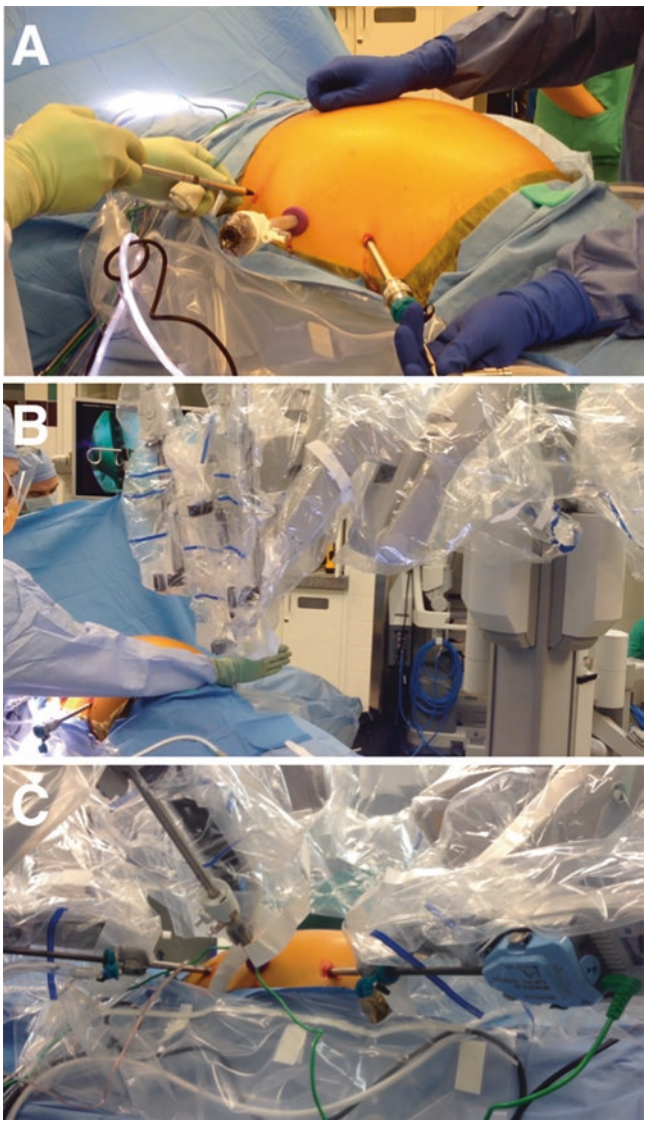

Fig. 49.2 Trocar placement and docking for rVHR. (**a**) Trocars placed laterally. (**b**) Center column of robotic cart aligned over the patients' hip. (**c**) Docked in standard fashion

beginning within the bounds of the hernia defect. The retromuscular plane is developed laterally to the linea semilunaris and vertically at least 5 cm above and below the hernia defect (Fig. 49.3). The linea semilunaris can be identified by the segmental neurovascular bundles that penetrate the lateral posterior sheath to innervate the rectus muscle. They course laterally between the internal oblique muscle anteriorly and the transversus abdominis muscle posteriorly, and are a critical landmark when initiating the transversus abdominis release. Additionally, the insertion of the obliques onto the lateral rectus sheath can be visualized as a dense fascial condensation lateral to the neurovascular bundles, and will distract the rectus muscle downward when posterior retraction is applied to the posterior sheath. Care should be taken not to damage the linea semilunaris, as this could lead to dissection of an interparietal plane between internal oblique and transversus abdominis, internal oblique and external oblique, or even a complete disconnection of the oblique complex from the rectus sheath, resulting in a lateral iatrogenic hernia.

The midline dissection superior and inferior to the defect is critically important to create adequate space for mesh overlap. The preperitoneal space above and below the hernia defect along the midline must be developed for a distance of at least 5 cm. The posterior sheath insertion onto the linea alba is then divided in order to create a continuous space from the contralateral retrorectus space to the ipsilateral retromuscular space, leaving the linea alba intact. While this portion of the dissection typically begins on the patients' left side, it is easiest to complete from the right side after beginning the contralateral retromuscular dissection (Fig. 49.4).

A transversus abdominis myofascial release is performed by dividing the transversus abdominis fascia and muscle beginning just medial to the segmental neurovascular bundles, allowing continued lateral dissection in the preperitoneal or pretransversalis fascia plane (Fig. 49.5a, b). Dissection is continued to approximately the anterior- to mid-axillary

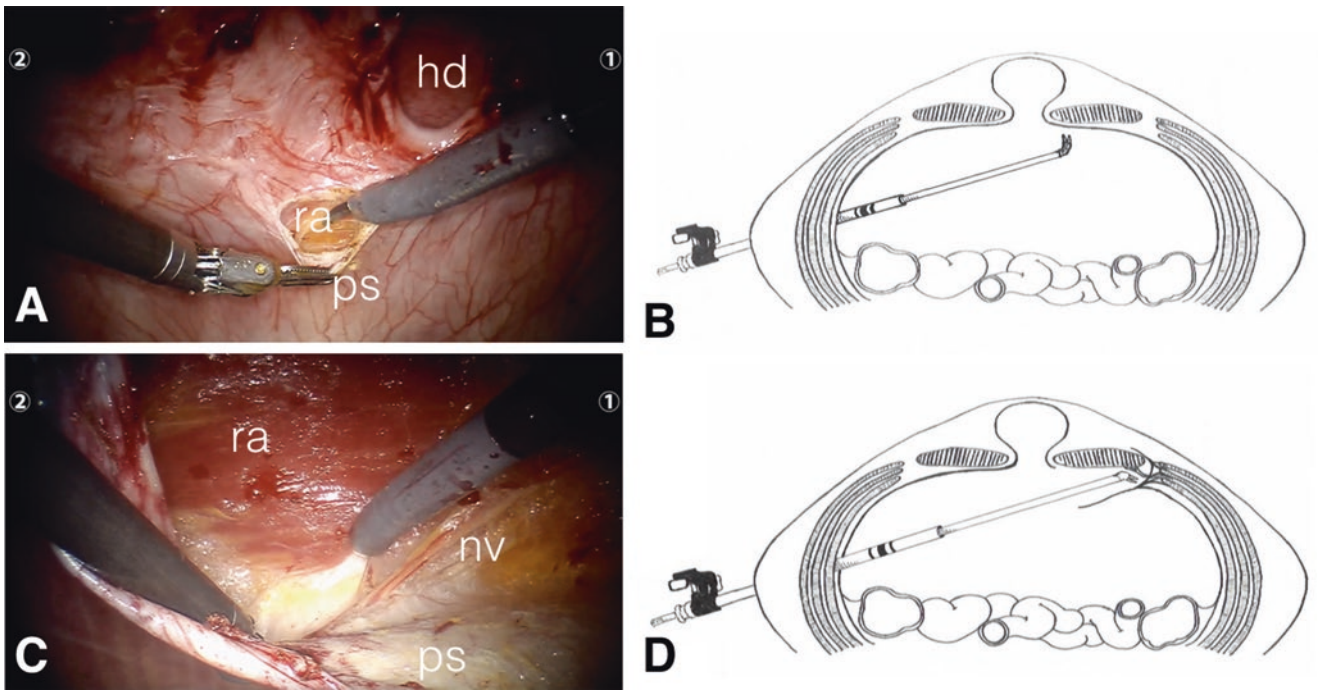

Fig. 49.3 Initiation of retromuscular dissection. (**a**) Posterior rectus sheath incision just lateral to linea alba on the *left*. (**b**) Cross-sectional schematic of same. (**c**) Retromuscular dissection extended to semilunar line. (**d**) Cross-sectional schematic of same. *ra* rectus abdominis muscle, *hd* hernia defect, *ps* posterior rectus sheath, *nv* neurovascular bundle

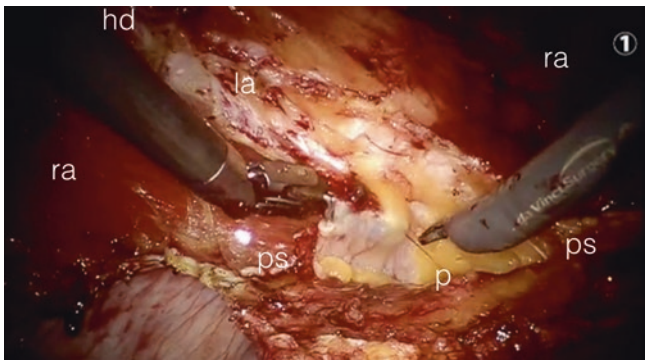

Fig. 49.4 Dissection of the midline above the hernia defect. *ra* rectus abdominis muscle, *hd* hernia defect, *la* linea alba, *p* peritoneum, *ps* posterior rectus sheath inserting onto the linea alba

line, and three additional trocars are placed into the dissected space in the left abdomen in a mirror image to the right side (Fig. 49.5c–e). A metric ruler is used to intracorporeally measure both the hernia defect height and width, and the extent of the dissected space. The height of the dissected space will correspond to the length of mesh required for repair. The left half of the dissected space is measured and assumed to be equal to half of the needed mesh width. This can be easily accomplished by laying the ruler on the posterior sheath, which is now lying over the viscera posteriorly, and passing a spinal needle through the abdominal wall at the left lateral edge of the hernia defect (Fig. 49.6).

We prefer a mid-weight, large pore, polypropylene mesh for repair. An appropriately sized mesh is selected, cut to our measured dimensions, rolled along its vertical axis, secured loosely with a single suture, and placed into the retromuscular space. This is secured just lateral to the nascent left-sided trocars with suture or absorbable tacks (Fig. 49.7). The patient is then repositioned and the robot docked on the opposite side. Dissection is carried out on the right side in the same fashion as the left to complete the bilateral retromuscular and transversus abdominis flaps. As the right retromuscular space is opened, the midline dissection above and below the defect is easily completed (Fig. 49.4). Dissection is carried out until the initially placed trocars are brought into the retromuscular space. The posterior fascial defect is then closed with a running self-fixating, slowly absorbable 2-0 suture, thereby closing the visceral sac (Fig. 49.8a, b). The mesh is unrolled across the closed posterior sheath and affixed to the right lateral abdominal wall just beyond the initially placed trocars, again using suture or tacks (Fig. 49.8c, d). The anterior fascial defect is closed using a self-fixating, slowly absorbable #1 suture in a running fashion for completion of the hernia repair (Fig. 49.9). It is often helpful to decrease the pneumoperitoneum to accommodate defect closure, particularly for larger defects. When possible, intermittent bites of the overlying hernia sac are included in the closure, imbricating the hernia sac and thus obliterating the dead space.

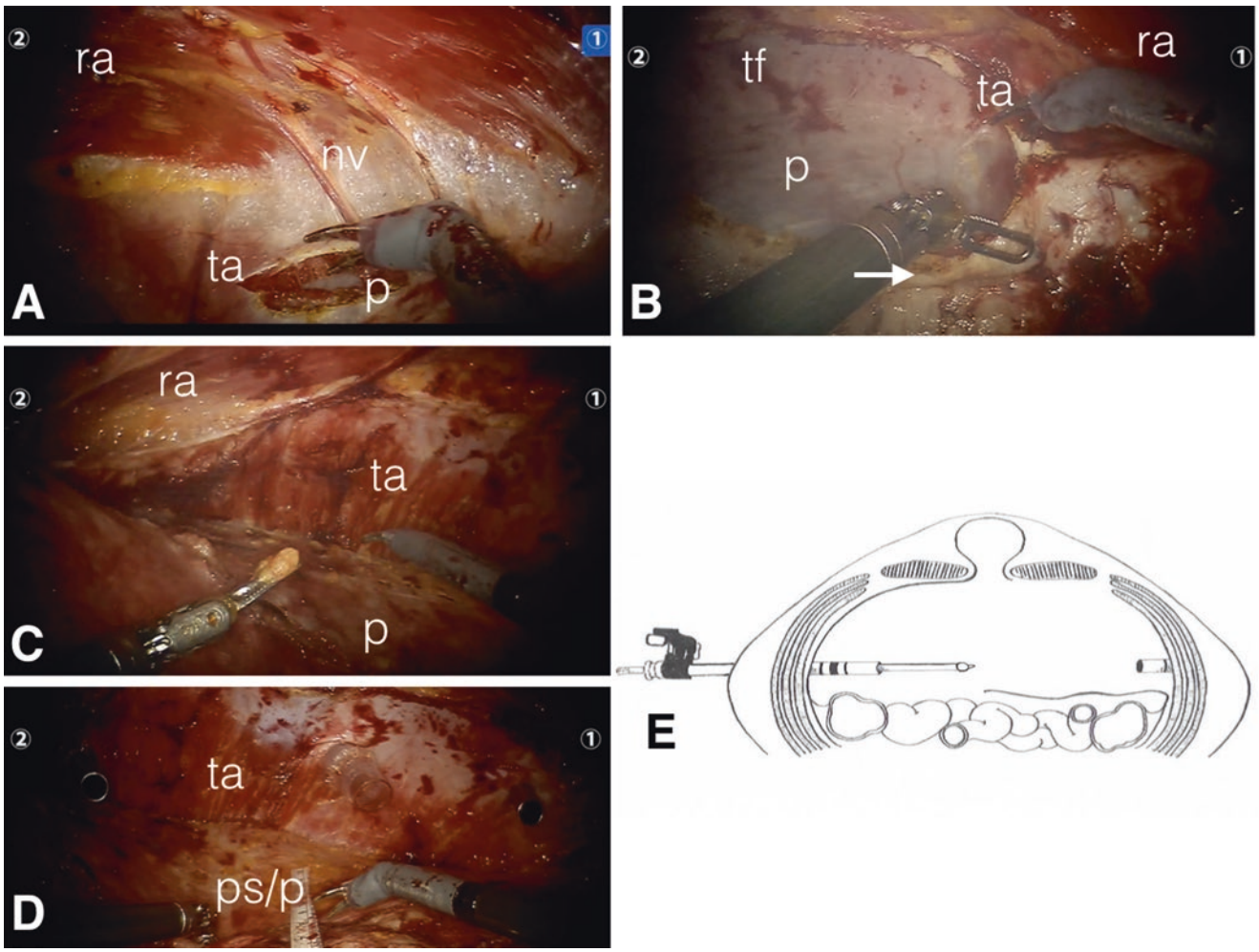

Fig. 49.5 Transversus abdominis myofascial release (TAR). (**a**) Initiation of the transversus abdominis release (TAR) by incising the TA fascia and muscle to enter the preperitoneal plane. (**b**) Extension of the TAR inferiorly along the aponeurotic portion of the TA. Cut edge of the TA denoted by *arrow*. (**c**) Lateral extension of the TAR to the mid-axillary line. (**d**) Contralateral ports placed in mirror image fashion into the dissected preperitoneal space. (**e**) Cross-sectional schematic of same. *ra* rectus abdominis muscle, *nv* neurovascular bundle, *ta* transversus abdominis muscle, *p* peritoneum, *tf* transversalis fascia, *ps/p* posterior flap comprising posterior rectus sheath medially and peritoneum laterally

49.6 Single-Dock Techniques

49.6.1 Single-Dock Retromuscular Repair

Smaller and mid-sized defects can often be approached using a single-dock approach. The patient is positioned and room set up in identical fashion. Rather than beginning the retromuscular dissection on the contralateral side, the lateral aspect of the right rectus sheath is incised to gain access to the ipsilateral retrorectus space. Dissection is continued from lateral to medial until the linea alba or lateral edge of the hernia defect is encountered. The posterior sheath is incised to enter the preperitoneal space along the midline, including dissection around and reduction of the midline hernia sac. Once across the midline, the left posterior sheath is incised in identical fashion as described above, and dissection completed to the left semilunar line. Here the sequence differs slightly. The anterior fascial defect is closed first, followed by placement of the mesh against the anterior abdominal wall. Defect closure, intracorporeal measurements, mesh sizing, and mesh fixation are all similar to that described above. Once the mesh is fixated, the posterior sheath is closed to completely cover the mesh. Figures 49.10 and 49.11 depict the single-dock retromuscular technique.

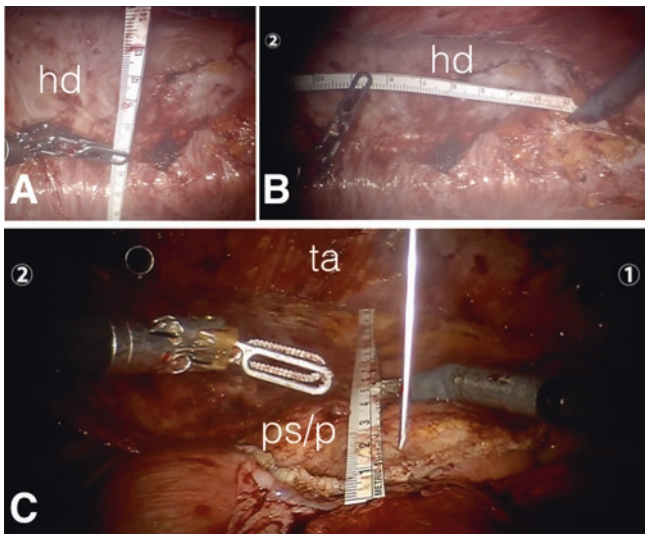

Fig. 49.6 Intracorporeal measurement of the hernia defect and dissected space for subsequent mesh placement. (**a**) Measurement of hernia width. (**b**) Measurement of hernia length and dissected vertical space. The vertical dissection corresponds to the length of mesh required. (**c**) Measurement of dissected transverse space. This is measured posteriorly along the dissected posterior flap and corresponds to half the width of mesh required. *hd* hernia defect, *ta* transversus abdominis muscle, *ps/p* posterior flap comprising posterior rectus sheath medially and peritoneum laterally

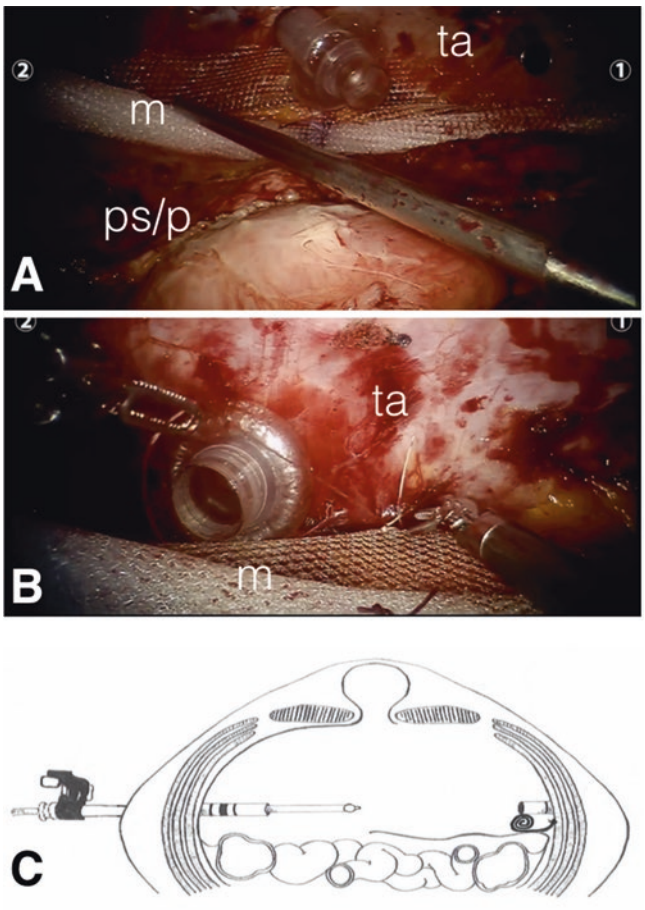

Fig. 49.7 Mesh placement. (**a**) Mesh rolled along its vertical axis and placed below the nascent trocars. (**b**) Mesh secured to the left lateral abdominal wall. (**c**) Cross-sectional schematic of same. *m* mesh, *ta* transversus abdominis muscle, *ps/p* posterior flap comprising posterior rectus sheath medially and peritoneum laterally

49.6.2 Single-Dock Preperitoneal Repair

Alternatively, repair can be completed without dissecting the retromuscular compartment by simply separating the peritoneum over a space surrounding the defect. Closure, mesh fixation, and peritoneal closure follow the same sequence as the single-dock retromuscular approach described above. This technique is depicted in Fig. 49.12, and is described in more detail elsewhere in this text.

49.6.3 Single-Dock Epigastric and Suprapubic Repair

For hernias in the epigastric or suprapubic regions, the robot can be docked in the opposite abdominal domain and approached from a midline position. Three trocars across the lower abdomen, with the addition of an assistant trocar, can easily access the upper abdomen, typically within about 3 cm above the umbilicus. In this case, the patient is positioned on a split leg table in moderate reverse Trendelenberg position. Conversely, for suprapubic defects, the robot can be docked in the epigastrum with the patient in a Trendelenberg position. In either case, the initial posterior sheath incision is made transversely, opening from semilunar line to semilunar line, with division of the posterior sheath on each side to preserve the midline linea alba above and below the hernia defect. If necessary, a transversus abdominis release can still be performed from these positions. The sequence of closure again follows that of the other single-dock approaches, with defect closure, followed by mesh placement and posterior sheath closure last. Repair of epigastric and suprapubic defects are depicted in Figs. 49.13 and 49.14, respectively.

49.7 Outcomes

To date, we have performed more than 80 true rRMVHRs, and over 120 total cases, including preperitoneal and intraperitoneal mesh placements. We have performed two comparison analyses evaluating the outcomes of RMVHR to both standard laparoscopic repair and open RM repair. We compared our robotic and laparoscopic cases between 2013 and 2015 contained in the Americas Hernia Society Quality Collaborative (AHSQC), a prospective, hernia-specific database. A total of

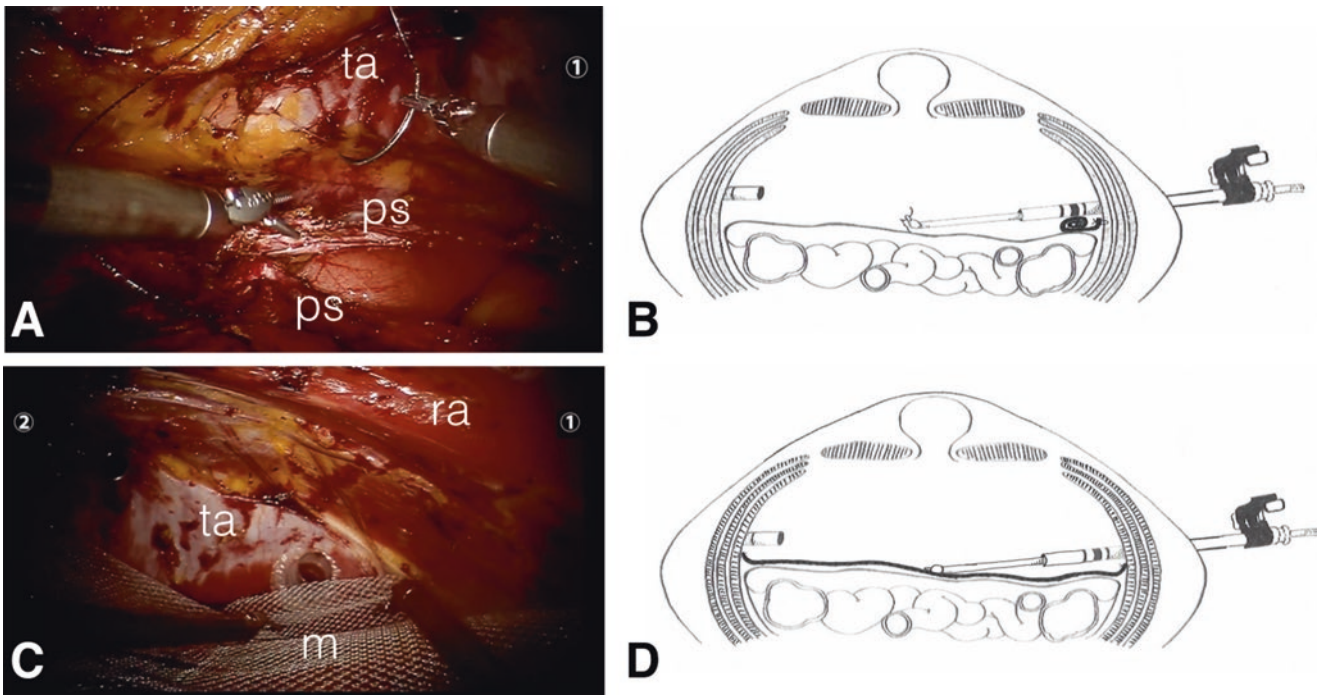

Fig. 49.8 Closure of the posterior sheath and mesh deployment. (**a**) Closure of the posterior sheath. (**b**) Cross-sectional schematic of same. (**c**) Deployment of mesh across the closed posterior sheath. (**d**) Cross-sectional schematic of same. *ta* transversus abdominis muscle, *ps* posterior rectus sheath, *ra* rectus abdominis muscle, *m* mesh

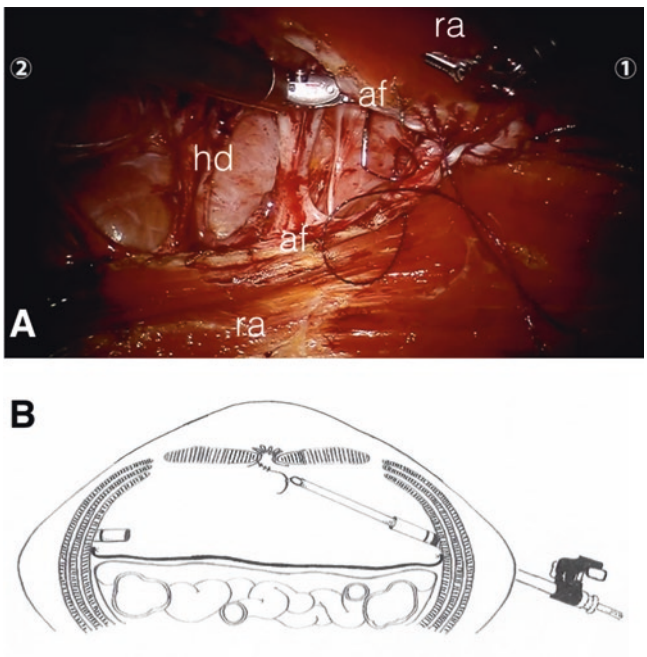

Fig. 49.9 Closure of anterior fascia/hernia defect. (**a**) Closure of the hernia defect with imbricating bites of the overlying hernia sac. (**b**) Cross-sectional schematic of same. *af* anterior fascia, *hd* hernia defect, *ra* rectus abdominis muscle

156 patients, 53 robotic and 103 laparoscopic, were identified. Patients had similar comorbidities and hernia characteristics. The robotic approach resulted in longer operative time and seroma formation compared to laparoscopy, but a much greater fascial closure rate, 96 versus 50 %, and a shorter median length of stay (LOS) at only 1 day, compared to 2 days after LVHR. Anecdotally, this difference seems to be due to less pain associated with rRMVHR, but we were unable to demonstrate this upon retrospective analysis of narcotic requirement during hospitalization. There was no difference in surgical site infections between groups [5]. Tables 49.1 and 49.2 summarize these findings.

While this is a useful comparison evaluating the potential benefits of two minimally invasive approaches to VHR, these techniques are truly distinct. To more appropriately compare techniques, we also analyzed our initial 21 rRMVHR compared to a matched cohort of 21 open RMVHR. Cases were matched based on body mass index (BMI), Center for Disease Control (CDC) wound classification, and hernia width. Comorbidities were similar between groups with the exception of chronic obstructive pulmonary disease (COPD), which occurred more frequently in the open group (Table 49.3). Again, a longer operative time was noted with the robotic approach, and a greater number or seromas were

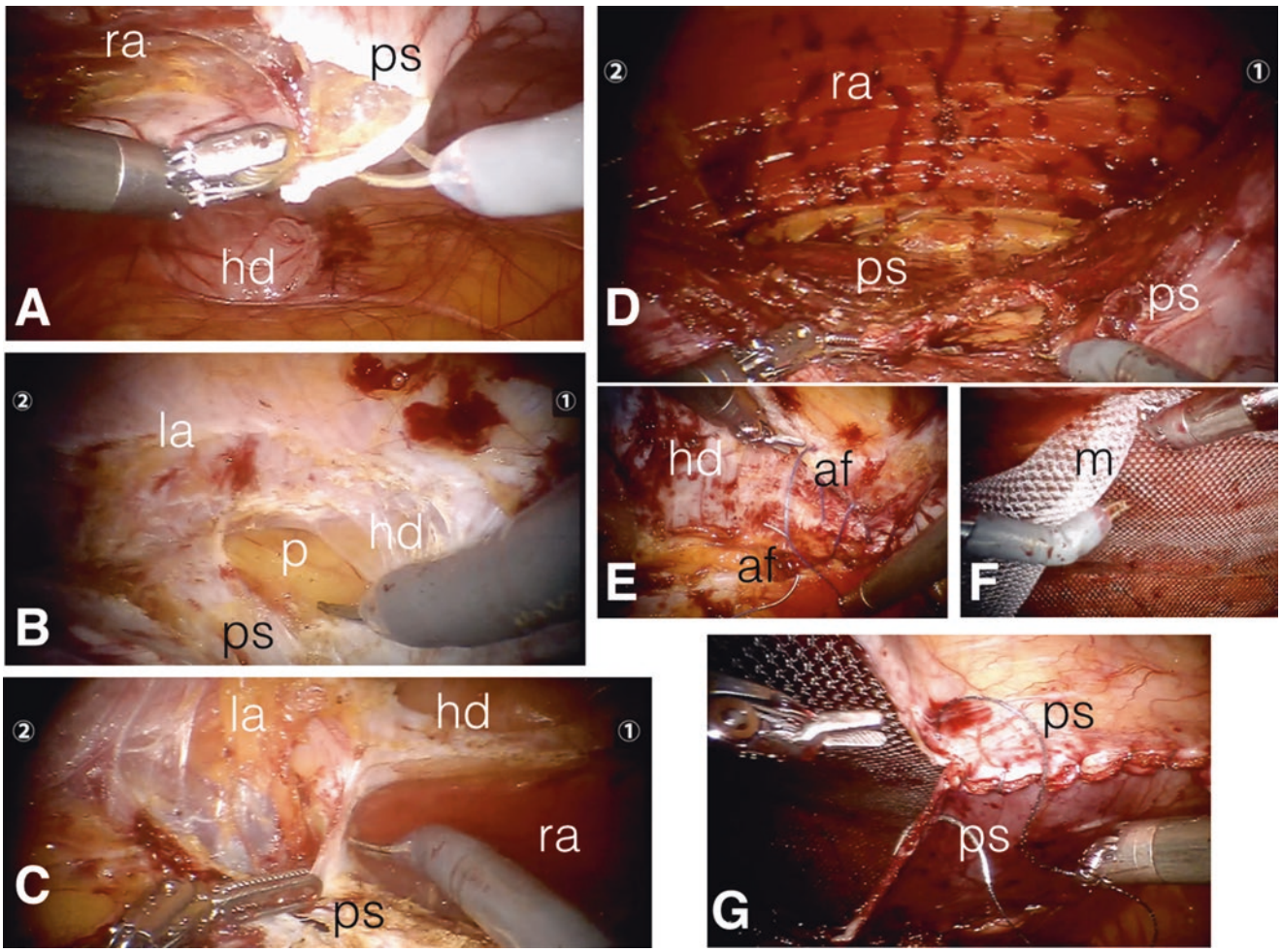

Fig. 49.10 Single-dock retromuscular approach for VHR. (**a**) Posterior rectus sheath incised laterally. (**b**) Retromuscular dissection continues to the linea alba and hernia defect medially, extending across the midline in the preperitoneal space. (**c**) Contralateral retromuscular dissection. (**d**) Completed flap consisting of the posterior rectus sheath bilaterally, connected by the peritoneum in the midline. (**e**) Closure of the hernia defect. (**f**) Mesh placed against the anterior abdominal wall. (**g**) Closure of the posterior sheath. *ra* rectus abdominis muscle, *ps* posterior rectus sheath, *hd* hernia defect, *la* linea alba, *p* peritoneum, *af* anterior fascia, *m* mesh

reported. No SSIs occurred in our initial robotic cases, compared with 9.5 % in the open cohort ($p=0.488$). The impact on LOS was more significant. Hospital LOS decreased from a mean of 4.2 days open to 2.3 days robotically ($p=0.046$). Interestingly, our rudimentary cost analysis, comparing direct hospital costs only, was similar between groups (Table 49.4). Further comparison is currently underway with encouraging early results [13].

49.8 Conclusion

The utility of robotics in ventral hernia repair remains a contentious issue. However, by fully utilizing the benefits of enhanced three-dimensional visualization and instrument articulation afforded by the robotic platform, we are able to duplicate the Rives-Stoppa VHR in a minimally invasive fashion. The implication of our initial comparative analyses is significant, as the ability to replicate an open repair, with the benefits of complete abdominal wall reconstruction, offsetting tension along the midline closure through myofascial release, and extraperitoneal mesh placement, combined with the wound morbidity of laparoscopic hernia repair, allows definitive hernia repair for increasingly complex and high-risk patients with decreasing perioperative morbidity. The optimal patient selection for this approach remains to be determined, and certainly the cost of robotic surgery must be considered. However, rRMVHR has the potential to dramatically improve the outcomes for VHR.

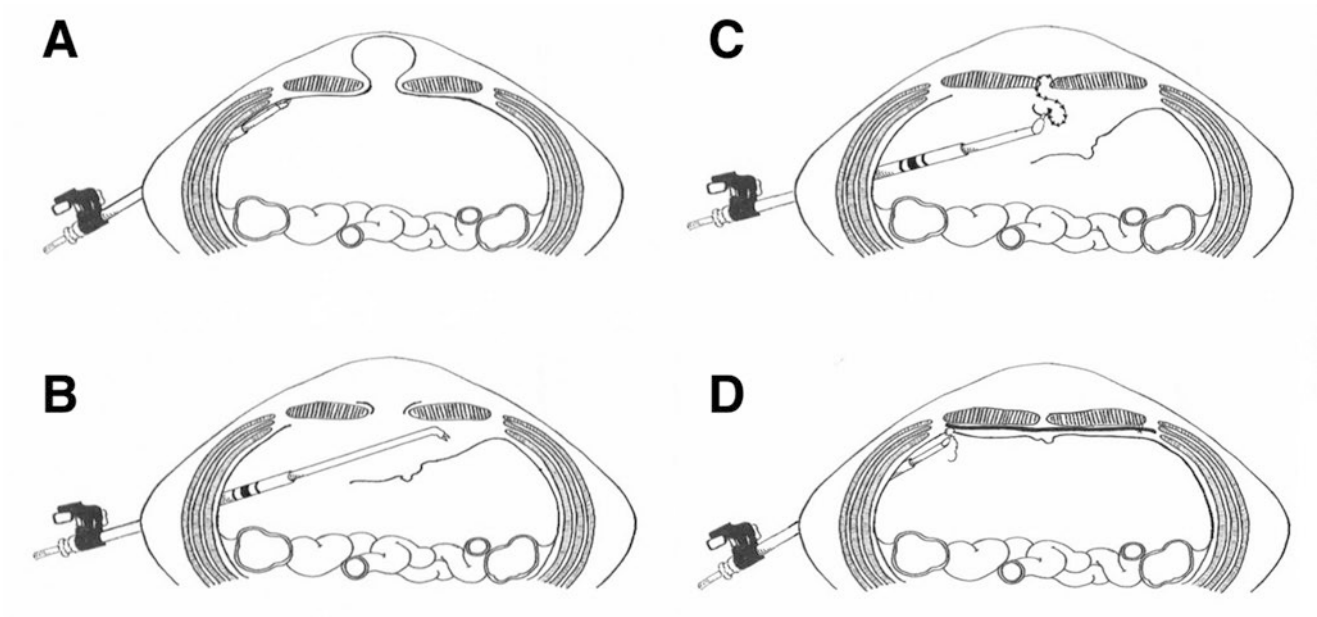

Fig. 49.11 Cross-sectional schematic of single-dock retromuscular rVHR. (**a**) Posterior sheath incised laterally. (**b**) Dissection across the midline, including reduction of the hernia sac, to the contralateral semilunar line. (**c**) Closure of hernia defect. (**d**) Mesh placement against anterior abdominal wall and closure of the posterior sheath

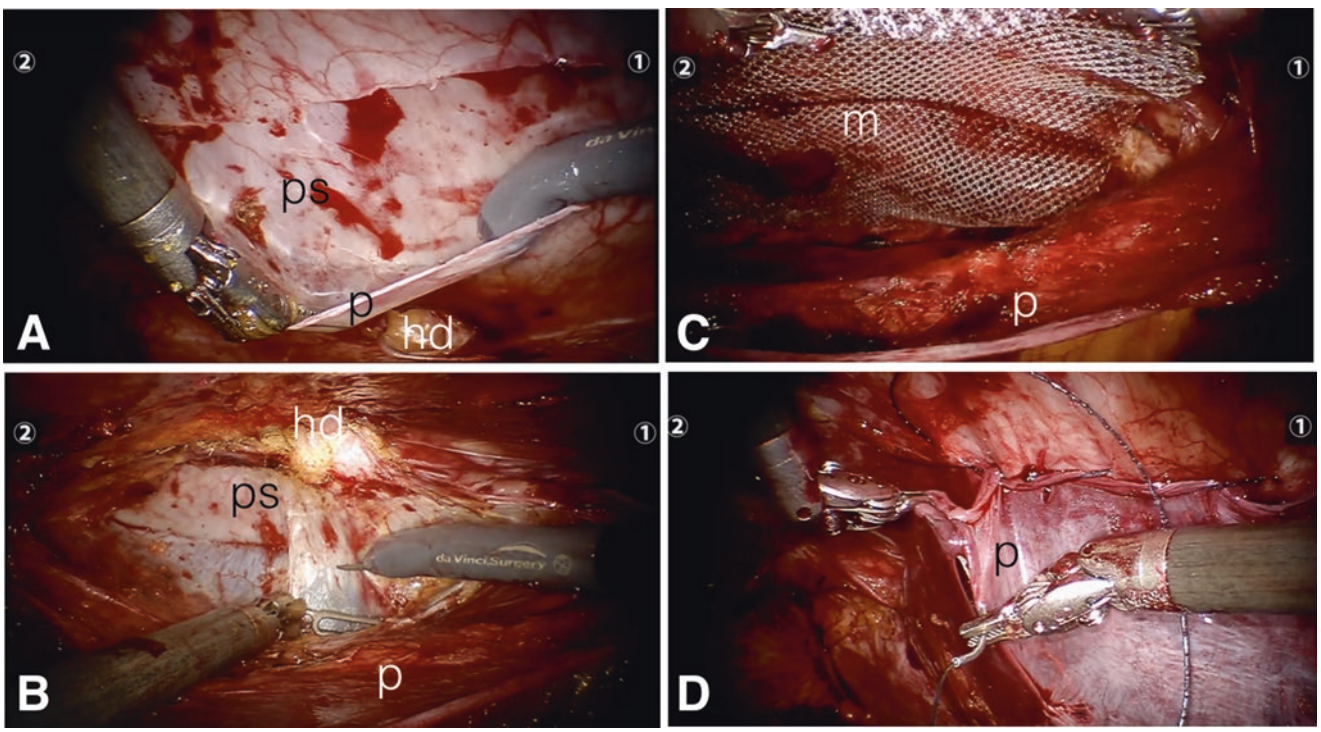

Fig. 49.12 Preperitoneal repair of small VHR. (**a**) Peritoneum dissected away from the posterior sheath, beginning at least 5 cm from hernia defect. (**b**) Preperitoneal dissection continues beyond the defect at least 5 cm. (**c**) Placement of mesh against the anterior abdominal wall after closure of the hernia defect. (**d**) Peritoneal flap closure. *ps* posterior rectus sheath, *p* peritoneum, *hd* hernia defect, *m* mesh

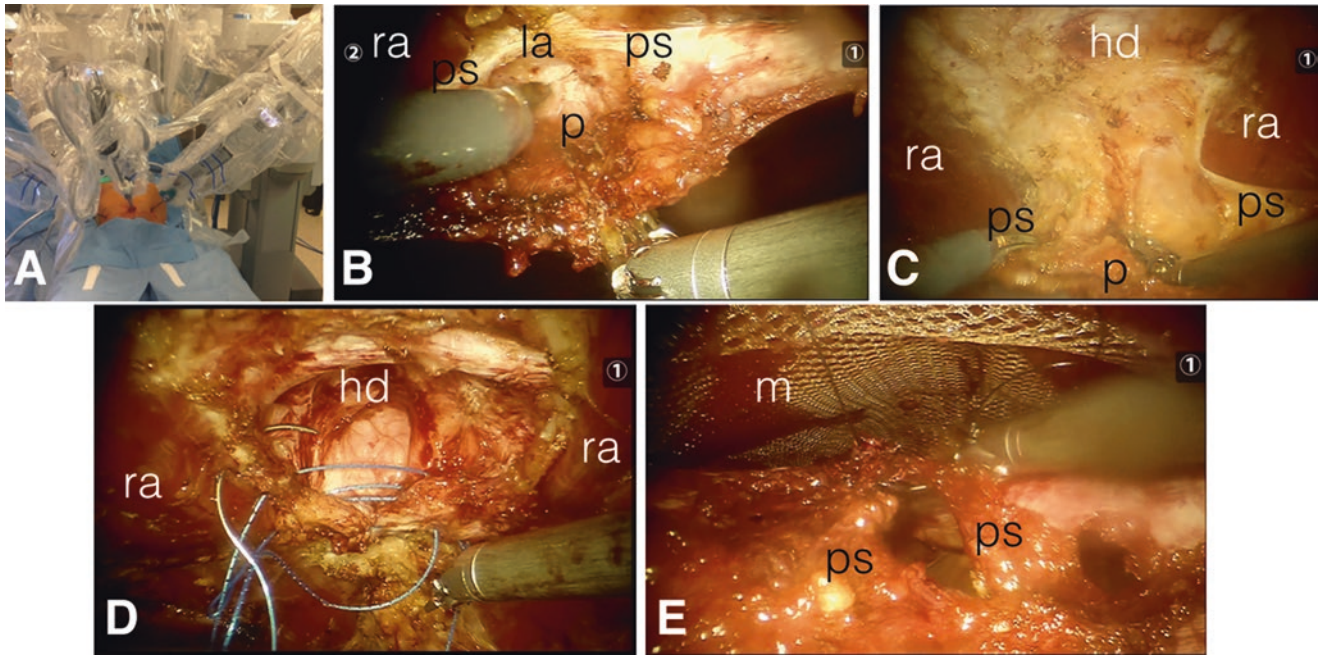

Fig. 49.13 Single-dock rVHR of epigastric defect. (**a**) Patient positioned on a split-leg table, trocars placed across the lower abdomen and the robot docked parallel to the bed. (**b**) Transverse incision of the posterior rectus sheath, including the preperitoneal space along the midline. (**c**) Extension of dissection above the hernia defect. (**d**) Defect closure. (**e**) Placement of mesh against the anterior abdominal wall and closure of the posterior sheath. *ra* rectus abdominis muscle, *la* linea alba, *ps* posterior rectus sheath, *p* peritoneum, *hd* hernia defect, *m* mesh

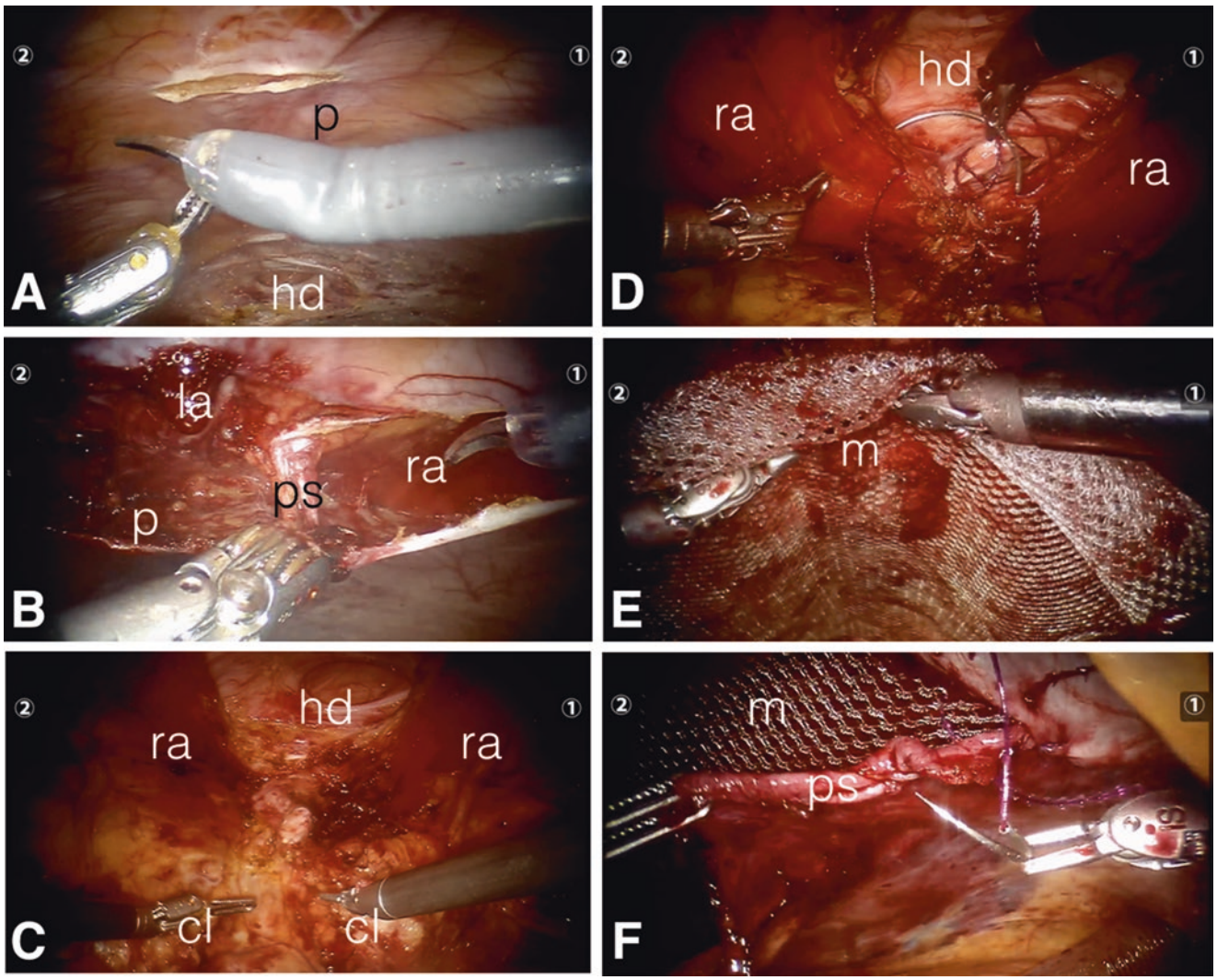

Fig. 49.14 Single-dock rVHR of suprapubic defect. (**a**) Transverse incision of the posterior sheath. (**b**) Dissection of the retromuscular space bilaterally and the preperitoneal space in the midline, preserving the linea alba. (**c**) Preperitoneal dissection to the Space of Retzius to expose Coopers' ligaments. (**d**) Defect closure. (**e**) Placement of mesh against the anterior abdominal wall. (**f**) Closure of the posterior rectus sheath. *p* peritoneum, *hd* hernia defect, *la* linea alba, *ps* posterior sheath, *ra* rectus abdominis muscle, *cl* Cooper's ligament, *m* mesh

Table 49.1 Standard laparoscopic versus robotic retromuscular hernia repair: demographics and operative details

Laparoscopic versus robotic			
Demographics	*Lap*	*Robotic*	*p Value*
N	103	53	
Age	60.2 ± 13.4	52.9 ± 12.3	0.001
Race			0.419
BMI, mean ± SD	35.7 ± 9.5	34.7 ± 7.4	0.468
DM	34 (33.01)	15 (28.3)	0.624
COPD	8 (7.77)	7 (13.21)	0.487
HTN	69 (66.99)	30 (56.6)	0.379
ASA			0.711
1–2	40 (38.83)	19 (35.85)	
3–4	63 (61.16)	34 (64.15)	
Smoking status	17 (16.5 %)	13 (24.5 %)	0.457
Converted to open	4 (3.88)	0 (0)	
Wound class			0.849
1	99 (96.12)	52 (98.11)	
2	4 (3.88)	1 (1.89)	
Operative details			
Hernia width (mean)	6.9 ± 4.1	6.5 ± 2.9	0.508
Hernia area (mean)	88.0 ± 94.0	82.5 ± 69.8	0.685
Mesh area (mean)	339.3 ± 164.1	435.0 ± 250.9	0.014
Fascial closure	52 (50.49)	51 (96.23)	<0.001
Bowel injury	9 (8.74)	1 (1.89)	0.011
OR time (mean)	121.5 ± 57.2	245.6 ± 98.5	<0.001

BMI body mass index, *SD* standard deviation, *DM* diabetes mellitus, *COPD* chronic obstructive pulmonary disease, *HTN* hypertension, *ASA* American Society of Anesthesiology

Table 49.2 Standard laparoscopic versus robotic retromuscular hernia repair: outcomes

Laparoscopic versus robotic			
Outcomes	*Lap*	*Robotic*	*p Value*
N	103	53	
SSI, *N* (%)	1 (0.97)	2 (3.77)	0.592
SSO, *N* (%)	19 (18.45)	28 (52.83)	<0.001
Seroma	17 (16.5)	24 (45.28)	
Infected seroma	0 (0)	1 (1.89)	
SSO PI, *N* (%)			1.000
None	94.7 %	92.9 %	
Percutanious drain	1 (0.97)	2 (3.77)	
LOS (median; IQR)	2 (2, 4)	1 (1, 3)	0.004

SSI surgical site infection, *SSO* surgical site occurrence, *SSO PI* surgical site occurrence requiring procedural intervention, *LOS* length of stay, *IQR* interquartile range

Table 49.3 Open versus robotic retromuscular VHR: demographics

Open versus robotic			
Demographics	*Open*	*Robotic*	*p Value*
n	21	21	
BMI (mean ± SD)	36.1 ± 6.4	35.6 ± 7.7	0.761
Wound class 1	21	21	1.000
DM (%)	7 (33.3)	3 (14.3)	0.277
Smoker (%)	3 (14.3)	7 (33.3)	0.277
COPD	9 (42.9 %)	1 (4.8 %)	0.009
Hernia width (cm) (mean ± SD)	6.5 ± 3.9	6.2 ± 3.3	0.766

BMI body mass index, *SD* standard deviation, *DM* diabetes mellitus, *COPD* chronic obstructive pulmonary disease

Table 49.4 Open versus robotic retromuscular VHR: operative details and outcomes

Open versus robotic			
Demographics	*Open*	*Robotic*	*p Value*
n	21	21	
Surgery time (mean ± SD)	178 ± 99	229 ± 88	0.087
EBL (mL) (mean ± SD)	106 ± 122	37 ± 39	0.022
LOS (mean ± SD)	4.2 ± 3.8	2.3 ± 1.6	0.046
SSO (%)	8 (38.1)	7 (33.3)	1.000
SSI (%)	2 (9.5)	0 (0.0)	.488
Recurrence (%)	3 (12.5)	1 (4.8)	0.611

SD standard deviation, *EBL* estimated blood loss, *LOS* length of stay, *SSO* surgical site occurrence, *SSI* surgical site infection

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Management of Mesh Infection

50

Lucas R. Beffa and Jeremy A. Warren

50.1 Introduction

Reinforcement of the abdominal wall with mesh is a mainstay of ventral hernia repair (VHR). However, there are multiple possible surgical approaches to VHR and numerous mesh prostheses to choose from, with little consensus on the optimal technique. Among the most feared complications of VHR is the development of a prosthetic mesh infection, which greatly influences preoperative planning and intraoperative decision-making. Patient comorbid conditions that increase the risk of postoperative surgical site infection (SSI), or in cases with intraoperative contamination are commonly repaired with biologic mesh or primary suture repair, or simply not offered an operation. However, there is growing recognition of the limitations of biologic constructs in the setting of contamination. There is also increasing evidence to suggest the safety of certain permanent synthetic meshes in these cases. Traditional teaching espouses early partial or complete removal of the mesh from the abdominal wall should a mesh infection occur, often requiring multiple operations involving sometimes complex and long-term wound care, followed finally with the inevitable hernia recurrence. This paradigm is shifting, however, and there are now numerous reports demonstrating the ability to salvage mesh infection without explantation. Technological advancement, coupled with the increasing interest in hernia repair as a subspecialty and renewed interest in scientific study, has led to greater understanding of the patient factors, surgical technique, and mesh material contributions to the outcomes of VHR.

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50.2 Epidemiology and Pathogenesis

Prosthetic mesh infection occurs in 0.7–25.6 % of VHR, but incidence varies widely across reported series depending on a number of patient factors, surgical technique, mesh selection, and reporting nomenclature [1–4]. Recent studies put this incidence around 1 % for laparoscopic repair, and <5 % for open repairs [1, 4–6]. There are a number of well-recognized patient factors known to increase the risk of SSI and mesh infection, including morbid obesity, tobacco abuse, chronic obstructive pulmonary disease (COPD), diabetes mellitus (DM), and immunosuppression [5, 7, 8]. Operative factors, including operative approach, duration of surgery, degree of soft tissue disruption, intraoperative contamination, size, type, and complexity of the hernia, choice of prosthetic material and its location within the abdominal wall also impact the risk of SSI [5, 6, 8, 9].

Infection typically occurs at the time of prosthetic implantation due to bacterial contamination from the patient or surgical staff skin flora, the surrounding environment, or mucosal surfaces of the patient [4]. Presentation of the infection may be significantly delayed, often not clinically relevant for months or even years postimplantation [10–13]. The ability of a prosthetic material to resist infection depends on the bacterial inoculum, virulence of the organism, adherence to the prosthetic, the architecture of the mesh material, and the host immune response, all of which can be affected by preoperative risk reduction, choice of mesh, and choice of technique [4, 6].

As expected, the most common causative organisms are skin flora, most notably *Staphylococcus* species, both *S. aureus* and *S. epidermidis.* Multiple other species have been reported as well, including *Proteus, Klebsiella, Enterococcus, Streptococcus, Corynebacterium, Pseudomonas, Escherichia, Acinetobacter,* and *Enterobacter* species [8, 11, 12, 14, 15]. *S. aureus* is the most commonly reported causative organism, occurring in up to 80 % of cases, and methicillin-resistant *S. aureus* (MRSA) can be particularly problematic [5]. Formation of an extracellular

W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4_50

polysaccharide matrix, or biofilm, can increase the virulence of adherent bacteria. Bacterial clearance in the presence of a biofilm is significantly impaired due to a phenotypic change in the bacteria, inducing a dormant phase that is not as susceptible to antimicrobial therapy as the planktonic form of the organism. Additionally, the biofilm acts as a physical barrier, preventing accumulation of therapeutic concentration of antibiotics and inhibiting the host immune response [4, 5, 16].

50.3 Mesh Material and Structure

The three-dimensional structural architecture, chemical and biologic characteristics of the implanted material significantly impact the risk of developing and ability to clear a prosthetic infection. Generally, increasingly complex mesh architecture increases risk of bacterial adherence [4]. Smaller pore size, multifilament mesh, and laminar mesh construction increase the surface area for bacterial adherence, impede leukocyte migration for bacterial clearance, and may increase the likelihood of biofilm formation [4, 5].

Several in vitro studies have evaluated the bacterial adherence to various mesh types. Sanders et al. evaluated bacterial adherence of *S. aureus* and *S. epidermidis* to eight different mesh types. Based on polymer type, expanded polytetrafluoroethylene (ePTFE) demonstrated significantly higher bacterial adherence than polypropylene (PP), polyethylene terephthalate (polyester, PET), or condensed PTFE (cPTFE). Multifilament, partially absorbable material (PP + polyglactin-910) also demonstrated greater bacterial adherence compared to monofilament PP or PET. Polymer filament diameter and mesh weight similarly influenced bacterial adherence, with increased adherence with increasing diameter and weight. Finally, pore size inversely impacted bacterial adherence, with increased adherence seen with decreasing pore size [17]. Using a different methodology, Harrell et al. compared methicillin-resistant *S. aureus* (MRSA) adherence to nine different commercially available meshes. Silver-impregnated ePTFE demonstrated no bacterial adherence and showed significant bactericidal effect. In contrast, and contradictory to previously cited study, the multifilament PP + polyglactin 910 demonstrated the greatest bacterial adherence. Other light-weight monofilament PP meshes had significantly lower bacterial adherence compared with the multifilament PP + polyglactin 910 [18].

In vivo models for prosthetic infection exhibit a similar pattern. Using a rat model and MRSA inoculum, Blatnik et al. showed 80–91 % bacterial clearance with monofilament PP and polyester (PE), while multifilament PE cleared only 36 % of the MRSA. Biologic material has demonstrated variable results. One early study comparing several biologic materials demonstrated 58–92 % bacterial clearance compared to control multifilament PET [19]. A more recent study contradicts this finding, demonstrating that monofilament PET cleared both *E. coli* and *S. aureus* 88 and 75 % of the time, respectively, compared to just 17 and 50 % clearance with porcine acellular dermal matrix (PADM) [20].

50.4 Management of Mesh Infections

For patients who develop an SSI after VHR, the first step is to determine if the infection actually involves the prosthetic material. Ultrasound and CT imaging is useful in determining the extent of any abdominal wall fluid collections and if there is direct connection with the space in which the mesh was placed. If a prosthetic mesh infection is present, the various options for management must be considered, ranging from antibiotic therapy alone to complete mesh excision, and must be tailored to the clinical condition of the patient. The operative technique, particularly the position of the mesh within the abdominal wall, the prosthesis involved, and the bacteriology of the SSI are all critically important factors that determine the ultimate success or failure of mesh salvage. A multidisciplinary approach is often helpful, including the surgeon, wound care, and infectious disease. Perhaps most importantly, the expectations of the patient must be managed. Prolonged wound care, repeated operations, and a high risk of hernia recurrence require patience and perseverance from both patient and surgeon.

50.4.1 Mesh Salvage

Most patients presenting with prosthetic mesh infection should have an initial attempt at mesh salvage due to the morbidity associated with mesh removal and the invariably recurrent incisional hernia. Traditional wound opening and local wound care with wet-to-dry dressings remains an important measure, but is not required for every patient and has been largely supplanted by percutaneous drainage with or without antibiotic irrigation, or negative pressure wound therapy (NPWT). The success of these techniques is significantly impacted by the bacteriology of the SSI, the mesh material, and mesh location. It is important to recognize that long-term management is typically necessary; complete wound healing when mesh salvage is successful can take several months [21]. The patient must be prepared to deal with the social, psychological, and physical impact of dealing with chronic wound therapy, and frequent office visits, counseling, and reassurance are required. A general algorithm to guide the management of infected mesh is shown in Fig. 50.1.

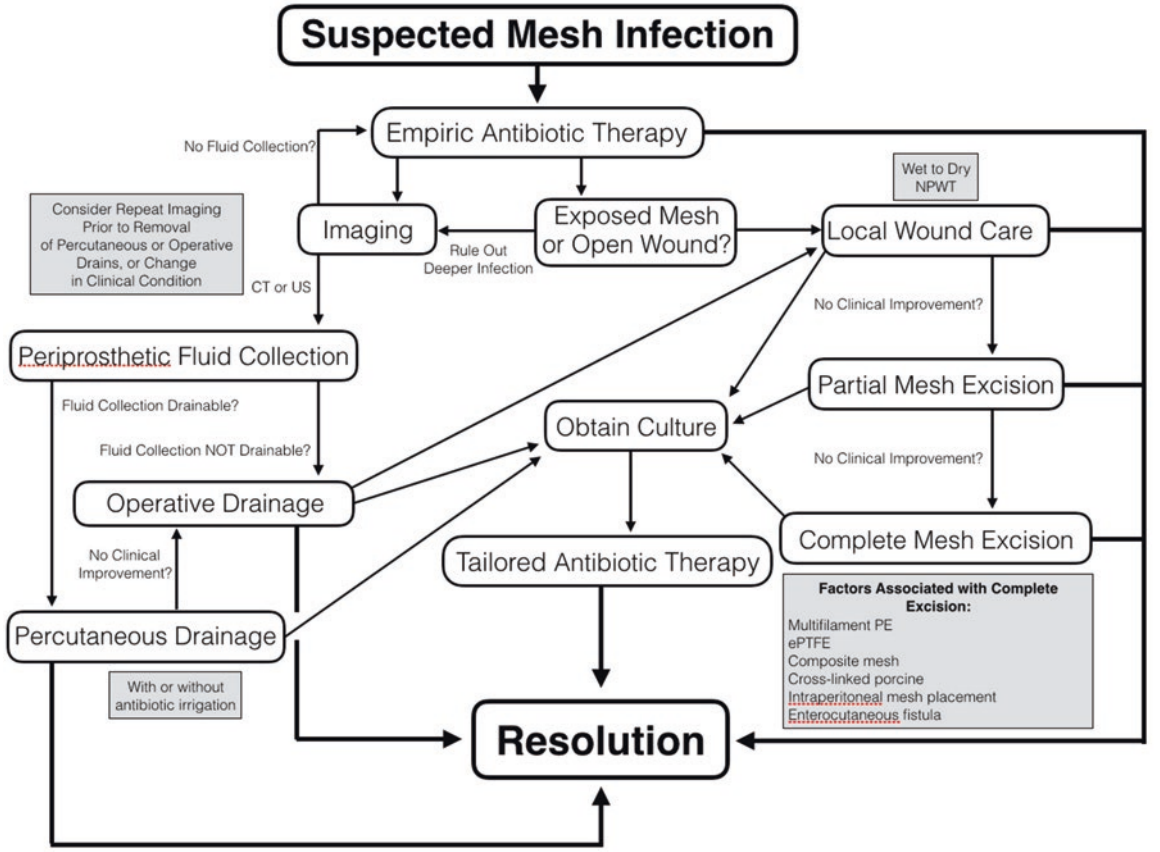

Fig. 50.1 Algorithm for the management of prosthetic mesh infection

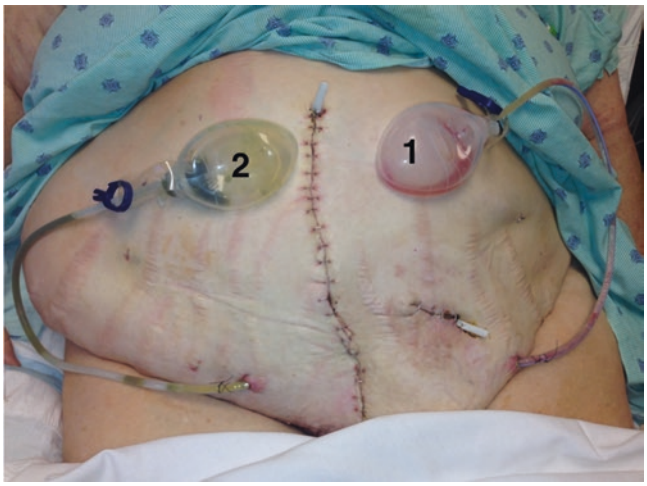

Fig. 50.2 Operatively placed drains after colostomy reversal and VHR with midweight, large-pore polypropylene in the retromuscular space with serous output in bulb *1* and enteric contents in *2*. Management with antibiotics and parenteral nutrition with complete resolution and no further mesh or wound complications at 2 years

50.4.2 Mesh Type

The mesh material and construct impacts the outcome of any attempt at mesh salvage. Polypropylene mesh is typically better suited for mesh preservation, with salvage rates as high as 100 % in some series [13, 22, 23]. This is likely due to the monofilament nature of the mesh construct, and more recently the larger interstices of the light- and midweight meshes. Our experience with large-pore polypropylene mesh in the retromuscular space is excellent, and mesh explantation is almost universally a result of intraabdominal complications, such as anastomotic leak, requiring reoperation, rather than direct mesh-related infection [24, 25]. Even with significant contamination, such as concurrent ostomy reversal, mesh explantation is rare, even in the event of deep space SSI (Fig. 50.2) [26]. Multifilament mesh has been shown to develop a greater density biofilm, inhibiting host and antibiotic effectiveness of bacterial clearance [16]. Clinically, multifilament polyester infection has a higher rate of salvage

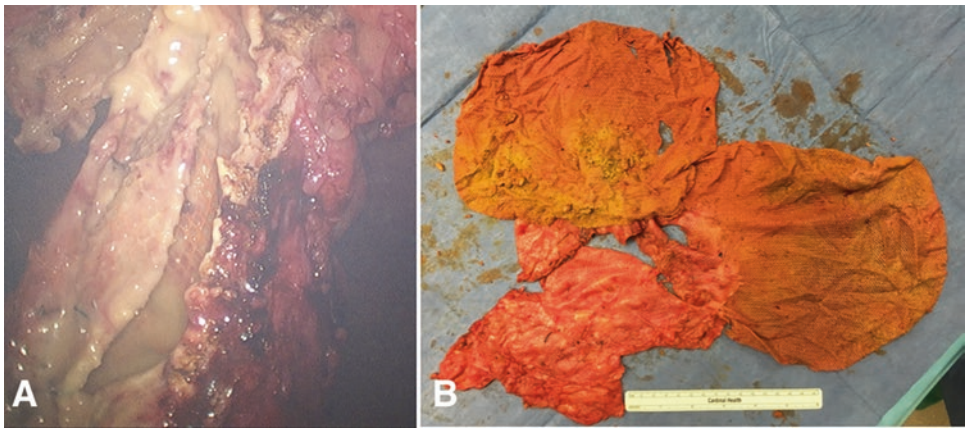

Fig. 50.3 (**a**) Infected intraperitoneal multifilament, barrier coated polyester requiring complete excision. (**b**) Explant of multiple pieces of intraperitoneal barrier coated multifilament polyester mesh fistulized to small bowel, colon, and vagina

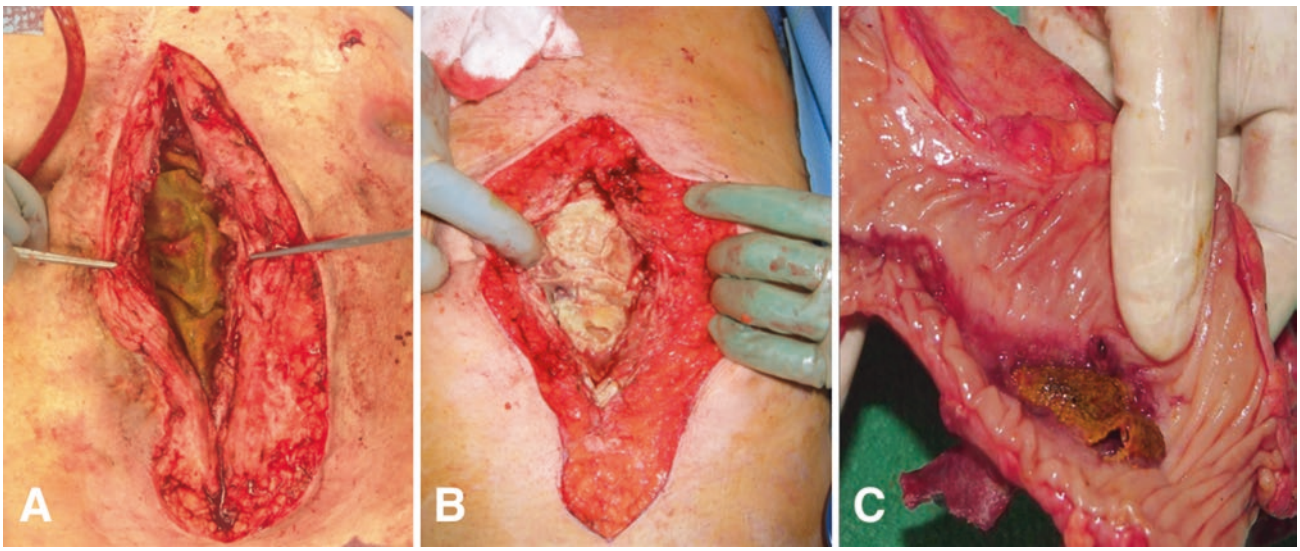

Fig. 50.4 (**a**) Infected retromuscular microporous polypropylene mesh associated with colocutaneous fistula requiring explantation of all unincorporated mesh. (**b**) Exposed infected ePTFE mesh requiring complete excision. (**c**) Heavyweight, microporous polypropylene fistulized into small bowel

failure reported in several series (Fig. 50.3) [22, 27]. Leber reported a three times higher rate of long-term complications with the use of polyester mesh, including a 15.7 % rate of enterocutaneous fistula formation [27]. In our experience with this construct, complete explantation is required almost universally if infection occurs, though it doesn't appear that the incidence of infection overall is any higher than other mesh materials. These outcomes are consistent with the animal studies discussed above demonstrating poor bacterial clearance with multifilament materials. However, other series report successful salvage of polyester mesh with adequate drainage, antimicrobials, and local wound care [13, 28]. Microporous, heavy-weight polypropylene mesh is also more difficulty to salvage, as is PTFE, due to its microporous, laminar structure, and each portends mesh removal in most cases [23], particularly if placed during an open VHR (Fig. 50.4) [22, 23, 29]. Composite mesh constructs are also poorly salvageable in the event of infection [8, 14], though explantation can sometimes be avoided with aggressive conservative therapy [21].

A variety of biologic matrices, derived from porcine, bovine, or human tissue, are also available. Theoretically, these materials serve as a biologic scaffold to facilitate native tissue in growth, new collagen deposition, and remodeling, though the true biologic activity of these materials in vivo is largely unknown. In the largest study of biologic mesh explants, no evidence of remodeling was seen, with little or no neovascularization, and the mesh induced significant foreign body reaction and even encapsulation, particularly with cross-linked porcine [30]. Use of biologic mesh for abdominal wall reconstruction is widely promulgated in high-risk patients and in the repair of hernias in a contaminated field. There is a paucity of literature to support this practice, however. It should also be noted that biologic mesh is not

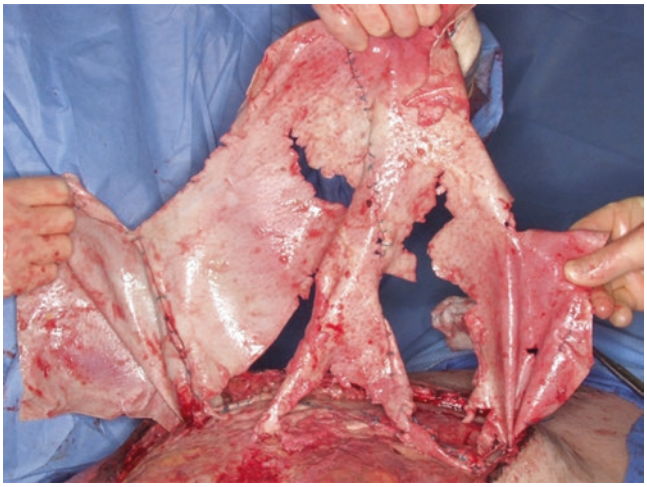

Fig. 50.5 (**a**) Explanation of infected, degraded porcine mesh

approved for use in contaminated fields by the Food and Drug Administration (FDA) [31]. Harth et al. compared four commercially available biologic products using a rat model of contaminated hernia repair, and demonstrated decreasing bacterial clearance and tensile strength across wound classification for all materials except the non-crosslinked porcine. Additionally, multiple material failures were seen with biomechanical testing in class II–IV wounds, while no material failure was seen in the synthetic mesh used as the control [32]. Clinically, heavily cross-linked porcine results in high rates of infection, mesh explantation, and hernia recurrence in contaminated hernia repairs [3, 33]. Non-crosslinked porcine appears to perform better than cross-linked, however rates of SSI are comparable to most series using synthetic mesh, and recurrence rates are typically higher [34–38]. Even considering studies that compare favorably with synthetic mesh [39–42], cost should be considered. Biologic grafts typically cost as much as ten times that of synthetic mesh [36].

Regarding salvageability of biologic materials, there is little data to guide decision-making. As with synthetic materials, attempt at salvage is appropriate providing the clinical stability of the patient. Cross-linked porcine was poorly salvageable in long-term analysis by Abdelfatah et al. with 25 % rate of mesh explantation with a mean follow-up of >5 years [3]. Removal of biologic implants for infection has been reported elsewhere as well (Fig. 50.5) [30, 41, 43, 44]. There is insufficient data to determine the particular benefit of percutaneous drainage, local wound care, or NPWT in biologic mesh infections.

Newer absorbable synthetic mesh may have a role in reconstruction in high-risk and contaminated cases, though current data is limited. The COBRA trial [45], in which a bioabsorbable construct of polyglycolide-trimethylene carbonate was used in the repair of contaminated hernias, demonstrated comparable results to previous studies published from the same group using porcine [34] and synthetic mesh [25]. Of 21 SSIs in this series, no patient required complete mesh removal, indicating the suitability of this material for mesh salvage. Cost of these materials is significantly lower than biologic and may present an alternative for use in this complex patient population.

50.4.3 Mesh Position

As already alluded to, the position of the mesh within the abdominal wall plays a significant role in the ability to salvage mesh. Retromuscular mesh position provides a well-vascularized compartment for mesh placement that is separate from the viscera, with musculocutaneous tissue coverage of the mesh, making this space ideal for decreasing the risk of infection and salvaging prosthetic mesh in the event of infection [13, 22, 24, 25]. This is our preferred technique for open VHR, using large pore PP mesh, and we very rarely remove mesh for infection in this space. Mesh onlay has been shown to have a higher rate of SSO and SSI in many studies [9, 46, 47], but local wound care, including partial mesh excision, can be successful. Mesh infection of intraperitoneal mesh is more difficult to preserve. This may be in part due to differing mesh properties, as mesh placed in an intraperitoneal position typically has some barrier coating designed to prevent visceral adhesions. The effect of these various tissue-separating layers on bacterial adherence and infection is unknown. Additionally, mesh placed over the peritoneum does not necessarily truly incorporate into the abdominal wall; rather, a neoperitoneum forms over the visceral mesh surface and the mesh is held to the abdominal wall by this thin layer and whatever fixation was used to secure the mesh. This is evidenced clinically in our experience with mesh removal, which typically peels off of the abdominal wall quite easily, leaving the posterior rectus sheath and even native peritoneum intact. In our experience with over 10 years of infected mesh management, we have found intraperitoneal mesh infection to be rarely salvageable, while large pore PP mesh placed in the retromuscular space was preserved 100 % of the time [14, 23].

Any attempt at mesh salvage should be accompanied by appropriate antibiotic therapy. Whenever possible, cultures should be obtained and therapy tailored to the organism grown. In the absence of speciation of the causative organism, empiric antibiosis should be directed toward the most common associated bacteria as noted above. There is currently no data to guide duration of therapy, or the most appropriate route of treatment, whether oral or parenteral. In the event of complete mesh explantation, once the offending

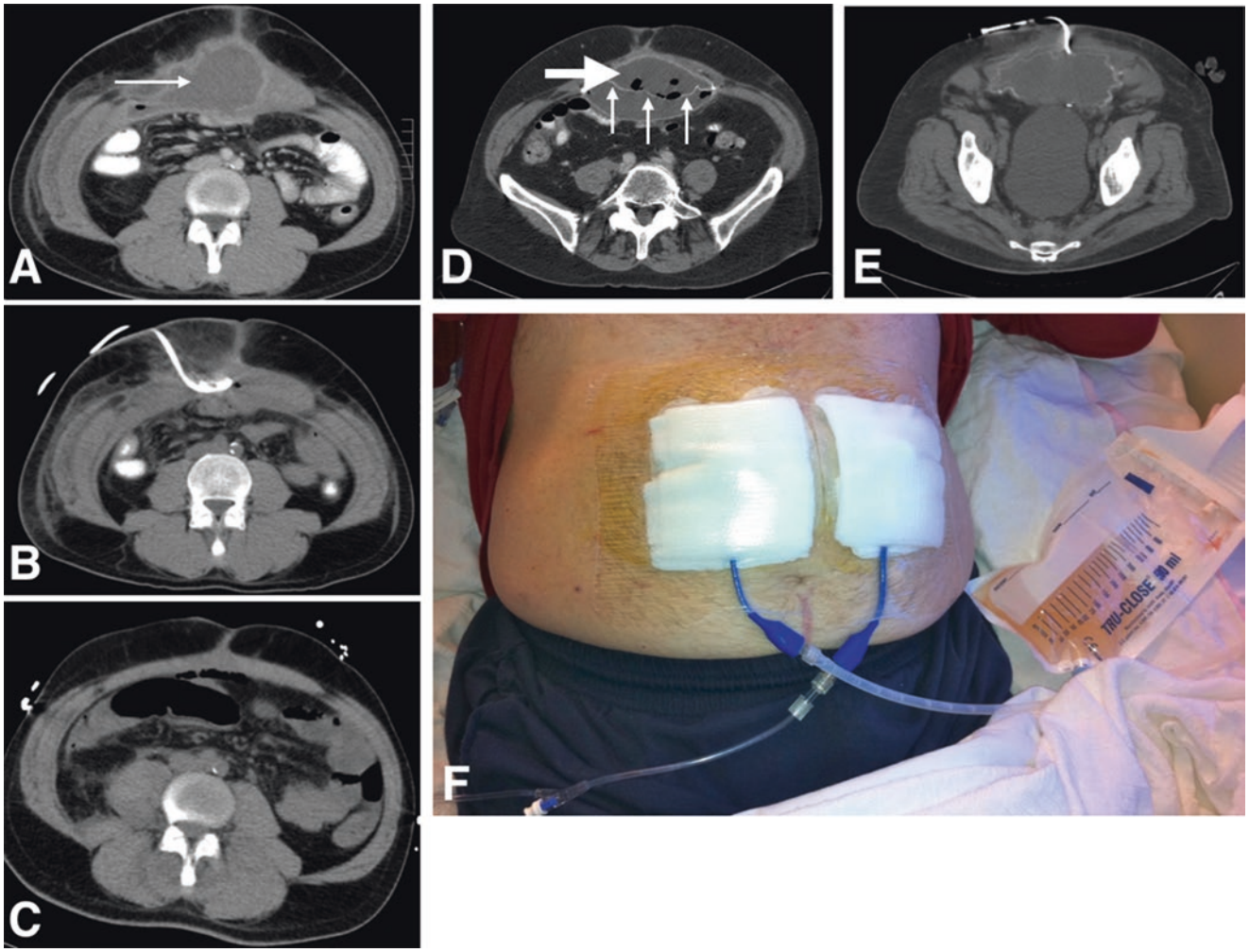

Fig. 50.6 (**a**) CT demonstrating periprosthetic SSI (*arrow*) after retromuscular repair with large-pore PP. (**b**) Percutaneous drainage of deep SSI. (**c**) Resolution of mesh infection at 3 months. (**d**) CT demonstrating periprosthetic infection (*large arrow*) after LVHR with IPOM (*arrows*). (**e**) Percutaneous drainage of fluid collection. (**f**) Daily antibiotic irrigation via percutaneously placed drains

prosthetic is removed, there should be relatively little need for continued antibiosis. These decisions are left to the judgment of the treating surgeon, guided by microbiologic data and local antibiograms.

50.4.4 Percutaneous Drainage

Percutaneous drainage of periprosthetic fluid collections after VHR is an excellent initial intervention for confirmed or suspected infection. Kuo et al. were able to successfully salvage 16 of 21 mesh infections with percutaneous drainage and antibiotic therapy. Greater success was seen with PP mesh than ePTFE, with 40 % of the ePTFE requiring eventual explantation, compared to just 14 % of PP meshes [48]. Similar poor salvageability was seen with infected ePTFE in other series, ranging from 36 to 100 % rates of explantation [13, 14, 21, 29]. The addition of antibiotic irrigation of the mesh via the drain may increase the likelihood of successful percutaneous treatment [15]. Aguilar et al. reported three cases of successfully salvaged intraperitoneal PTFE mesh using percutaneous drainage, long-term parenteral antibiotics, and thrice daily gentamycin irrigation through the drain [49]. Figure 50.6 shows successful mesh salvage with percutaneous drainage.

50.4.5 Negative Pressure Wound Therapy

Negative pressure wound therapy can be employed for mesh preservation as well, with excellent reported results (Fig. 50.7). Berrevoet et al. applied NPWT to a total of 63 patients with infection following VHR. Of 30 patients repaired with PP mesh in a retromuscular position who developed a deep SSI, none required mesh explantation. Conversely, three of nine patients with mesh in the intraperitoneal position

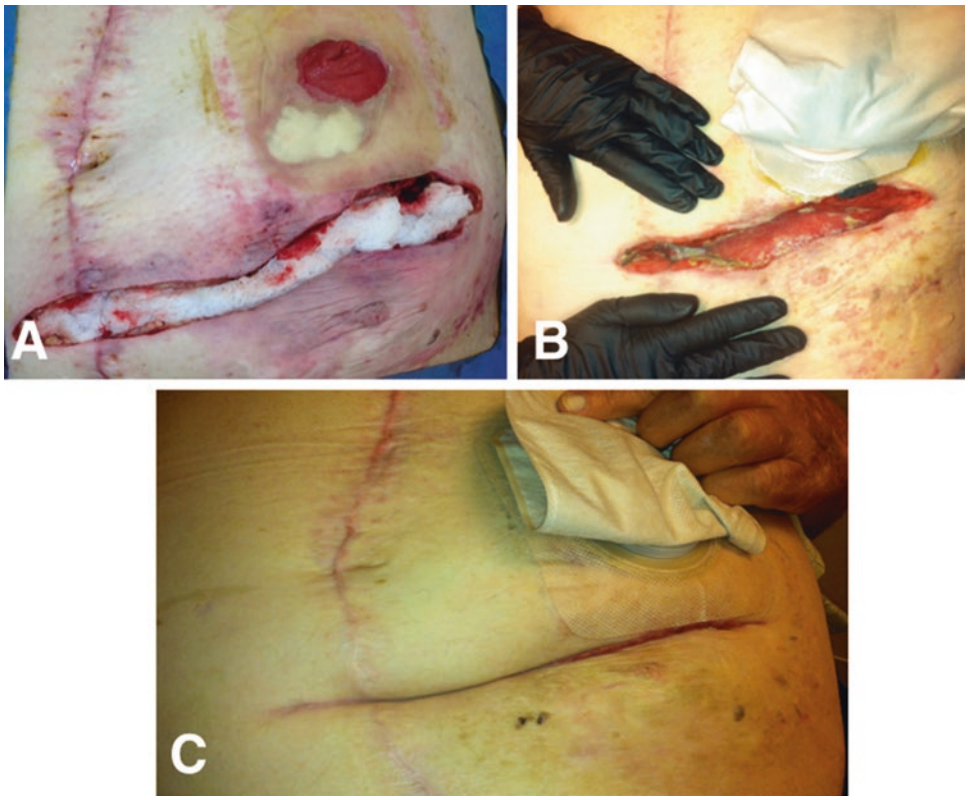

Fig. 50.7 (**a**) Local wound care, initially with WTD for infected, exposed large-pore, midweight polypropylene mesh. (**b**) After 3 weeks of NPWT. (**c**) 3 months of therapy. No further wound or mesh complications

who developed a prosthetic infection required excision, all of which were PET-based meshes. One patient developed a chronic enterocutaneous fistula through a composite mesh, while the remaining five PP meshes were able to be salvaged successfully [22]. Stremitzer et al. similarly used NPWT in their treatment algorithm for infected mesh, salvaging 100 % of large-pore polyglactin/polypropylene mesh, but only 23 % of ePTFE and 20 % of pure PP mesh. The lower salvage rate of PP in this study may be accounted for by use of heavier weight, smaller pore mesh, or its location in the abdominal wall, neither of which is clearly stated in the manuscript [8]. Twelve of 13 meshes were successfully salvaged with NPWT reported by Meagher et al. though the operative technique was not clearly discussed and four different mesh types were used [50]. The effectiveness of NPWT seems to be due to alterations in the cytokine milieu, enhanced angiogenesis, endothelial proliferation, and reduced edema, thereby promoting granulation and wound healing [50].

50.4.6 Mesh Excision

Despite maximal conservative therapy, mesh explantation will still be required 3–67 % of cases [29, 44]. Partial mesh excision, removing only the unincorporated or grossly infected portions of the mesh, can be successfully employed in order to minimize the operative morbidity and risk of recurrence [51, 52]. Sabbagh et al. successfully managed 23 of 25 patients presenting with mesh infection using partial excision only, with a recurrence rate at 40 months of just 20 % [52]. In our practice, partial excision is primarily used only after failure of conservative measures when mesh is exposed through an open abdominal wound. We have had good success with this approach when needed for polypropylene, but multifilament polyester, ePTFE, and composite mesh more often require complete removal.

For intraperitoneal prosthetic infection, mesh can often be removed laparoscopically. This approach avoids a large midline incision and the associated soft tissue SSI risk, facilitating a more rapid initial recovery and typically avoids any complex wound care. Adhesiolysis, as with any reoperation in the presence of intraperitoneal mesh, can be difficult. However, once the mesh is exposed, its removal from the abdominal wall is relatively easy, and the entire mesh, including all fixation constructs, can be removed. The mesh can be retrieved through a 12 mm port site in most instances, or can be cut intracorporeally to facilitate removal. This is our preferred method for removing infected intraperitoneal mesh.

In the event that complete mesh excision is necessary, management of the abdominal wall defect must be considered. This is most appropriately staged in the majority of cases, addressing the immediate need for mesh removal in order to resolve the chronic infection and delaying definitive

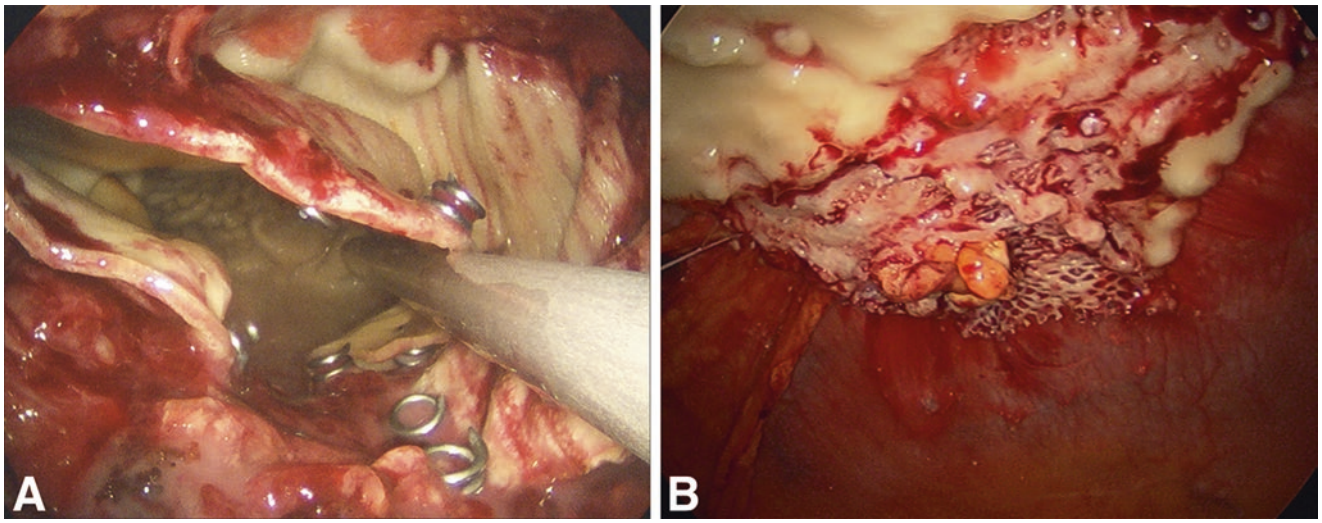

Fig. 50.8 (**a**) Laparoscopic complete excision of infected ePTFE mesh. (**b**) Laparoscopic removal of infected barrier coated polypropylene

hernia repair. If laparoscopic removal of intraperitoneal mesh is possible, that is our preferred approach (Fig. 50.8), followed by definitive VHR 3–6 months later. If open explantation is performed, we make every attempt to reapproximate the fascia upon removal of the mesh. This limits the immediate hernia morbidity to the patient, and allows the inevitable recurrence to be repaired in an elective, clean setting. Single-stage repair is possible, and has been successfully reported using both biologic and synthetic meshes with reasonable outcomes [12, 35]. In our practice, this is done very selectively. When the degree of contamination related to the prosthetic infection is relatively low, the abdominal wall tissue is healthy with limited inflammation, and new mesh can be readily placed into the retromuscular compartment, completely isolated from the peritoneal cavity and the site of infected mesh, we have successfully performed single-stage repair using large-pore PP mesh with minimal wound morbidity and without subsequent mesh removal.

50.5 Prevention of Mesh Infection

Strategies to reduce the risk of developing an SSI are critical in order to reduce the potential of mesh infection. This begins with the initial evaluation, patient selection, and operative planning. Optimization of patient comorbidities, including control of diabetes, smoking cessation, and weight loss, is critical to minimize the risk of SSO and SSI. Perioperative and intraoperative measures include appropriate selection of perioperative prophylactic antibiotics, meticulous sterile technique, careful handling of the prosthetic to minimize contact with both the external environment and the patients' skin, and appropriate postoperative wound management.

Operative approach clearly impacts the risk of postoperative SSI and prosthetic mesh infection. Laparoscopy significantly decreases the rate of postoperative SSI and mesh infection compared to open VHR [1, 47, 53–55]. However, not every patient is a candidate for laparoscopic repair. Patients with very large defects are not only more technically difficult, but also have a higher rate of recurrence and mesh eventration through the hernia defect [53, 56]. Poor skin condition, such as chronic wounds, prior skin graft, or wide laparotomy scars, is often not appropriate for LVHR. Finally, despite the overall reduction in SSI and mesh infection for LVHR, there are potential long-term risks of intraperitoneal mesh, particularly in the event of subsequent abdominal operations, including enteroprosthetic fistula, secondary mesh infection, and difficult adhesiolysis or enterotomy [23, 57, 58]. While these complications are relatively uncommon, consideration for extraperitoneal mesh placement must be given for patients who may be at higher risk of subsequent operations. The rate of reoperation has been reported between 17 and 25 %, resulting in prolonged operative times, increased risk of postoperative SSI, and up to a 20 % risk of enterotomy or unplanned bowel resection [29, 44, 59, 60]. While the precise risk of secondary mesh infection is unknown, in our own experience, 60 % of patients treated for a mesh infection had an intervening operation between their index hernia repair and presentation with prosthetic infection [23].

Operatively, we have employed several techniques to minimize the risk of SSI. We routinely use an iodine-impregnated drape for all hernia cases. Iodine exhibits bactericidal activity with penetrance into the deeper dermal layer of skin and shows effective antimicrobial activity against MRSA [61]. A recent prospective study in cardiac surgery patients demon-

strated a significant benefit of iodine-impregnated drape in both development of superficial SSI and cost [62]. However, a recent Cochrane review failed to substantiate this finding, concluding there was no benefit to the use of adhesive drapes, either iodine-impregnated or non, in the prevention of SSI [63]. We also do not open any mesh prosthesis until we are ready to place it into the abdominal wall. Prior to opening the mesh, all team members change their outer gloves, and only the operating surgeon handles the mesh. The routine change of outer gloves has been shown to decrease the rate of bacterial contamination, though it is unknown if this translates to an actual decrease in SSI [64]. Finally, we use an antibiotic irrigation of 240 mg of Gentamycin and 600 mg of Clindamycin once the mesh is implanted during open VHR, letting this dwell for 3–4 min before evacuating. While there is no evidence that this affects outcomes for VHR, this protocol has shown significant reduction in SSI following colorectal surgery [65].

Modification of materials to confer antimicrobial properties is another area of interest in prevention of mesh infection. In experimental models, impregnation of prosthetic with various antibiotics, including cefazolin, gentamycin, allicin-chlorhexidine, ofloxacin, amoxicillin, or vancomycin, significantly inhibits *S. aureus* growth [66–70]. The antimicrobial silver-chlorhexidine coating of DualMesh Plus (W.L. Gore) is the only mesh known to demonstrate bactericidal properties [18, 71]. However, there is only one clinical trial evaluating the effect of antimicrobial mesh on SSI during VHR. Yabanoglu et al. showed no difference in SSI after implantation of vancomycin-impregnated mesh in a small randomized control trial [72].

50.6 Conclusion

Management of prosthetic mesh infection presents a number of unique challenges for the treating surgeon. With little clear evidence in the literature to support a single optimal approach, clinical judgment is paramount. Mesh salvage is possible in a variety of settings and mesh types, usually requiring a multimodal approach, and should be attempted in most cases. Large-pore monofilament mesh seems to be salvable in a majority of cases, particularly when placed in an extraperitoneal position, while microporous, multifilament, and composite meshes typically require explantation. When mesh removal is required, hernia recurrence is almost a certainty. As with many surgical complications, prevention is crucial. Optimization of patient comorbidities, patient selection, perioperative management, operative approach, and meticulous technique all play an important role in the development of, and therefore the prevention of, mesh infection. Research of best practices in surgical technique, perioperative care, and mesh materials is ongoing, and much remains to be learned on prevention and management of this complex and potentially devastating complication.

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W.W. Hope et al. (eds.), *Textbook of Hernia*, DOI 10.1007/978-3-319-43045-4