REPAIR OF VENTRAL ABDOMINAL WALL HERNIAS

Clayton C. Petro, MD, and Michael J. Rosen, MD, FACS*

Requiring almost 350,000 annual operations, the repair of noninguinal abdominal wall defects is one of the most common procedures performed by general surgeons.1 Despite the frequency of ventral hernia repair, there is little consensus in the literature as to the ideal approach for this difficult problem. Variability in patient comorbidities, hernia dimensions, wound class, prosthetic choice, and technique make standardized algorithms difficult to define. In the past, personal recollections and single-center series were the principal data sources that surgeons relied on in choosing the optimum treatment strategy. In recent years, population-based studies have provided better data on the true failure rates associated with the various herniorrhaphies. In addition to recurrence, wound morbidity has simultaneously emerged as an important outcome measure and definitions by the Ventral Hernia Working Group (VHWG) have begun to standardize such benchmarks. Ultimately, future evidence will be begotten from large multi-institutional collaborations that are currently being formed. Needless to say, ventral hernia repair has grown into a complex, dynamic field with exciting evolutions in technique, prosthetic choice, and patient complexity. A once oversimplified topic has now become an area with more controversy and less clarity. Importantly, debate has fueled investigation and collaboration that hope to provide the evidence-based guidance that is desperately needed. As such, the future of ventral hernia repair is bright.

In this topic review, we describe classic operations for noninguinal abdominal wall hernias as well as newly developed techniques. In the repair of abdominal wall defects, the surgeon must consider a multitude of factors to identify the appropriate surgical technique to accomplish the reconstructive goals. Given that a full spectrum of patients develop hernias, it is unlikely that any single technique will be appropriate for all hernias. An individualized approach is needed to find the appropriate procedure. To do this, all surgeons must familiarize themselves with important factors such as patient comorbidities, physiologic status, defect size, available local tissue, and presence of contamination. Likewise, an understanding of the available reconstructive techniques and an honest assessment of the surgeon’s ability to perform each of these techniques should guide the surgeon in establishing the most appropriate repair for the patient. A well-known surgical dictum states that when numerous different operations exist to treat the same disease, the perfect procedure does not exist. This dictum holds true for abdominal wall herniorrhaphy; as the disease is so heterogeneous, different techniques are needed to address individual patients’ needs.

Epidemiology

In the United States, approximately 1,000,000 abdominal wall herniorrhaphies are performed each year, of which 750,000 are for inguinal hernias, 166,000 for umbilical hernias, 97,000 for incisional hernias, 25,000 for femoral hernias, and 76,000 for miscellaneous hernias.2 In 2006, the cost of 348,000 ventral hernia repairs in the United States was $3.2 billion, and a recent market analysis predicted that hernia repair devices would be a $5.9 billion global industry by 2019.3,4 The prevalence of abdominal wall hernias is difficult to determine as the wide range of published figures in the literature illustrates. The major reasons for this difficulty are (1) the lack of standardization in how ventral hernias are defined; (2) the inconsistency of the data sources used (which include self-reporting by patients, audits of routine physical examinations, and insurance company databases, among others); (3) the subjectivity of physical examination, even when performed by trained surgeons; and (4) the lack of long-term follow-up on all patients with previous surgery at risk for developing incisional hernias.

The incidence of an incisional hernia, for instance, depends on how the condition is defined. The best definition of incisional hernia is any abdominal wall gap, with or without a bulge that is perceptible on clinical examination or diagnostic imaging within 1 year after the index operation. A definition that requires the presence of a visible bulge will lead to underestimation of the true incidence of the condition. The reported incidence of incisional hernia after a midline laparotomy ranges from 11 to 23% and doubles if the index operation was associated with infection.4,5 Incisional hernias are most common after midline and transverse incisions but are also well documented after paraxiphoid, subcostal, McBurney (gridiron), and Pfannenstiel incisions.6 An analysis of 11 publications dealing with ventral hernia incidence after various types of incisions concluded that the risk was 10.5% for midline incisions, 7.5% for transverse incisions, and 2.5% for paramedian incisions.7 A randomized controlled trial comparing midline versus transverse incisions did not find a difference in analgesia use, pulmonary complications, or hernia recurrence after 1 year but did find increased wound infections in the transverse incision group.8 Muscle-splitting incisions probably have a lower incidence of incisional hernias, but such incisions restrict access to the abdominal cavity and can potentially hinder creation of an ostomy in an emergent laparotomy. Long-term function of the abdominal core musculature must also be considered. Given similar recurrence rates between midline and transverse incisions, the operative visualization required should dictate the choice of incision. Most incisional hernias are detected within 1 year of surgery. Clinically, separation of the wound edges by more than 12 mm or separation of the rectus muscles on a

* The authors and editors gratefully acknowledge the contributions of the previous author, Karem Harth, MD, MHS, to the development and writing of this topic review.
computed tomographic (CT) scan within 1 month of a laparotomy were both found to be predictive of an incisional hernia. The male-to-female incidence ratio is 1:1, even though early evisceration is more common in males.

At present, little information is available on the risk of major complications arising from untreated noninguinal abdominal wall hernias. The main reason for this scarcity of data is that surgeons are taught, first, that all hernias, even asymptomatic ones, should be repaired at diagnosis to prevent potential strangulation or bowel obstruction and, second, that herniorrhaphy becomes more difficult the longer the repair is delayed. As a result, it is difficult to find a whole population in which at least some of the members do not routinely have their hernias repaired regardless of symptoms. In these circumstances, accurate estimates of the natural history of the disease are impossible to know.

Classification

Unfortunately, a universal classification system for abdominal wall hernias has not been accepted. The benefits of such a system would be uniformity between studies comparing technique and the subsequent exchange of homogeneous information. The European Hernia Society (EHS) proposed separate classification schemes for primary and incisional hernias in 2009. Because of the symmetrical dimensions of primary hernias, experts agreed on a simple system, which classifies these herniations based on diameter and location [see Table 1]. Although experts agreed on this system, it should be noted that this scheme has not been validated to show any meaningful association between subtype and outcomes.

The EHS classification system for incisional hernias was more complex, including nine potential locations on the abdominal wall, as well as length, width, and recurrent nature. Although experts agreed that there was likely a relationship between width and recurrence, categories for width could not be agreed on, and cutoffs were somewhat arbitrarily chosen. In an attempt to validate these classification variables, we characterized 333 hernia patients by preoperative CT scan using this system. With regard to hernia recurrence and wound morbidity, we found no association with hernia length, location, or recurrent nature. These findings are corroborated by data from Chevrel and Rath. Interestingly, with width cutoffs of less than 10 cm, 10 to 20 cm, and 20 cm or greater, we identified associations with hernia wound morbidity and recurrence. Therefore, width appears to be the incisional hernia dimension with the most meaningful ties to short- and long-term morbidity.

Intuitively, patient and wound characteristics also contribute to wound morbidity after incisional hernia repair. To properly stratify patients by their risk of developing a wound complication, the VHWG was established to generate uniform definitions and risk groups based on expert opinion. Wound morbidity, defined as a surgical site occurrence (SSI), was officially described as an infection, seroma, hematoma, wound dehiscence, or enterocutaneous fistula. Infections were further subclassified into definitions used by the Centers for Disease Control and Prevention (CDC): wound cellulitis, stitch abscess, and surgical site infection (SSI), which could further be broken down into superficial, deep, and organ space. The VHWG then formulated a grading system that would risk stratify patients’ risk of developing an SSO after incisional hernia repair. In an attempt to validate this system, we characterized wound morbidity in 299 hernia repairs at our institution and were able to consolidate the original four-tiered system into a three-tiered modified VHWG Grading Scale [see Table 2]. To summarize, grade 1 patients are healthy, with a low risk of wound morbidity. Grade 2 patients have comorbidities or a history of a wound infection, and grade 3 patients have some degree of wound contamination and can be further divided into 3a (clean-contaminated), 3b (contaminated), or 3c (dirty/infected) based on CDC wound class.

Acknowledging that hernia characteristics (i.e., width), patient comorbidities, and wound class are all important contributors to both wound morbidity and hernia recurrence, we sought to create a simple, unified classification system for incisional hernias that would incorporate all of these variables. Akin to the “TNM” model for cancer staging, we created an “HPW” staging system for incisional hernias. Hernias (H) would be characterized by width (< 10 cm, 10–20 cm, ≥ 20 cm) and patient (P) comorbidities/ wound (W) class summarized by our modified VHWG Grading Scale (grade 1 = healthy, grade 2 = comorbid, grade 3 = contaminated). Permutations with similar complication profiles would be grouped accordingly. The result is an HPW staging system that ordinarily ranks stages (I to IV) by the risk of developing an SSO and hernia recurrence [see Table 3]. This system is comprehensive, evidence based, and easy to remember and predicts both short-term (SSO) and long-term (recurrence) morbidity [see Table 4].

In summary, a uniform classification system will provide the platform for inclusion/exclusion criteria in future investigations regarding technique, prosthetic choice, and perioperative optimization. The importance of defining our patients in a thoughtful and consistent manner will provide meaningful outcomes research that is both widely accepted and widely applicable.

### Table 1: EHS Classification for Primary Ventral Hernias

<table>
<thead>
<tr>
<th>Classification</th>
<th>Type</th>
<th>Diameter (cm)</th>
<th>Small (&lt; 2 cm)</th>
<th>Medium (&gt; 2–4 cm)</th>
<th>Large (&lt; 4 cm)</th>
</tr>
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<tbody>
<tr>
<td>Midline</td>
<td>Epigastric</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Umbilical</td>
<td></td>
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<tr>
<td>Lateral</td>
<td>Spigelian</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Lumbar</td>
<td></td>
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</table>

EHS = European Hernia Society.
**Anatomy**

Anterior and lateral cutaneous branches of the ventral rami of the seventh through 12th intercostal nerves and ventral rami of the first and second lumbar nerves innervate the skin of the lower anterior abdominal wall. These nerves course between the transversus abdominis and internal oblique muscles with a corresponding intercostal artery/vein and intermittently provide branches to the skin and subcutaneous tissue. Importantly, these neurovascular bundles continue medially and pierce the posterior rectus sheath between the aponeuroses of the internal oblique and transversus abdominis muscles before providing innervation to the rectus abdominis muscle [see Figure 1]. A thorough appreciation for the pathway of these nerves and vessels is critical if they are to be preserved during abdominal wall dissection, particularly during myofascial releases.16

The first layers encountered beneath the skin are the Camper and Scarpa fasciae in the subcutaneous tissue. The only significance of these layers is that when sufficiently developed, they can be reapproximated to provide another layer between a repaired abdominal wall and the outside.

**Table 2**  
VHWG Grading Scale and Modification

<table>
<thead>
<tr>
<th>Grade</th>
<th>Original VHWG Characteristics</th>
<th>Modified VHWG Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low risk of complications, no history of wound infection</td>
<td>No medical comorbidities; history of wound infection or contamination</td>
</tr>
<tr>
<td>2</td>
<td>Smoker, obese, diabetic, immunosuppressed, COPD</td>
<td>Smoker, obese, diabetic, COPD, previous wound infection</td>
</tr>
<tr>
<td>3</td>
<td>Previous wound infection, stoma present, violation of the GI tract</td>
<td>Presence of contamination: 3A = clean-contaminated; 3B = contaminated; 3C = dirty/contaminated</td>
</tr>
<tr>
<td>4</td>
<td>Infected mesh, septic dehiscence</td>
<td>—</td>
</tr>
</tbody>
</table>

COPD = chronic obstructive pulmonary disease; GI = gastrointestinal; VHWG = Ventral Hernia Working Group.

**Table 3**  
HPW Incisional Hernia Staging System

<table>
<thead>
<tr>
<th>Grade</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 10 cm</td>
</tr>
<tr>
<td>1</td>
<td>H1, P0, W0 (I)</td>
</tr>
<tr>
<td>2</td>
<td>H1, P1, W0 (II)</td>
</tr>
<tr>
<td>3</td>
<td>H1, W1 (III)</td>
</tr>
</tbody>
</table>

1–IV = stage; H = hernia; H1 = < 10 cm, H2 = 10–20 cm, H3 = ≥ 20 cm; P = patient; P0 = healthy, P1 = comorbid; W = wound; W0 = clean; W1 = contaminated.

*Obese, diabetes mellitus, chronic obstructive pulmonary disease, smoker, history of wound infection.

1 Low risk of complications, no history of wound infection No medical comorbidities; history of wound infection or contamination
2 Smoker, obese, diabetic, immunosuppressed, COPD Smoker, obese, diabetic, COPD, previous wound infection
3 Previous wound infection, stoma present, violation of the GI tract Presence of contamination: 3A = clean-contaminated; 3B = contaminated; 3C = dirty/contaminated
4 Infected mesh, septic dehiscence —

**Table 4**  
Associated Outcomes of HPW Incisional Hernia Staging System

<table>
<thead>
<tr>
<th>Stage</th>
<th>SSO Rate (%)</th>
<th>Recurrence Rate (%)</th>
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<tbody>
<tr>
<td>I</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>II</td>
<td>12.5</td>
<td>11.4</td>
</tr>
<tr>
<td>III</td>
<td>26.4</td>
<td>15.2</td>
</tr>
<tr>
<td>IV</td>
<td>42.3</td>
<td>34.6</td>
</tr>
</tbody>
</table>

SSO = surgical site occurrence.
Figure 1  Cross-sectional anatomy of the abdominal wall. Note the medial insertion of the transversus abdominis fascia onto the posterior rectus sheath, medial to the linea semilunaris. The posterior rectus sheath only consists of fibers from the internal oblique fascia until contributions from the transversus abdominis muscle. The lateral neurovascular bundles supplying the rectus muscle travel between the internal oblique and transversus abdominis muscle and pierce the posterior rectus sheath before the insertion of the transversus abdominis fascia.

Figure 2  The great flat muscles of the abdominal wall, depicting the relationship of the great muscles to the groin.
over the round ligament or the spermatic cord, forming the superficial part of the internal (deep) inguinal ring.

Beneath the internal oblique muscle is the transversus abdominis. This muscle arises from the inguinal ligament, the inner side of the iliac crest, the endoabdominal fascia, and the lower six costal cartilages and ribs, where it interdigitates with the lateral diaphragmatic fibers. The medial aponeurotic fibers of the transversus abdominis contribute to the rectus sheath and insert on the pecten ossis pubis and the crest of the pubis, forming the falx inguinialis. Infrequently, these fibers are joined by a portion of the internal oblique aponeurosis; only when this occurs is a true conjoined tendon formed.26 Regarding its contribution to the posterior rectus sheath above the arcuate line, it is important to note that the aponeuroses of the transversus abdominis insert onto the posterior rectus sheath medially to the linea semilunaris. As such, there is a space between the linea semilunaris and the insertion of the transversus abdominis aponeuroses insertion point, where the posterior rectus sheath only consists of posterior fibers from the internal oblique aponeuroses. It is in this space that intercostal neurovascular bundles travel and pierce the posterior rectus sheath to supply the rectus muscle. Again, understanding this subtlety is critical during myofascial dissections.16

Aponeurotic fibers of the transversus abdominis also form the structure known as the aponeurotic arch. It is theorized that contraction of the transversus abdominis causes the arch to move downward toward the inguinal ligament, thereby constituting a form of shutter mechanism that reinforces the weakest area of the groin when intra-abdominal pressure is raised. The area beneath the arch varies. Many authorities believe that a high arch, resulting in a larger area from which the transversus abdominis is, by definition, absent, is a predisposing factor for a direct inguinal hernia. The transverse aponeurotic arch is also important because the term is used by many authors to describe the medial structure that is sewn to the inguinal ligament in many of the older inguinal hernia repairs.

The rectus abdominis forms the central anchoring muscle mass of the anterior abdomen. It arises from the fifth through seventh costal cartilages and inserts on the pubic symphysis and the pubic crest. It is innervated by the seventh through 12th intercostal nerves, which laterally pierce the aponeurotic sheath of the muscle. The semilunar line is the slight depression in the aponeurotic fibers coursing toward the muscle. In a minority of persons, the small pyramidalis muscle accompanies the rectus abdominis at its insertion. This muscle arises from the pubic symphysis. It lies within the rectus sheath and tapers to attach to the linea alba, which represents the conjunction of the two rectus sheaths and is the major site of insertion for three aponeuroses from all three lateral muscle layers. The line of Douglas (i.e., the arcuate line of the rectus sheath) is formed at a variable distance between the umbilicus and the inguinal space because the fasciae of the large flat muscles of the abdominal wall contribute their aponeuroses to the anterior surface of the muscle, leaving only transversalis fascia and underlying peritoneum to cover the posterior surface of the rectus abdominis.

The innervation of the anterior wall muscles is multifaceted. The seventh through 12th intercostal nerves and the first and second lumbar nerves provide most of the innervation of the lateral muscles, as well as of the rectus abdominis and the overlying skin. As previously mentioned, the nerves pass anteriorly in a plane between the internal oblique muscle and the transversus abdominis, eventually piercing the lateral aspect of the rectus sheath to innervate the muscle therein. The external oblique muscle receives branches of the intercostal nerves, which penetrate the internal oblique muscle to reach it. The anterior ends of the nerves form part of the cutaneous innervation of the abdominal wall. The first lumbar nerve divides into the ilioinguinal nerve and the iliohypogastric nerve [see Figure 3]. These important nerves lie in the space between the internal oblique muscle and the external oblique aponeurosis. They may divide within the psoas major or between the internal oblique muscle and the transversus abdominis. The ilioinguinal nerve may communicate with the iliohypogastric nerve before innervating the internal oblique muscle. The ilioinguinal nerve then passes through the external inguinal ring to run parallel to the spermatic cord, whereas the iliohypogastric nerve pierces the external oblique muscle to innervate the skin above the pubis. The cremaster muscle fibers—derived from the internal oblique muscle—are innervated by the genitofemoral nerve. Notably, there can be considerable variability and overlap.

The blood supply of the lateral muscles of the anterior wall comes primarily from the lower three or four intercostal arteries, the deep circumflex iliac artery, and the lumbar arteries. The rectus abdominis has a complicated blood supply that derives from the superior epigastric artery (a terminal branch of the internal thoracic (internal mammary artery), the inferior epigastric artery (a branch of the external iliac artery), and the deep circumflex iliac artery. The rectus abdominis is perforated by numerous vessels from the intercostal arteries near the costal margin. These vessels supply the deep part of the rectus abdominis, the internal oblique muscle, and the posterior part of the external oblique muscle.

Figure 3 The important nerves of the lower abdominal wall.
iliac artery), and the lower intercostal arteries. The lower intercostal arteries enter the sides of the muscle after traveling between the oblique muscles; the superior and the inferior epigastric arteries enter the rectus sheath and Anastomose near the umbilicus. Preservation of superficial perforators in this region during the creation of skin flaps for anterior component separation has been described as a way to decrease complications such as the aforementioned skin flap necrosis.\(^19\)

The endoabdominal fascia is the deep fascia covering the internal surface of the transversus abdominis, the iliacus, the psoas major and minor, the obturator internus, and portions of the peristeme. It is a continuous sheet that extends throughout the extraperitoneal space and is sometimes referred to as the wallpaper of the abdominal cavity. Commonly, the endoabdominal fascia is subclassified according to the muscle being covered (e.g., iliac fascia or obturator fascia).

Between the transversalis fascia and the peritoneum is the preperitoneal space. In the midline behind the pubis, this space is known as the space of Retzius; laterally, it is referred to as the space of Bogros. The preperitoneal space is of particular importance for surgeons because several hernia repairs (see below) are performed in this area. The inferior epigastric vessels, the deep inferior epigastric vein, the iliopectineal fascia, the rectus femoris, the internal spermatic vessels, the vas deferens, and even the inferior vena cava can all be encountered via this space.\(^20\)

**Choice of Prosthetic**

Long-term follow-up has confirmed the superiority of prosthetic mesh reinforcement over primary fascial closure for all but the smallest abdominal wall hernias.\(^21,22\) A multitude of prosthetic grafts are currently available, all with their own unique advantages and disadvantages. Most synthetic prosthetic grafts can be categorized as derived from polypropylene, polyester, or polytetrafluoroethylene (PTFE). Uscher is credited with developing polypropylene mesh and introduced it in the early 1960s.\(^23\) Since its introduction, there has been an increase in use. An American population-based study of approximately 11,000 patients reflected an increase in mesh use for hernia repair from 35% in 1987 to 65% by 1999.\(^24\) A detailed discussion comparing various prosthetic materials is beyond the scope of this topic review; however, some general statements may be made.

The use of mesh presupposes a situation in which the prosthesis can be isolated from contact with intra-abdominal viscera by one or more layers of human tissue (e.g., peritoneum, posterior rectus fascia). In situations where contact with intra-abdominal viscera cannot be avoided, a standard synthetic mesh prosthesis should not be used as it causes a significant fibroplastic response and risks subsequent bowel-related complications such as erosion, chronic mesh infection, or enterocutaneous fistula formation.\(^25,26\) Options for intraperitoneal mesh placement include a nonmesh material, such as expanded polytetrafluoroethylene (ePTFE). Unfortunately, the absence of porosity in nonmesh prosthetics prevents incorporation, compels encapsulation, and often elicits an intense foreign-body reaction.\(^27\) A more popular choice for intraperitoneal mesh placement is a dual-layer (“coated”) prosthesis, with a standard plastic mesh on the side facing the abdominal wall (to encourage an intense fibroplastic response) and an adhesion barrier of some type coating the peritoneal side. Numerous dual-sided prosthetics, incorporating a variety of adhesion barriers, are now available [see Table 5]. It has consistently been shown that when these materials are used, adhesions are not only less common but also less tenacious than when mesh alone is used in an intraperitoneal position.\(^28,29\) Often bowel adhesions can be easily wiped from the peritoneal surface of a dual-layer prosthesis with gentle blunt traction, in sharp contrast to the typically tedious and sometimes impossible dissection of bowel loops from an unprotected mesh prosthesis placed directly on the viscera. Although all of the dual-layer prostheses currently on the market are approved for decreasing adhesions to the adhesion barrier side, no manufacturer has sought approval for complete prevention of adhesions. Consequently, the long-term effects of these less severe (but still present) adhesions are unknown. Currently, a prospective multicenter randomized trial is under way to elucidate the difference in adhesion characteristics and adhesion-related complications following intraperitoneal placement of barrier-coated and uncoated synthetic mesh (clinicaltrials.gov protocol number: NCT01355939).

At present, there is some controversy regarding the weight of polypropylene mesh used in abdominal wall hernia repairs, although the controversy almost certainly applies to the other types of mesh prosthesis as well. Data from randomized studies indicate that use of a lightweight polypropylene mesh compared with standard mesh results in similar long-term pain in incisional hernia repair.\(^30\) When used in the setting of inguinal hernia repair, two randomized controlled trials have shown varied results with regard to pain control.\(^30,31\) In the randomized controlled multicenter trial for incisional hernia repair, no difference in recurrence was found at 24 months in the lightweight (17%) versus the standard (7%) mesh repair (\(p = .052\)). However, a closer look at their methodology reveals important considerations. After 24 months, there was approximately 20% loss of

<table>
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<tr>
<th>Table 5</th>
<th>Select Commercially Available Synthetic Prostheses for Abdominal Wall Hernia Repair</th>
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<tbody>
<tr>
<td>Bard Composix E/X Mesh (PPL + ePTFE)</td>
<td></td>
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<tr>
<td>Bard Dulex Mesh (dual-sided) (PPL + ePTFE)</td>
<td></td>
</tr>
<tr>
<td>Bard Kugel Hernia Patch (PPL + ePTFE + PPL ring)</td>
<td></td>
</tr>
<tr>
<td>Bard Ventralex (PPL + ePTFE + PPL tail)</td>
<td></td>
</tr>
<tr>
<td>Bard Sepramesh (PPL + Seprafilm)</td>
<td></td>
</tr>
<tr>
<td>Covidien Parietene (PPL + hydrophilic collagen)</td>
<td></td>
</tr>
<tr>
<td>Covidien Parietex (POL + hydrophilic collagen)</td>
<td></td>
</tr>
<tr>
<td>Ethicon Prolene Soft Mesh (PPL)</td>
<td></td>
</tr>
<tr>
<td>Ethicon Proceed (PPL + PDS + ORC)</td>
<td></td>
</tr>
<tr>
<td>Ethicon Ultrapro (PPL + poliglecaprone 25)</td>
<td></td>
</tr>
<tr>
<td>Ethicon Vieryl Knitted Mesh</td>
<td></td>
</tr>
<tr>
<td>Gore Soft Tissue Patch (ePTFE)</td>
<td></td>
</tr>
<tr>
<td>Gore DualMesh (ePTFE)</td>
<td></td>
</tr>
<tr>
<td>Gore DualMesh Plus (ePTFE + silver + chlorhexidine)</td>
<td></td>
</tr>
<tr>
<td>Gore MycroMesh (ePTFE)</td>
<td></td>
</tr>
<tr>
<td>Gore Infinet mesh (knitted PTFE)</td>
<td></td>
</tr>
<tr>
<td>Atrium CQur (PPL + omega-3 fatty acid coating)</td>
<td></td>
</tr>
</tbody>
</table>

\(^{\text{ePTFE} = \text{expanded polytetrafluoroethylene}}; \text{ORC} = \text{oxidized regenerated cellulose}}; \text{POL} = \text{polyester}; \text{PPL} = \text{polypropylene.} \)
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...follow-up for each lightweight and standard mesh group, which may have underpowered their ability to detect a statistically significant difference. Also, technical variables may have impacted the observed hernia recurrence rates, including poor cephalad mesh tissue coverage and use of absorbable sutures to secure the mesh and close the midline. Recently, we found an alarming recurrence rate of 22% in patients repaired with lightweight monofilament polyester mesh.33 Central mesh failure was noted on reoperation in seven of eight recurrences that occurred on average 13 months after initial repair. Whether this is a function of a single prosthetic or a foreshadowing of all lightweight mesh limitations remains to be seen.

Lighter-weight mesh has several other benefits. Larger pore size has been affiliated with more bridging fibrosis and less foreign-body reaction.27,34 Lightweight mesh also addresses the theoretical concern about the possible carcinogenic effects of polypropylene, as has been suggested by experimental studies in rats, although it should be kept in mind that there has never been a documented case of a sarcoma developing in a human being as a result of an inguinal hernia prosthesis.35 To illustrate the difference between a lightweight mesh and a normal one, a 7.5 × 15 cm piece of polypropylene mesh (Prolene, Ethicon, Inc., Somerville, NJ) weighs about 80 g/m², whereas a similarly sized piece of a polypropylene–poliglecaprone 25 (Monocryl, Ethicon, Inc.) lightweight mesh (UltraPro, Ethicon, Inc.) weighs less than 30 g/m² after absorption of the poliglecaprone 25 component.

North American surgeons have been slow to accept the use of lightweight mesh for inguinal hernia repair, fearing a higher recurrence rate.30 Many also have some concerns about possible bias in the data, noting that the research supporting the use of lightweight mesh has been almost exclusively funded by industry. Nevertheless, the randomized trials mentioned earlier cannot be entirely discounted. Most likely, lightweight mesh will have a role in abdominal wall reconstruction in appropriately selected patients. Although the limits of this mesh are currently being evaluated in several long-term studies, several comments can be made regarding our experience. In instances where myofascial coverage of the mesh cannot be achieved, or the abdominal wall and muscle is significantly attenuated, we chose to use a heavyweight mesh to help prevent significant bulging or evolutions after repair. Conversely, we prefer the use of lightweight mesh for ostomy reinforcement to theoretically decrease the chance of mesh erosion into the bowel.

The potential for mesh infection is also a topic with significant research in hernia surgery, particularly as mesh infection has been diagnosed as late as 39 months following implantation.36 Inherent mesh characteristics can influence the likelihood of mesh infection and the ability to treat this complication. The hydrophobicity, porosity, and weave characteristics are all important factors that affect the outcomes of mesh sepsis. Although some macroporous mesh (polypropylene, polyester) infections can be treated with local measures, it is very rare to salvage an infected macroporous (PTFE) prosthetic. Several nonrandomized studies have evaluated risk factors for SSI as they relate to different mesh morphologies in the setting of laparoscopic or open incisional hernia repair. Although not initially planning to investigate infection, some studies have found greater potential for infection with ePTFE mesh compared with lower rates with monofilament polypropylene mesh.36,37 Polyester-based materials have varied results in the literature, with some studies showing acceptable rates of infection.36-40

To elucidate favorable synthetic mesh characteristics in regard to bacterial clearance, animal studies have been done to demonstrate clearance of infection. Several authors have demonstrated that multifilament, coated, antiadhesive barriers and laminar, antimicrobial-impregnated meshes decreased bacterial clearance rates compared with monofilament, unprotected equivalents.41-43 Macroporosity has also been demonstrated to improve bacterial clearance.44 These data led us to use monofilament polypropylene in almost all circumstances.

The quest for the perfect mesh has driven the introduction of a wide variety of synthetic meshes into the market since the 1960s. More recently, one of the fastest growing markets for hernia repair is that for prosthetics derived from animal or human tissue called biologics [see Table 6]. The widespread use of these grafts in abdominal wall reconstruction has resulted in close to 400 million dollars spent on biologic grafts in the United States in 2007. The fear of potential complications associated with synthetic mesh such as chronic infection, bowel erosion, enterocutaneous fistula formation, and reoperation have driven the appeal of these expensive alternatives.

The sources of biologic grafts (human, porcine, bovine), their processing techniques (cross-linked and non–cross-linked), and their sterilizing techniques (radiation, ethylene oxide gas sterilization, or nonsterilization) are widely variable. Theoretically, collagen matrices or bioscaffolds provide the platform for tissue integration and collagen regeneration, allowing the original material to biodegrade over time. Integration portends collagen ingrowth and neovascularization, potentially allowing the delivery of macrophages and antibiotics to resist bacterial proliferation. Ideally, these slowly absorbable “natural” materials would allow for hernia repair in the presence of contamination without the fear of developing a dreaded prosthetic mesh infection. Unfortunately, the evidence endorsing these claims is minimal, and research has mostly been limited to clean cases. Still, the sequelae of infected synthetic mesh can be so devastating and expensive that the absence of alternatives in the presence of contamination may justify their enormous cost. Interestingly, in a survey of 215 surgeons who use biologic mesh, there was statistically significant variability regarding indications for biologic mesh usage in regard to wound class.45 The lack of evidence-based guidance, however, prevents meaningful conjecture as to whether biologic mesh is being under- or overused.

Newer data regarding biologic mesh have started to accrue. In vivo analysis has demonstrated that cross-linking is associated with macrophage activation, increased cytokine expression, profound inflammatory response, foreign-body reaction, encapsulation, and poor tissue integration.46,47 Clinically, Shah and colleagues reported increased infection and explantation rates of cross-linked biologics, although non–cross-linked mesh demonstrated a higher recurrence rate (29% versus 20%).48 Diaz-Siso and colleagues reported an 8% recurrence rate in 40 patients using non–cross-linked

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mesh, with a mean follow-up for 40 months. At our institution, patients repaired with biologic mesh in the presence of contamination had a hernia recurrence rate of 31% (40 of 128) after a mean follow-up of 22 months. A prospective, multicenter, single-arm trial (Repair of Infected and Contaminated Hernias [RICH] Study) demonstrated a 28% recurrence rate in 80 patients followed for 2 years. Although no definitive appraisal of biologic mesh can be made at this time, concerns regarding the durability and the true nature of “biologic” behavior certainly warrant further study.

More recently, newer absorbable synthetics that do not biodegrade for several months have been introduced into the market and proposed as less costly alternatives to biologic grafts. Clinical trials are currently under way to characterize these potential alternatives (clinicaltrials.gov protocol number: NCT01794338).

Future investigation will no doubt need to clarify the role of all prosthetic material. Remembering that all synthetics have variable abilities to clear a bacterial load and that mesh location may impact ingrowth, bacterial clearance, and, ultimately, durability, thoughtful studies will need to be designed to answer these questions. The number of variables inherent to hernia repair—patient comorbidities, hernia size, contamination, and technique—underscores the complexity in answering a question regarding the ideal prosthetic choice.

Incisional Hernia Repair

Incisional hernias occur as a complication of previous surgery. As noted, their incidence depends on how they are defined [see Epidemiology, above]. In the literature, the incidence of incisional hernia ranges from 3 to 12% of all laparotomy incisions and largely depends on several underlying patient characteristics. Notably, postoperative wound infections result in a much higher incidence of incisional hernia formation.

The root cause of incisional hernia is undoubtedly multifactorial. Technical factors such as slippage of knots, suture fractures, excessive tension, or rapidly absorbable sutures can result in incisional hernia formation. However, certain patients with collagen metabolism disorders are also prone to incisional hernia formation. In particular, patients with aortic aneurysms and diverticular disease likely have systemic disorders of collagen metabolism [see Table 7]. Nevertheless, the importance of careful attention to technical detail in the closure of any abdominal incision should not be minimized.

Surgeons’ practices in closing laparotomies tend to be far more dependent on tradition and often lack high-quality level I scientific evidence. We do know that generally a monofilament suture material should be chosen due to higher rates of SSI with the use of multifilament material. Regarding absorbable versus nonabsorbable suture, a meta-analysis of randomized controlled trials evaluating different midline closure techniques concluded that nonabsorbable suture in a continuous fashion led to lower rates of incisional hernia. A follow-up meta-analysis with similar criteria found no difference in hernia recurrence between slowly absorbable suture and nonabsorbable suture. This study, however, found higher rates of suture-related sinus drainage and pain in the nonabsorbable group and found no difference in hernia recurrence when continuous versus interrupted techniques were compared.

Table 6 Commercially Available Biologic Prostheses Approved for Abdominal Wall Hernia Repair

<table>
<thead>
<tr>
<th>Biologic Mesh</th>
<th>US Approval</th>
<th>Manufacturer</th>
<th>List Price* (US$/cm^2)</th>
<th>Source</th>
<th>Cross-linking</th>
<th>Sterilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgisis 1999</td>
<td>Cook</td>
<td>18.00</td>
<td>Porcine SIS</td>
<td>No</td>
<td>EO</td>
<td></td>
</tr>
<tr>
<td>Tutopatch 2000</td>
<td>Tutogen Medical/Bard</td>
<td>Unavailable</td>
<td>Bovine pericardium</td>
<td>No</td>
<td>Gamma irradiation</td>
<td></td>
</tr>
<tr>
<td>Permacol 2000</td>
<td>TSL → Covidien</td>
<td>21.00</td>
<td>Porcine dermis</td>
<td>Diisocyanate</td>
<td>Gamma irradiation</td>
<td></td>
</tr>
<tr>
<td>Alloderm 2001</td>
<td>LifeCell</td>
<td>32.00</td>
<td>Human dermis</td>
<td>No</td>
<td>Gamma irradiation</td>
<td></td>
</tr>
<tr>
<td>Peri-Guard 2002</td>
<td>Synovis</td>
<td>Unavailable</td>
<td>Bovine pericardium</td>
<td>Glutaraldehyde</td>
<td>Liquid alcohol</td>
<td></td>
</tr>
<tr>
<td>SurgiMend 2002</td>
<td>TEI Biosciences Inc.</td>
<td>22.00</td>
<td>Fetal bovine dermis</td>
<td>No</td>
<td>EO</td>
<td></td>
</tr>
<tr>
<td>Veritas 2003</td>
<td>Synovis</td>
<td>20.00</td>
<td>Bovine pericardium</td>
<td>No</td>
<td>E-beam</td>
<td></td>
</tr>
<tr>
<td>Xenmatrix 2003</td>
<td>Bard/Davol Inc.</td>
<td>27.36</td>
<td>Porcine dermis</td>
<td>No</td>
<td>E-beam</td>
<td></td>
</tr>
<tr>
<td>Allmax 2006</td>
<td>Bard/Davol Inc.</td>
<td>32.50</td>
<td>Human dermis</td>
<td>No</td>
<td>Gamma irradiation</td>
<td></td>
</tr>
<tr>
<td>CollaMend 2006</td>
<td>Bard/Davol Inc.</td>
<td>18.00</td>
<td>Porcine dermis</td>
<td>EDAC</td>
<td>EO</td>
<td></td>
</tr>
<tr>
<td>Strattice 2007</td>
<td>LifeCell</td>
<td>28.00</td>
<td>Porcine dermis</td>
<td>No</td>
<td>E-beam</td>
<td></td>
</tr>
<tr>
<td>FlexHD 2008</td>
<td>MTF — Ethicon</td>
<td>30.00</td>
<td>Human dermis</td>
<td>No</td>
<td>Proprietary</td>
<td></td>
</tr>
</tbody>
</table>

EDAC = 1-ethyl-3-[3-dimethylaminopropyl]carbodiimide hydrochloride; EO = ethylene oxide; SIS = small intestinal submucosa.

*Prices are as of January 2010. Pricing may vary based on institutional contracts and quantity of annual sales.

Table 7 Causes of Incisional Hernias

<table>
<thead>
<tr>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient related</td>
</tr>
<tr>
<td>Wound related</td>
</tr>
<tr>
<td>Genetic</td>
</tr>
<tr>
<td>Molecular</td>
</tr>
</tbody>
</table>
The most recent randomized controlled trial evaluating interrupted rapidly absorbable suture with continuous slowly absorbing suture (polydioxanone [PDS], Ethicon, Inc., and MonoPlus, B. Braun, Germany) was unable to detect a difference in hernia recurrence between the groups, although it appeared that PDS had the least overall rates of recurrence.6

The suture length (SL) to wound length (WL) ratio has been identified as an important parameter in preventing incisional hernias. Prospective randomized studies have consistently identified an SL to WL ratio of less than 4 as a significant predictor of herniation.61–64 This ratio can be achieved with large stitches (≥1 cm) from the wound edge or small stitches placed at closer intervals. Counter to traditional teachings that advocate 1 cm fascial bites, smaller stitches (5 to 8 mm) have been associated with lower wound dehiscence (0% versus 0.3%), SSI (5.2 versus 10.2%), and incisional hernia (5.6 versus 18.0%) rates.60 The weakness in larger stitches is likely related to the suture cutting through or compressing soft tissue (muscle and subcuticular fat), allowing for necrosis, laxity, and separation of the aponeurotic edges.65,66 The wound necrosis also serves as a harbinger for infection, further contributing to potential dehiscence and, ultimately, herniation.

Various patient-related risk factors for incisional hernia have been identified [see Table 8].67,68 Although some controversy remains, the current consensus is that there appears to be an association between these comorbid conditions and the incidence of incisional hernia. The type of wound incurred also plays a role [see Epidemiology, above].

Over longer periods, the incidence of incisional hernia recurrence increases, with the majority developing in the first 4 years after the sentinel operation.5 It is anticipated that as the use of minimally invasive surgical techniques increases, the incidence of incisional hernia will drop. Hernias developing within 10 and 12 mm port sites are well documented; hernias in 5 mm port incisions are rare. At present, long-term data on the incidence and natural history of port-site hernias are lacking.69

Genetic factors are important as well: familial predisposition to incisional hernia has long been recognized as contributory by surgeons caring for patients with this condition. An increased incidence of incisional herniation in patients with certain connective tissue diseases (e.g., osteogenesis imperfecta, Marfan syndrome, and Ehlers-Danlos syndrome) has been documented. Finally, the molecular details of incisional hernia causation are now beginning to be appreciated. Type 1 to type 3 collagen imbalance, abnormal matrix metalloproteinase (MMP) expression, and growth factor relations are among the molecular-level processes that are currently under intense scrutiny by the scientific community with regard to the etiology of incisional hernia.

Not every patient who presents to a surgeon with an incisional hernia is necessarily a candidate for surgical repair. There are three indications for operation: (1) a hernia that is symptomatic, causing pain, discomfort, or changes in bowel habits; (2) a hernia resulting in an unsightly bulge that affects the patient’s quality of life; and (3) a hernia that poses a significant risk of bowel obstruction (e.g., a large hernia with a narrow neck). However, the natural history of slow, continued growth of incisional hernias attributable to increased intra-abdominal pressure should be taken into consideration. In young patients with moderate-size hernias, a nonoperative approach can result in a more complex reconstruction in the future if the hernia becomes larger and more symptomatic. Conversely, patients with massive hernias in the presence of contamination or in patients who have multiple comorbidities can sometimes be so complex that the risk of an operation outweighs the benefits of a repair. We liken these “stage 4” hernias to an advanced metastatic “stage 4” cancer, where palliative measures may be more appropriate. If nothing else, properly identifying high-risk patients allows for frank discussions regarding long-term expectations in terms of morbidity and mortality.

The repair of incisional hernias is often more complicated than inguinal repair for several reasons. By definition, all incisional hernias are reoperative cases, demanding careful adhesiolyis and delineation of the anatomy. Additionally, it is important that the patient and the surgeon have a clear understanding of the goals of the procedure. For all ventral hernias, the surgeon must reduce the hernia contents into the abdominal cavity and prevent future migration and recurrent herniation. This can be performed by simply patching a defect with prosthetic material or can similarly be accomplished by reconstructing a functional dynamic abdominal wall via medialization of the rectus muscles with potential prosthetic reinforcement.

The importance of reconstructing the linea alba and rectus medialization has been an area of active investigation. Conceptually, reconstruction of the midline restores the medial insertion point for lateral abdominal wall musculature and returns the rectus muscles to their original anatomic position. The clinical benefits of this reconstruction, however, have not been clearly elucidated. We recently showed that reconstruction of the midline causes hypertrophy (or atrophy reversal) for lateral and rectus muscles as demonstrated by CT scan compared with patients who underwent a laparoscopic bridge repair.70 Correlation with improved core function and/or quality of life, however, has actually been poorly studied. Shestak and colleagues used a dynamometer to measure improved rectus muscle function (“sit-up”

Table 8 Comorbid Factors Associated with Incisional Hernia

| Male sex | Old age | Morbid obesity | Abdominal distention | Cigarette smoking | Pulmonary disease | Mechanical ventilation | Type 2 diabetes mellitus | Oral anticoagulants | Malnourishment | Hypoalbuminemia | Anemia/transfusion | Malignancy | Jaundice | Corticosteroid therapy | Chemotherapy | Radiation therapy | Renal failure |
|----------|---------|----------------|---------------------|-------------------|------------------|----------------------|-----------------------|---------------------|----------------|---------------|----------------|----------------|----------|---------|-----------------------|------------|----------------------|-------------|

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strength) after an anterior component separation with restoration of the midline in two patients. Our group repeated this study in 13 patients undergoing a posterior component separation and showed improvement in rectus function by every measure as well as quality of life. Unfortunately, there is currently no formalized methodology for measuring lateral abdominal wall musculature. This will be an important area of future investigation to measure the sequelae of various myofascial releases that are growing in popularity.

Operative Techniques

Primary Repair

Historically, primary suture repair was the procedure of choice for most incisional hernias; prosthetic material was reserved for particularly difficult cases as a result of the perceived risks of this material. In the latter part of the 20th century, large population-based studies changed this way of thinking, revealing that primary suture repair was associated with a much higher recurrence rate than most surgeons would have assumed (25 to 55%). Studies comparing primary suture with prosthetic repair showed that the recurrence rate was dramatically lower with the latter. In a randomized controlled study from the Netherlands, even small incisional hernias (< 10 cm²) had a recurrence rate of 67% when primary suture repair was employed. Additionally, a recent Cochrane review of available randomized trials with a minimum of 1-year follow-up showed that suture repair had a recurrence risk of 85% greater compared with mesh repair.

The role of primary suture repair only remains for the smallest of primary hernias (< 2 cm). As described by Mayo, a transverse closure is preferable to avoid perpendicular tension on the suture line and take advantage of the longitudinal compliance of the linea alba. The transverse closure is fashioned by suturing a free edge 1 to 1.5 inches from the opposing free edge (“vest-over-pants” manner) with permanent suture using horizontal mattress stiches. Classically, the free edge can be secured with a running absorbable suture. In elective cases of small primary defects, recurrence rates as low as 5.4% have been reported with 24 to 70 months of follow-up.

Prosthetic Repair: Mesh Placement

The use of prosthetic material to reduce tension in ventral hernia repair was first described in the 1950s. Since its introduction, inclusion of mesh in ventral hernia repair has unquestionably reduced the recurrence rate. With the addition of synthetic prosthetics to the surgeon’s armamentarium, the debate for the ideal surgical approach for placing mesh continues unanswered. Although each approach has its ardent supporters, there are few data carefully evaluating each approach in appropriately designed comparative trials. Given the lack of definitive data, it is difficult to provide a clear, concise recommendation as to the ideal approach. However, certain general guidelines can be stated. Basically, three options exist for mesh placement: as an overlay (onlay), as a bridge secured to the fascial edges (inlay), or as an underlay (sublay) in either a retrorectus, preperitoneal, or intraperitoneal position [see Figure 4].
advantage over the simple repair that the prosthesis overlies and that it is typically associated with a similarly disappointing recurrence rate of up to 25%. Additional disadvantages of placing prosthetic material in this position are its close proximity to the skin with higher potential for exposure following a wound infection and the wide skin undermining needed to achieve broad coverage.\textsuperscript{40} Wound complications are estimated to be between 4 and 26% using this approach secondary to the creation of skin flaps necessary to secure the mesh.\textsuperscript{41} Proponents of this technique claim an advantage of the mesh not being placed in direct contact with the abdominal viscera. However, if the midline fascial closure breaks down, the bowel will interact with an often unprotected macroporous mesh. Retrorectus and preperitoneal mesh ("sublay") placement likewise benefit from bilaminar fascial coverage without direct exposure to the viscera.

\textit{Inlay}

Prosthetic inlay (bridging) repair became popular in the 1990s, in keeping with the tension-free ideal for inguinal herniorrhaphy. The principle underlying this technique is that for a prosthetic repair to be truly tension free, the defect should be bridged. Unfortunately, the abdominal wall likely experiences different forces during activity than the groin. In fact, a true tension-free repair might not be ideal in the anterior abdominal wall. Given that contraction of the rectus and lateral abdominal wall muscles that are not joined at the linea alba results in lateral displacement, a constant force of separation is placed on the prosthetic. Coupled with the incidence of some shrinkage of most prosthetics, this has resulted in a predictably high recurrence rate at the mesothelial tissue interface.\textsuperscript{42,43} Following a systematic review of 119 studies on ventral hernia repair, the inlay technique was found to have the highest reported rate of recurrence, largely attributed to poor mesh fixation and inadequate lateral overlap.\textsuperscript{44} The recurrence rate is especially high in obese patients and greater with increasing hernia size. In a study from the Netherlands, the recurrence rate even with mesh repairs (mostly onlay and inlay) was 32% for large defects and 17% for small (\textless{} 10 cm\textsuperscript{2}) defects.\textsuperscript{45}

\textit{Retrorectus ("Sublay")}

Retrorectus or sublay repair is characterized by the placement of a large prosthesis in the space between the rectus muscles and the posterior rectus sheath superiorly or the transversalis fascia and peritoneum inferior to the arcuate line. Originally described as an approach to repair complicated groin hernias, the technique was promulgated by French surgeons Jean Rives and René Stoppa in the 1970s as a method to address large incisional hernias. Following Stoppa’s English manuscript in 1989 and a publication of 30 successful retrorectus repairs by American surgeon George Wantz in 1991, the technique (often referred to as the Rives-Stoppa-Wantz repair) has become increasingly popular [see Figure 5].\textsuperscript{46,47} At least 32 reports in 12 countries have consistently demonstrated acceptable recurrence (0 to 32%) and morbidity rates [see Table 9]. The benefits of mesh sublay are (1) giant prosthetic reinforcement of the visceral sac with (2) bilaminar fascial coverage of the mesh so as not to expose the viscera directly to the prosthesis in a (3) well-vascularized plane. Finally, (4) reconstruction of the midline is also achieved, allowing for the aforementioned benefits of rectus medialization. Importantly, the technique obviates the need for skin flaps and their associated wound morbidity. Because it has proven so successful, it is now being increasingly used to repair smaller defects. Sublay prosthetic repair is currently considered the most effective conventional incisional hernia repair and is therefore the one against which all other procedures are measured.

There are single-center series with evidence of improved outcomes using this technique.\textsuperscript{48} For example, in a Finnish study of 84 consecutive patients treated with a retromuscular polypropylene mesh repair and followed for 3 years, the recurrence rate was 5%. In a separate US study, no recurrences were reported in 102 patients after 28 months of follow-up.\textsuperscript{49} A 2006 study from Sweden confirmed the superiority of this operation, reporting a 7.3% recurrence rate for sublay prosthetic repair, compared with 19.3% for onlay mesh repair and 29.1% for suture repair.\textsuperscript{50} Sublay prosthetic repair has been successfully employed to treat massive hernias with substantial loss of domain.\textsuperscript{51} A retrospective review from the Mayo Clinic evaluated their experience with a modified Rives-Stoppa technique using prosthetic mesh in complex incisional hernia repair over a 13-year period.\textsuperscript{52} With a median follow-up of 59 months and 254 patients, their overall hernia recurrence rate was 5%, with most hernias being detected within 12 months of repair.

\textit{Underlay: Laparoscopic}

Although intraperitoneal mesh placement can be performed during an open approach, it is most commonly done during laparoscopic repair. LeBlanc and Booth were the first to describe successful laparoscopic ventral hernia repair in 1993.\textsuperscript{53} Several technical benefits are ascribed to a laparoscopic approach, including the opportunity to evaluate the entire abdominal wall for other smaller, Swiss cheese-like defects that may otherwise be missed and allowing for wide underlay mesh placement while avoiding large tissue dissection and the associated wound morbidity. Studies with varied design methodologies have compared a laparoscopic approach with an open approach on several important outcome parameters, including wound morbidity, mesh infections, hernia recurrence, and hospital length of stay.

One of the largest series evaluating the safety and efficacy of laparoscopic ventral hernia repair was reported in 2003.\textsuperscript{54} In this 10-year study, the authors reported a 3.6% conversion rate from laparoscopic repair to open repair, an average length of stay of 2.3 days (0 to 33 days), and an overall complication rate of 13%, with an overall infection rate of 1.8% (including wounds and mesh infection). Other important complications reported included bowel or bladder injury (1.7%), prolonged ileus (3%), prolonged seroma (2.6%), and prolonged pain (1.6%). Following an average 20-month follow-up (range 0 to 96 months), they reported a 4.7% hernia recurrence rate. Important factors associated with their recurrences included larger hernias, increased operative times, a history of previous hernia repairs, and postoperative complications. Indeed, Heniford and colleagues reported an increased recurrence rate with larger hernias fixed laparoscopically (184 cm\textsuperscript{2} versus 124 cm\textsuperscript{2}).\textsuperscript{55} A more recent prospective randomized study of open versus laparoscopic incisional hernia repair supported this study with similar findings, including improved rates of complications,
Figure 5  Incisional hernia repair. Illustrated is a retromuscular approach. (a) The anterior rectus sheath has already been incised, rotated medially, and closed in the midline. The space beneath the rectus abdominis is being developed. Dissection should continue to the lateral edge of the posterior rectus sheath, but care should be taken to prevent injury to the neurovascular bundles; denervation or abdominal wall necrosis is possible if these bundles are injured. (b) The prosthesis is prepared with U-shaped sutures. (c) A suture passer is used to push the two tails of each U stitch through separate musculofascial sites. However, the two tails exit through the same skin incision; this eventually allows the prosthesis to be firmly secured deep in the pocket. The sutures are tied above the skin, and the knot is secured down to the fascial level. The suture is cut under tension so that the tails will retract back into the skin incision, which is then closed. If the flaps permit, the sutures can be tied in the subcutaneous tissue and not passed through the skin. The disadvantage of this latter approach is that there are likely to be more problems with seromas because of the more extensive dissection. (d) A penetrating towel clip is used to release the skin dimples created by the gathering of subcutaneous tissue when the full-thickness sutures are tied. This measure prevents a potentially permanent deformity. It is important to inspect the sutures to confirm that they have not been disrupted. EAO = external abdominal oblique; IAO = internal abdominal oblique; TA = transversus abdominis.
decreased hospital length of stay, and a quicker return to work in the laparoscopic group. Given similar patient characteristics and an average defect size of approximately 9 to 10 cm, the authors noted a decrease in postoperative complications (16% versus 29%), including decreased wound complications (1.1% versus 8.2%), for the laparoscopic group. Hospital length of stay (2.7 versus 9.9 days), rates of complications (16% versus 29%), and quicker return to work (13 versus 25 days) were significantly decreased in the laparoscopic group. Hernia recurrences were similar at

### Table 9  Reports of Retrorectus Hernia Repair

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>N</th>
<th>Number of SSO or SSI (%)</th>
<th>Mesh Excision, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoppa83</td>
<td>1989</td>
<td>368</td>
<td>16/NA (12)</td>
<td>0</td>
</tr>
<tr>
<td>Wantz84</td>
<td>1991</td>
<td>30</td>
<td>NR</td>
<td>0</td>
</tr>
<tr>
<td>Riverae83</td>
<td>1992</td>
<td>258</td>
<td>20/NA (7.7)</td>
<td>NR</td>
</tr>
<tr>
<td>Amid et al162</td>
<td>1994</td>
<td>54</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Liakakos et al163</td>
<td>1994</td>
<td>102</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>McLanahan et al164</td>
<td>1997</td>
<td>86</td>
<td>16/NA (18)</td>
<td>NR</td>
</tr>
<tr>
<td>Schumpelick et al81</td>
<td>1999</td>
<td>81</td>
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<td>2 (2.5)</td>
</tr>
<tr>
<td>Luijendijk et al83</td>
<td>2000</td>
<td>84</td>
<td>3/NA (4)</td>
<td>0</td>
</tr>
<tr>
<td>Martin-Duce et al165</td>
<td>2001</td>
<td>152</td>
<td>17/NA (11)</td>
<td>7 (4.6)</td>
</tr>
<tr>
<td>Bauer et al166</td>
<td>2002</td>
<td>57</td>
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<tr>
<td>Flamente81</td>
<td>2002</td>
<td>693</td>
<td>17/NA (2.5)</td>
<td>1 (0.001)*</td>
</tr>
<tr>
<td>Ferranti et al167</td>
<td>2003</td>
<td>35</td>
<td>5/NA (14.2)</td>
<td>1 (2.8)†</td>
</tr>
<tr>
<td>Langer et al168</td>
<td>2003</td>
<td>155</td>
<td>NR</td>
<td>NR</td>
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<tr>
<td>Sruussadaporn et al169</td>
<td>2003</td>
<td>9</td>
<td>NR</td>
<td>0</td>
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<td>Petersen et al170</td>
<td>2004</td>
<td>175</td>
<td>14/NA (8)</td>
<td>3 (1.7)§</td>
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<tr>
<td>Kingsnorth et al171</td>
<td>2004</td>
<td>33</td>
<td>NR</td>
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<tr>
<td>Paajanen and Laine171</td>
<td>2005</td>
<td>84</td>
<td>13/5 (15, 6)</td>
<td>1 (1.2)†</td>
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<tr>
<td>Novitsky et al173</td>
<td>2006</td>
<td>128</td>
<td>3/NA (2.3)</td>
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<tr>
<td>Israelsson et al184</td>
<td>2006</td>
<td>228</td>
<td>NR</td>
<td>NR</td>
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<tr>
<td>Lamanto et al172</td>
<td>2006</td>
<td>50</td>
<td>6/3 (12, 6)</td>
<td>2 (4)</td>
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<tr>
<td>Yaghoobi Notash et al173</td>
<td>2007</td>
<td>86</td>
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<td>2013</td>
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NA = not available; NR = not reported; SSI = surgical site infection; SSO = surgical site occurrence.

* - 2 – both ePTFE mesh.
† - 1 – polyester.
‡ - 1 – polypropylene.
§ - 3 – all ePTFE.
¶ - 1 – partial mesh excision.
|| - 1 – partial mesh excision – lightweight polypropylene.
* - 5 – all mesh removed within 30 d of operation after deep SSI.
** - all had a concurrent panniculectomy.
†† - 5 – all partial excision of polyester.
§§ - concurrent intraperitoneal mesh.
Other studies have also described benefits similar to those of a laparoscopic approach for ventral hernia repair but point toward a need to standardize issues related to patient selection. A recent meta-analysis summarized the results of five randomized controlled trials comparing open versus laparoscopic ventral hernia repair. This study supported the associated decreased length of stay and decreased rates of complications reported by other studies. However, the authors were unable to find decreases in operative time, pain, and recurrence between the two groups. An important contributor to this lack of difference was attributed to the heterogeneity that existed across the various study methodologies. This resulted from the lack of double-blinded randomized trials, patient selection factors such as the varied hernia sizes included across studies, and the varied open techniques being compared. This subsequently underscores the need to clarify these important variables within the context of a well-defined multicenter trial. Furthermore, there are still areas of significant controversy that require further well-controlled trials, such as the method of securing the mesh in place (sutures, tacks, fibrin glue, or a combination), the best approach to address postoperative pain related to mesh fixation techniques, and the management of seromas.

A laparoscopic approach might have distinct advantages over an open ventral hernia repair for obese patients. As obesity has been identified as a risk factor for wound infections and recurrence in open surgery, studies have investigated the safety and efficacy of laparoscopy for this group of patients. Although comparable decreased rates of complications such as wound and mesh infections are reported in obese patients, it is unclear if the same benefit of decreased recurrence rates applies to this population. A multi-institutional case series of 901 laparoscopic ventral hernia repairs compared outcomes for patients with a body mass index (BMI) above 40 versus those with a BMI less than 40. Although similar improved rates of conversion to open repair (= 2.5%) and mesh infections (= 1%) were found between the two groups, the rates of recurrence were higher in the obese group (BMI ≥ 40; 8.3 versus 2.9%) and had an associated fourfold risk after a 19-month follow-up. Although this rate of 8% at 19 months might be acceptable relative to an open approach, it is important that obese patients understand that their rates of recurrence following laparoscopic repair may differ from those of their lean counterparts. Several issues further complicate the decision to perform surgery in this select group of patients, such as the timing of gastric bypass surgery in relation to ventral hernia repair and the indications for pancreatectomy. Although some small studies have attempted to evaluate this question, there are no high-quality studies available to guide answers to these complex problems.

Although a perfect case match is difficult to achieve, it appears that outcomes after laparoscopic repair are at least equivalent to those after open techniques. Importantly, mortality from a missed enterotomy was identified as being more likely in multiply recurrent hernias, and in our experience, recurrent incisional hernias were more likely to recur when fixed laparoscopically. Due to the aforementioned benefits of midline reconstruction, which are not achieved laparoscopically, our use of laparoscopic repairs is limited to hernias less than 8 cm or complex/comorbid patients unable to tolerate an open repair. Some have described laparoscopic defect closure above mesh underlay as an adjunct to the traditional repair. Although this does not appear to affect recurrence rates, seroma formation is potentially decreased and midline reconstitution is achieved, although often at the cost of increased pain. Future studies will need to investigate whether benefits of this supplement exist.

### Component Separations

#### Traditional (“Anterior”)

Patients undergoing abdominal wall reconstruction for massive defects each require individualized preparation and consideration prior to surgery. Physiologic changes occur in both the abdominal and the thoracic cavities following definitive closure of these large defects. In addition to the general preoperative screening, each patient should be assessed for pulmonary status and the potential for return to routine daily activities. Additionally, smoking status is critical as patients who smoke are at significantly higher risk for wound complications. Since its original description in 1990, component separation has undergone several adaptations. We describe the traditional open approach and two newer techniques to achieving a more minimally invasive separation of components.

A limitation to the classic Rives-Stoppa-Wants retrorectus repair is that the retrorectus dissection is limited laterally by the linea semilunaris. For larger hernias that require additional mesh overlap as well as myofascial advancement for closure under physiologic tension, a component separation must be considered. Originally described by Ramirez and colleagues in 1990, as much as 10 cm of unilateral medial fascial advancement could be achieved by incising the external oblique aponeurosis lateral to the linea semilunaris—coined as a “component separation.” Reinforcement has been described with onlay, sublay, and underlay mesh placement. The Achilles heel of the operation—as previously alluded to—lies in the need to create large skin flaps to access the external oblique muscle lateral to the linea semilunaris. Wound necrosis, not surprisingly, is a frequent sequela.

In an effort to avoid the significant tissue trauma and the large open surface areas created following the open component separation technique, endoscopic approaches have been described. This minimizes the lipocutaneous flaps created in the open approach and can be used in conjunction with a planned laparotomy. Adaptations from its original approach have been made over time. This technique maintains the same principles as the open approach, which is to achieve medialization of the abdominal wall through lateral release of the external abdominal oblique fascia. Medial advancement, however, is not as significant in patients undergoing endoscopic release due to fixation by the subcutaneous tissue. Furthermore, medial advancement in the xiphoid or suprapubic areas can be difficult to obtain using this technique.

As somewhat of a compromise between the aforementioned techniques of “anterior” component separation, approaches known as “periumbilical perforator sparing” and “modified minimally invasive” component separation have been described. Although details are beyond the scope of this review, component separation may also be considered in circumstances where the traditional approach is not feasible.
of this text, suffice it to say that both approaches aim to preserve some of the periumbilical perforators that supply the subcutaneous tissue above rectus muscles, thereby attempting to minimize the wound morbidity associated with large skin flaps. Importantly, data supporting these techniques have cited reduced wound complications, particularly infection.17,111

POSTERIOR COMPONENT SEPARATION

In addition to the traditional anterior component separation, other supplements to the traditional retrorectus repair have been developed to provide additional myofascial advancement. The chief advantage of these techniques, in contrast to an anterior component separation, is to completely obviate the need for skin flaps or tunnels necessary to access the external oblique muscle. Rather than release the myofascial external oblique, other fascial layers can be incised to allow for medial advancement.

When the retrorectus space is matured to the linea semilunaris, the original Rives-Stoppa-Wantz dissection is considered complete. At this point, if additional advancement is required, Ramirez and colleagues described use of anterior component separation for additional advancement, as previously described.104 However, the lateral posterior rectus sheath at the linea semilunaris can be recinced just medial to the laterally perforating neurovascular bundles. Given the more medial insertion of the transversus abdominis muscle onto the posterior rectus sheath [see Anatomy, above], recinicing the posterior rectus sheath just medial to the neurovascular bundles allows access to the space above the transversus abdominis muscle and below the internal oblique muscle. At this point, two types of “posterior” component separation can be completed. An intramuscular dissection matures the plane between transversus and internal oblique muscles. Unfortunately, neurovascular bundles that travel within this space are often sacrificed with lateral dissection. Furthermore, intramuscular dissection does not allow for release of one of the lateral abdominal wall muscles and therefore inhibits medial fascial advancement. Alternatively, our preference after posterior component separation is to perform a transversus abdominis muscle release (TAR). Immediately after recinicing of the lateral posterior rectus sheath, the underlying transversus abdominis muscle is revealed. At this point, the transversus abdominis muscle can be separated from underlying peritoneum and transversalis fascia and peritoneum. The preperitoneal plane can then be developed laterally beneath the transversus abdominis muscle and above the peritoneum/transversalis fascia that is now contiguous exclusively with the posterior rectus sheath. This preperitoneal plane can be matured all the way to the retroperitoneum and the psoas muscle, allowing for incredible medial advancement of the posterior rectus sheath as well as a large space for mesh reinforcement with wide overlap. The remaining anterior fascia also benefits from significant medial advancement owing to division of the transversus abdominis muscle, whose vector of force is directly perpendicular to the midline, opposing apposition of the reconstituted linea alba. Importantly, neurovascular bundles traveling in the transversus plane are preserved, preventing denervation and/or defunctionalization of the rectus muscles. With posterior component separation as an adjunct to retrorectus repair, the aforementioned benefits of mesh sublay are maintained: giant prosthetic reinforcement of the visceral sac, bilaminar fascial coverage of the prosthetic without direct exposure of the prosthetic to the viscera, reconstruction of the linea alba, and maintenance of the neurovascular integrity of the abdominal wall.

Selected Operative Techniques

OPEN RETRORECTUS REPAIR (RIVES-STOPPA-WANTZ)

Step 1: Incision

The initial incision is typically midline and should remove all old scar tissue that might compromise subsequent wound healing. In patients with a large pannus, concurrent panniculectomy should be avoided due to the increased likelihood of wound morbidity.112 Some authors advocate remaining in the extraperitoneal space throughout the dissection. This provides the distinct advantage of avoiding potential bowel complications; however, it can be a very tedious and difficult dissection plane, especially in large hernia sacs and complicated defects. It is our preference to enter the peritoneal cavity and perform a complete adhesiolysis to identify all defects and mobilize the entire abdominal wall. The abdominal cavity is typically entered most safely in the subxiphoid midline above the original scar.

Step 2: Entering the Retrorectus Plane

Several options exist for entering the correct plane in the lateral abdominal wall. One technique involves maintaining a preperitoneal dissection. This is similar to the groin dissection, but along the anterior abdominal wall, the peritoneum can be densely invested in the posterior rectus sheath, making this very difficult. Alternatively, the posterior rectus sheath can be entered at the linea alba. Graspers are placed on the linea alba, and the posterior rectus sheath is incised just off the midline. This release is completed throughout the length of the incision and at least 5 cm beyond the defect in a cephalad-caudad orientation. The dissection is then carried laterally deep to the rectus muscle above the posterior rectus sheath. Below the arcuate line, this is above the transversalis fascia and peritoneum. The dissection is continued laterally to the linea semilunaris at the edge of the rectus muscle. In routine hernias, the rectus muscle is typically anywhere from 5 to 10 cm in width. This provides ample overlap of the mesh [see Figure 6].

Step 2b: Supplemental Posterior Component Separation and TAR

In larger or multiply recurrent hernias, there is often atrophy, or loss of the rectus muscle, and this retrorectus space does not provide adequate mesh overlap. In these circumstances, several options exist. The lateral abdominal compartment can be accessed in either the intramuscular or preperitoneal plane. The intramuscular plane can be reached by incising the lateral border of the posterior rectus sheath just medial to the linea semilunaris. The plane between the transversus abdominis and the internal oblique can be carried far laterally to obtain substantially more mesh overlap. One of the drawbacks of this approach is that the perforating nerves to the rectus muscle can be damaged, rendering it nonfunctional. In addition, the intercostals vessels travel within this intramuscular plane.

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Our preferred approach attempts to maintain the neurovascular integrity of the abdominal wall while still achieving wide lateral dissection for mesh overlap and myofascial release to gain medial advancement. When the retrorectus space is matured laterally to the linea semilunaris, the neurovascular bundles can be visualized piercing the posterior rectus sheath. The posterior rectus sheath can then be reincised just medial to the perforating bundles to reveal the underlying transversus abdominis muscle (recall that the transversus abdominis muscle inserts medially onto the posterior rectus sheath [see Anatomy, above]) [see Figure 7]. Once exposed, the transversus abdominis muscle can then be isolated from the underlying transversalis fascia and peritoneum. The preperitoneal plane between the incised transversus abdominis muscle and the peritoneum/transversalis fascia can then be matured laterally as far back as the psoas muscle in the retroperitoneum [Figure 8].

Step 3: Reapproximating the Posterior Rectus Sheath

The posterior rectus sheath, peritoneum, and transversalis fascia are reapproximated in the midline. Recreation of this anatomic plane completely excludes the viscera from the

Figure 6  (a) Incising the posterior rectus sheath just lateral to the linea alba to access the retrorectus space. (b) Development of the retrorectus space laterally to the linea semilunaris. Neurovascular bundles can be seen perforating the posterior rectus sheath just medial to the linea semilunaris.
mesh. Alternatively, the hernia sac, omentum, or a piece of absorbable mesh can be used to buttress this visceral sac.

**Step 4: Mesh Placement**

The mesh is placed in the retrorectus position. If necessary, the mesh can be secured to the Cooper ligament along the pelvis and placed under the xiphoid process. Several transfascial fixation sutures are placed through puncture sites in the lateral abdominal wall. These sutures are placed through the full thickness of the abdominal wall, with the knots placed below the skin. These sutures should be placed under moderate tension. By placing these sutures under tension, when they are tied, the rectus muscle is medialized and the forces are distributed to the lateral abdominal wall away from the midline. Securing the mesh to the lateral abdominal wall under tension also allows the rectus muscle to be reapproximated over the mesh without buckling of the prosthetic material.

**Step 5: Closure**

After the mesh is secured, every attempt should be made to reapproximate the linea alba in the midline. This serves the functional purpose of restoring the native abdominal wall contour and function. Also, it covers the mesh to avoid potential wound complications and subsequent mesh sepsis. When neither fascia nor soft tissue coverage can be achieved from native abdominal wall tissue, tissue flaps should be used with the help of a plastic surgeon.

**OPEN COMPONENT SEPARATION**

**Step 1: Incision**

A long midline incision or transverse panniculectomy-type incision is made through the scar to expose the hernia. The hernia sac is dissected up to its neck, deep to the fascial edge.

**Step 2: Creation of Flaps**

The lipocutaneous flap is dissected away from the anterior sheath of the rectus abdominis and the aponeurosis of the external abdominal oblique muscle. A technique that may help decrease skin flap necrosis is to preserve the periumbilical perforators by creating lipocutaneous tunnels above and below the umbilicus. There are no exact landmarks to delineate the most lateral extent of this flap. The surgeon must bimanually assess the rectus muscle belly. Once the lateral edge of the rectus is palpated, the dissection is carried 2 cm lateral to the linea semilunaris.
Step 3: Incising the External Oblique Muscle

The aponeurosis of the external oblique muscle is transected longitudinally about 2 cm lateral to the rectus sheath, with care to avoid cutting into the linea semilunaris [see Figure 9]. Transecting the linea semilunaris will result in a full-thickness defect and a subsequent lateral hernia. If the surgeon inadvertently begins incising the external oblique muscle too medially, he or she runs the risk of potentially transecting the internal oblique fascia too. Transecting the internal oblique muscle will likely result in a lateral abdominal wall bulge. By making the incision lateral on the external oblique muscle, the internal oblique muscle is often muscular and can be clearly delineated from the external oblique. This incision is extended cranially onto the muscular components of the external abdominal oblique to about 5 to 7 cm above the costal margin and caudally to the inguinal ligament. The external oblique muscle is then separated from the internal oblique muscle in the avascular plane to the posterior axillary line. Similarly, this same dissection can be achieved through the suprapubic and subxiphoid lipocutaneous tunnels using lighted retractors to preserve the periumbilical vessels.

Step 4: Posterior Rectus Sheath Release

If primary closure is still not possible without undue tension, 2 to 4 cm of additional length can be gained by separating the posterior rectus sheath from the rectus abdominis.

Step 5: Mesh Placement

Depending on the nature of the case (i.e., clean or contaminated), synthetic or biologic mesh, either in the retrorectus or the intraperitoneal position, with a minimum of 3 to 4 cm of tissue-mesh overlap, can be placed. Others have described onlay positioning of the mesh after open component separation. Technically, onlay mesh positioning is easier than underlay placement. However, the mesh is then placed in the subcutaneous position, with a fairly high potential for wound breakdown and mesh exposure. Additionally, the mesh is placed below a devascularized subcutaneous fatty tissue, potentially impeding ingrowth. Particularly in the context of the periumbilical perforator-sparing technique, onlay would be impeded by the umbilical vascular pedicle.
Step 6: Skin Closure

Excess skin should be liberally resected. Resecting excess skin provides two distinct advantages: the most devascularized tissue is removed, and excess dead space is reduced. Finally, the subcutaneous space should be widely drained with the use of Jackson-Pratt drains.

Endoscopic Component Separation

Step 1: Incision

In the setting of contaminated single-stage abdominal wall reconstruction, a standard laparotomy incision is commenced and the major infectious issues are addressed, including takedown of fistulas or removing an infected prosthetic. The entire anterior abdominal wall is freed of adhesions, and the defect size is assessed. Those cases that will not close primarily undergo component separation. There is no absolute indication for this as all patients have a different level of compliance to their abdominal wall. A more compliant abdominal wall will come together more easily at the midline than one that is not very compliant. Generally, good surgical judgment, coupled with realistic expectations, should guide the decision-making process.

Step 2: Initial Component Separation Incision

Once a component separation is deemed necessary, a 1 cm incision just inferior to the tip of the 11th rib is made and the external abdominal oblique is identified with blunt dissection and Kocher clamps. The avascular plane between the external abdominal oblique and the internal abdominal oblique is identified by use of retractors. Careful identification of the correct anatomic plane is imperative at this juncture to avoid placing the dissecting balloon in the wrong plane and requiring conversion to an open procedure.

Step 3: Balloon Dissector

A bilateral inguinal hernia balloon dissector is inserted in a caudal direction toward the pubic tubercle. Under direct visualization, the balloon is inflated and the orientation of the muscle fibers is confirmed. A structural balloon port is placed, and insufflation pressures of 10 to 12 mm Hg are maintained. The camera tip bluntly completes the posterior lateral dissection.

Step 4: External Oblique Release

A 5 mm port is placed in the posterior axillary line. This port needs to be quite lateral to obtain the appropriate angle to incise the external oblique fascia. Much like in the open approach, the linea semilunaris should be carefully identified and avoided to prevent a lateral hernia. Anatomically, the linea semilunaris is identified at the junction of the external and internal oblique. Typically, scissors and cautery are used to release the external oblique fascia to the inguinal ligament.

Step 5: Cephalad Dissection

Another 5 mm port is placed medially through this inferior release to be used for the cephalad release of the external abdominal oblique fascia and muscle. The camera is now positioned in the lateral trocar. Given that the external oblique is typically quite muscular at its cephalad extent, some form of ultrasonic dissection is helpful in maintaining hemostasis. The external oblique is then released for at least 5 to 7 cm above the costal margin. Once this is performed bilaterally, it completes the endoscopic component separation and the surgery.

Reinforcement or bridging of a midline defect for both the open and endoscopic approaches can be performed with mesh in the retrorectus or intra-abdominal position with lateral transfascial fixation sutures. The exact technique regarding mesh placement is still under debate. Biologic mesh may be used in the setting of contamination. Synthetic mesh can be used for elective clean cases. If synthetic mesh needs to be placed in the intraperitoneal position, a synthetic mesh of choice with an antiadhesive side should face the bowel.

Complications

There is overwhelming proof that tension-free prosthetic repairs yield lower recurrence rates than direct suture repairs. In a Medline search for complications of incisional hernia repair, recurrence rates ranged from 31 to 63% for direct suture repairs and from 0 to 32% (mostly less than 10%) for prosthetic repairs. Although the primary adverse outcome of hernia repair is recurrence, the short-term morbidity of open hernia repair must also be assessed. In one meta-analysis, the overall complication rate after open repair was 27%, ileus, postoperative pain, sepsis, fistulization, and necrotizing fasciitis have all been documented. Tissue response, which is variable from person to person, can be so intense that the prosthetic material is deformed by contraction. Erosion can result in intestinal obstruction or fistulization, especially if there is physical contact between the intestine and the prosthetic.115 Prosthesis-related infection, although it occurs less with the laparoscopic technique, remains a major problem with open incisional hernia repairs. A pooled analysis of randomized trials comparing primary versus mesh repair of incisional hernias found an overall 10% infection rate. Prosthesis-related infection occurs in as many as 25% of repairs in some series, delays healing for prolonged periods, and is one of the most important risk factors for recurrence. Higher rates of prosthesis infection are associated with preexisting infection, ulceration of the skin overlying the hernia, obesity, incarcerated or obstructed bowel within the hernia, and perforation of the bowel during hernia repair. Seromas are common, especially when a large prosthesis is required or there has been extensive flap dissection of the subcutaneous layer from the fascia. Untreated seromas can become infected secondarily. Suction drains can be useful, but there is little guidance in the literature as to appropriate times for removal. Drains can both remove bacteria or function as a two-way street, allowing seeding of the mesh. Strategies for preventing and managing seromas are largely based on empirical evidence and personal opinion; objective data are virtually nonexistent. It is not always necessary to remove the mesh if infection develops. A trial of local wound care after opening the incision and débriding the infected area is warranted. Some authorities believe that ePTFE prostheses are less prone to infection; however, once infection is established, ePTFE prostheses, unlike mesh prostheses, are almost never salvageable.
LAPAROSCOPIC REPAIR

As the benefits of an open versus a laparoscopic approach for varied groups of patients become more defined, an important criterion for choosing an approach is surgeon comfort. A laparoscopic ventral hernia repair, particularly for more complex patients with multiple previous surgeries, requires a special skill set. Here we describe our technique for laparoscopic ventral hernia repair.

Step 1: Intraoperative Patient Preparation

Following general anesthesia, the patient should be placed in the supine position, arms abducted, with appropriate padding. Gastric and bladder decompression should be performed with the aid of a nasogastric tube and Foley catheter prior to entering the abdominal cavity. A three-way Foley catheter is used for hernias below the umbilicus to aid in identifying and potentially mobilizing the bladder for mesh placement. Appropriate antibiotic and venous antithrombosis prophylaxis should be administered.

Step 2: Gaining Access to the Abdominal Cavity

The initial access port (10 or 12 mm) can be placed in the right or left upper quadrant using an open cut-down technique. A 5 mm 30° laparoscope is preferred to have adequate visualization of the anterior abdominal wall and allow placement through any trocar. Two to three other ports (5 mm) can be placed along the same side of the lateral abdominal wall under direct laparoscopic visualization. As a general rule, these ports should be placed as far laterally as possible to the midline defect to allow sufficient distance to place a large piece of mesh and to allow the surgeon to work in the midline without difficulty.

Step 3: Adhesiolysis and Defect Measurement

To avoid bowel injury, we prefer the use of sharp dissection. If bleeding is encountered, liberal use of clips may be applied. If any part of this step becomes too challenging and the repair is compromised, conversion to an open repair should be considered. When working near the bladder, if there is any concern for an inadvertent bladder injury, the three-way Foley catheter can be used to fill the bladder and inspect for any evidence of leak. Following completion of adhesiolysis, the defect can be measured in preparation for mesh placement. Under direct laparoscopic visualization, long spinal needles are placed intra-abdominally along the edge of the hernia defect. A 15 cm ruler is then placed intra-abdominally and used to measure the hernia defect under standard insufflation pressures and estimate the mesh size required for repair.

Step 4: Mesh Placement

Following defect measurement, the desired mesh can be cut with the goal of achieving an additional 4 to 5 cm of mesh overlap. Given its intra-abdominal position, either a dual-sided antiadhesive mesh or PTFE mesh should be used for this repair. The cephalad and caudal ends of the mesh can be marked to guide intra-abdominal orientation and placement. Nonabsorbable monofilament or PTFE sutures are secured in four quadrants of the mesh, with the knot landing on the ingrowth-promoting side. The mesh can then be rolled and inserted through the 10 mm trocar. Transfascial fixation sutures are additionally placed with suture passers at approximately 5 cm intervals to further secure the mesh in place. All knots are buried in the subcutaneous space. Additionally, helical tacks are placed circumferentially every 5 mm to secure the mesh in place at the edges.

Step 5: Postoperative Management

Most laparoscopic ventral hernia repairs require overnight admission secondary to perioperative pain management. Despite the minimally invasive nature of the procedure, most patients experience significant discomfort, and the average length of hospital admission ranges from 2 to 4 days. We place an abdominal binder on all patients for 6 weeks to reduce seroma formation.

Special consideration should be given to complications associated with laparoscopic ventral hernia repair. An enterotomy is a critical complication of laparoscopic approach that may occur while achieving abdominal cavity access or during adhesiolysis. It has been reported to occur in 1 to 6% of cases, with greater challenges encountered in the reoperative abdomen.92,93,117,118 Varied methods of accessing the abdominal cavity have been described, with no prospective randomized trial evaluating the true risk associated with the several available approaches. Although there is no standard way to access the abdominal cavity prior to pneumoperitoneum, an open cut-down technique with access under direct visualization may provide a safer route for complex patients. Extensive adhesiolysis, particularly in the patient with multiple previous surgeries and with previous intra-abdominal mesh placement, is another high-risk opportunity to inadvertently cause an enterotomy. Judicious use of cautery and opting for sharp dissection with the use of clips for hemostasis may help decrease cautery-related injury. In situations where there are dense adhesions onto intra-abdominally placed mesh, resecting the involved piece of mesh and bowel off the abdominal wall allows for safer clearance of the abdominal wall in preparation for mesh placement. Whether an enterotomy is encountered or questioned, conversion to an open approach is a safe next step to the management of this complication as diagnosing a delayed enterotomy is associated with increased morbidity and mortality.119 The ideal surgical management of an enterotomy is controversial and in some cases may require delaying definitive hernia repair.

Special Circumstances

LOSS OF DOMAIN

Loss of abdominal domain is a poorly understood phenomenon that lacks clear definitions in the literature. In its simplest terms, it implies a massive hernia where the herniated contents have resided for so long outside the abdominal cavity that they cannot simply be replaced into the peritoneum. Unfortunately, several circumstances can result in this occurrence, and each poses unique reconstructive challenges. We typically divide loss of domain hernias into those in which there is contamination or no contamination. Next, each group is subcategorized into those patients with a small hernia defect and a large mushroom cloud of hernia contents and those patients with a massive abdominal wall defect and a massive hernia sac. In the former group, the
challenges are mainly focused around having the patient accommodate the abdominal contents. In the latter group, not only must the patients be able to accommodate the abdominal contents, but the surgeon must also use various reconstructive methods to rebuild the abdominal wall.

Patients should be carefully evaluated and counseled as to the potential morbidity and mortality of these reconstructive efforts. The surgeon and the patient must set reasonable goals as to what can be accomplished. First, the abdominal contents must be returned to the abdominal cavity without causing respiratory embarrassment and hemodynamic compromise. In these circumstances, the use of progressive preoperative pneumoperitoneum and staged mesh excision has been described. After the contents are returned to the abdominal cavity, the reconstructive procedure must begin. This method should be approached with extreme caution as it can be associated with deep vein thromboembolism. Depending on the circumstances, a retrorectus repair, a bridged repair, component separation, and serial mesh excision may all be appropriate for massive ventral hernias. These procedures are technically demanding, require ample hospital resources, and likely should be attempted only in high-volume centers.

Most recently, we have worked to elucidate the physiologic sequelae of massive ventral hernia repair. An elevation of plateau pressure by 6 mm Hg or greater after repair was found to be predictive of respiratory events (reintubation or transfer to a higher level of care), and as such, we now keep patients intubated overnight in this circumstance. Interest-ingly, we have found that these patients have significantly improved plateau pressures by the following morning and are ready for extubation at that time. This observation has led us to develop the idea of a transient or “permissive” intra-abdominal hypertension that occurs after an elective hernia repair yet quickly resolves without significant sequelae. This is possibly related to myofascial releases, which allows for accommodation of the viscera once returned to the abdominal cavity. We are currently investigating this concept and look forward to sharing our findings.

**Contaminated Surgical Fields**

A dilemma arises when a patient has a large incisional hernia and the wound is contaminated either by skin infection or by injury to the bowel during the repair at the time of adhesiolysis. In this scenario, the use of synthetic mesh has traditionally been avoided due to the concern of a chronic mesh infection or bowel erosion leading to enterocutaneous fistula formation. In the past, the use of absorbable mesh made of polyglycolic acid was recommended to prevent evisceration. This staged approach to repair a contaminated ventral hernia would result in granulation tissue development over the mesh, allowing for subsequent skin grafting. The mesh itself is absorbed in about 3 weeks, leaving no permanent foreign body to serve as a persistent focus of infection. Unfortunately, recurrence of the incisional hernia is nearly inevitable and leads to a multistage approach to a contaminated abdominal wall defect. Single-stage repairs for this complex problem have been reported in the literature, particularly in conjunction with the component separation technique. Currently, many surgeons prefer to use one of the newer biologic prostheses in this setting to achieve closure or add repair reinforcement. This has now become the best indication for these very expensive materials. Long-term data, however, report recurrence rates as high as 31%. A better understanding of ideal mesh characteristics in terms of bacterial clearance (i.e., macroporous, monofilament, uncoated polypropylene [see Choice of Prosthetic, above]) and the benefits of bilaminar fascial coverage in the well-vascularized sublay position has caused some investigators to rethink the relative contraindication of synthetic mesh in contaminated fields. Carbonell and colleagues recently reported 100 cases of synthetic mesh use in contaminated ventral hernia repairs, which resulted in four patients requiring mesh excision and seven recurrences with 11 months of average follow-up. Although infrequent, the complications of infected synthetic mesh can be devastating and incredibly expensive. Ongoing prospective studies will shed light on the real risk of prosthetic materials in contaminated fields and provide the evidence-based guidance that is desperately needed.

**Periumbilical Hernia Repair**

Unlike an omphalocele, an umbilical hernia is covered by skin. If the defect is located to one side of the umbilicus, it is called a paraumbilical hernia (this variant is more common in adults). Umbilical hernias developing during childhood are congenital, whereas those developing during adult life are acquired. Accordingly, in adult patients, it is important to look for an underlying cause of increased intra-abdominal pressure (e.g., ascites or an intra-abdominal tumor). The differential diagnosis of an umbilical hernia includes caput medusae of varices at the umbilicus from portal hypertension, a metastatic tumor deposit (the so-called Sister Mary Joseph node), a granuloma, an omphalomesenteric duct cyst, or an urachal cyst.

Management of umbilical hernia is determined by the age of the patient. The majority of hernias occurring in children younger than 2 years will heal spontaneously; therefore, watchful waiting is the rule, and only symptomatic hernias are operated on. In children older than 2 years and in adults, surgical correction is required, with the type of repair employed depending on the size of the hernia. If the defect is small (< 2 to 3 cm), a direct suture repair may be performed. For larger umbilical and paraumbilical hernias, particularly those in adults, a mesh repair is preferred. The sac is dissected away from the undersurface of the rectus and the linea alba circumferentially and then reduced into the abdomen. If the peritoneum remains intact, a mesh prosthesis may be placed in a subfascial position and secured with sutures. If the abdomen is entered, a dual-layer prosthesis with an adhesion barrier on the visceral side is recommended. In a series of 100 adult patients with a median follow-up period of 4.5 years, the recurrence rate was 11.5% for suture repairs and 0% for mesh repairs.

A patient with an umbilical hernia and cirrhosis with or without ascites presents a challenging scenario to the general surgeon. Over a lifetime, a patient with cirrhosis has a 20% risk of developing an umbilical hernia, and in the presence of ascites, the risk is as high as 40%. Knowing the surgical complications that can occur following operating on a cirrhotic patient creates a tempting scenario for delayed...
umbilical hernia repair. However, with advancing disease and progression of umbilical hernia come greater risks, including incarceration, skin ulceration, perforation, leakage of ascites, bacterial peritonitis, and possibly evisceration. Although there are certainly risks with elective repair in a patient with cirrhosis, the counterpart morbidity and mortality associated with emergent repair are far greater and have prompted many surgeons to consider early repair.

Aggressive control of ascites is necessary before and after surgery to ensure an improved repair. Several studies have shown that when ascites is controlled, hernia repair outcomes are improved. In addition to medical approaches to controlling ascites, other approaches, such as concomitant peritoneovenous shunting, transjugular intrahepatic portosystemic shunt, or the use of a peritoneal dialysis catheter, have been described, but mainly through descriptive studies. A recent review of 34 patients with a symptomatic umbilical hernia and cirrhosis showed greater morbidity and mortality in patients in the watchful nonoperative group compared with those who underwent elective repair with primary closure. Cirrhotic and noncirrhotic patients undergoing repair of a noninguinal hernia had similar morbidity and mortality when repair was performed electively; however, higher morbidity and a nearly sevenfold mortality were observed in the cirrhotic patients when surgery was emergent. Hassan and colleagues reported elective repairs in 70 cirrhotics (average Model for End-Stage Liver Disease [MELD] score of 18) with sublay mesh placement and only one (1.4%) recurrence with a minimum of 6 months of follow-up. In 30 cirrhotics (average MELD score of 12), Eker and colleagues reported two recurrences with an average of 25 months of follow-up. Both recurrences were in cases where mesh was not used. Given the challenges of conducting a randomized study on such a small subset of patients, we advocate for early elective repair with mesh sublay when possible.

**Atypical Ventral Hernias**

**Subxiphoid (epigastric) hernia**

Epigastric hernias occur through a single defect or multiple defects in the linea alba. These can be primary in origin, incisional hernias following an abdominal or cardiothoracic procedure, or recurrences above a previously placed mesh. A resounding theme in all “atypical ventral hernias” is the difficulty of mesh fixation due to adjacent bony structures. Here the costal margin and xiphoid process limit transfascial fixation. Wide mesh overlap and appropriate fixation are a recurrent theme for subxiphoid and other atypical types.

In most patients with the primary sort, only a single decussation of the fibers of the linea alba is present, as opposed to the triple decussation seen in most persons. The reported incidence of epigastric hernia ranges from less than 1% to as high as 5%. Hernias are two to three times more common in men than in women, and 20% are multiple. Most defects are smaller than 1 cm and contain only incarcerated preperitoneal fat, with no peritoneal sac. For this reason, they generally cannot be visualized laparoscopically. Left untreated, an epigastric hernia can become large enough to develop a peritoneal sac into which intra-abdominal contents can protrude. Usually, however, the sac is wide, and serious complications are infrequent. Symptoms, however, should prompt repair.

Our preference is to repair these defects by an open preperitoneal or retrorectus approach to allow for adequate mesh overlap. The upper edge of the mesh should overlap the ribs and diaphragm and should be secured first with transfascial sutures just below the costal margin before securing inferior and lateral portions of the mesh. Subsequently, anterior and posterior fascial coverage are generally achieved without difficulty.

Laparoscopic repair is also a reliable technique. Takedown of the falciform ligament is a key feature for adequate mesh overlap above the liver. Importantly, mechanical fixation above the costal margin is highly discouraged due to potential chronic pain or pericardial injury caused by tacks. Tacks can be used at the costal margin and additional transfascial suture below the costal margin when necessary. Due to the limitations of fixation, wide mesh overlap above the liver adjacent to the diaphragm is encouraged. Glue can also be used for fixation when necessary.

**Supravesical hernia**

Supravesical hernias develop anterior to the urinary bladder as a consequence of failure of the integrity of the transversus abdominis and the transversalis fascia, both of which insert into the Cooper ligament. The preperitoneal space is continuous with the retropubic space of Retzius, and the hernia sac protrudes into this area. The sac is directed laterally and emerges at the lateral border of the rectus abdominis in the inguinal region, the femoral region, or the obturator region. It may therefore mimic a hernia from any of these areas and sometimes is associated with a hernia from one of these regions. It is important to recognize this hernia during groin exploration for a suspected groin hernia and then to repair the defect appropriately.

Supravesical hernias can be repaired by an open retro muscular dissection or laparoscopic transabdominal preperitoneal approach. Both techniques mature the space of Retzius and allow for mesh fixation to the Cooper ligament and/or the pubic bone. Filling the bladder with saline via a three-way catheter aids its dissection. Wide mesh overlap is a key feature of both operations, although the need for suture fixation in addition to tacks is controversial. Regardless of the method for fixation, care must be taken not to injure adjacent neurovascular structures.

A variant of this hernia, known as an internal supravesical hernia, may also arise. These hernias are classified according to whether they cross in front of, extend beside, or pass behind the bladder. Bowel symptoms predominate in patients with these defects, and urinary tract symptoms may develop in as many as 30%. Treatment is surgical and is accomplished transperitoneally via a low midline incision. The sac can usually be reduced without difficulty, and the neck of the sac should be divided and closed.

**Lumbar hernia**

The lumbar region is the area bounded inferiorly by the iliac crest, superiorly by the 12th rib, posteriorly by the erector spinae group of muscles, and anteriorly by the posterior border of the external oblique muscle as it extends from the 12th rib to the iliac crest. There are three varieties of lumbar hernia:
1. The superior lumbar hernia of Grynfelt. In this variety, the defect is in a space between the latissimus dorsi, the serratus posterior inferior, and the posterior border of the internal oblique muscle.
2. The inferior lumbar hernia of Petit. Here the defect is in the space bounded by the latissimus dorsi posteriorly, the iliac crest inferiorly, and the posterior border of the external oblique muscle anteriorly.
3. Secondary lumbar hernia that develops as a result of trauma—mostly surgical (e.g., renal surgery)—or infection. In the past, this hernia was encountered relatively frequently as a consequence of spinal tuberculosis with paraspinal abscesses but is less common today. Unlike traumatic flank hernias, surgical repair of these eventrations related to infection is specifically discouraged because the natural history is more consistent with that of diastasis recti than that of a true hernia. Denervation appears to play a significant role in the pathogenesis. In other words, this “hernia” reflects a weakness in the abdominal wall more than it does a dangerous hernia defect. Therefore, appropriate repair is commonly followed by gradual eversion, which is perceived by the patient as a recurrence.

Lumbar hernias should be repaired if they are large or symptomatic. Mesh should be used for reinforcement unless there is a contraindication. The difficulty of lumbar hernias—akin to suprapubic and subxiphoid equivalents—lies in the ability to achieve adequate mesh overlap and fixation next to bony prominences. We typically perform a retroperitoneal repair with wide lateral dissection in the preperitoneal plane to the retroperitoneum. If necessary, the mesh can be fixed to the iliac bone with orthopedic bone fixation devices. In a series of 16 patients with 16.8 months of follow-up, we had no recurrences using this technique with low wound morbidity (< 5%). Laparoscopic repair of lumbar hernias has also been described with increasing frequency and is proving successful. We reserve a laparoscopic approach for patients unable to tolerate an open repair and for small defects at least 4 cm from the iliac crest. Although no direct comparative studies have been done, outcomes appear to be similar as the tenets of wide mesh overlap with adequate fixation are maintained.

**Diastasis Recti**

In diastasis recti, the two rectus abdominis muscles are separated, and the linea alba is stretched and protrudes like a fin. This is a common scenario after pregnancy. Because the eventration is not a true hernia, it does not carry the risk of visceral strangulation. Most patients, when reassured, will decline further surgical intervention. Still, many patients find it unsightly and request treatment for cosmetic reasons. Comparison of surgical techniques and studies that address and compare conservative management with surgery are needed.

Treatment typically involves plication of the anterior rectus sheaths with either nonabsorbable or slowly absorbable suture. Some patients, however, can develop a hernia within a diastasis. In this scenario, primary reapproximation of an attenuated linea alba would likely result in a recurrence. In this situation, we advocate the use of a prosthetic reinforcement in the retromuscular position.

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**Parastomal Hernia**

Parastomal hernias are one of the most common complications of stoma formation. By definition, the creation of a stoma implies some form of an abdominal wall hernia. There is good evidence to suggest that more than 50% of patients will eventually be found to have a parastomal hernia if followed for longer than 5 years. The rate of herniation with small bowel stomas is also discouraging, although less so than that with colostomies. The results of parastomal hernia repair are particularly dismal, with recurrence being the rule rather than the exception.

Some parastomal hernias can be accounted for by poor site selection or technical errors (e.g., making the fascial opening too large or placing a stoma in an incision), but the overall incidence is too high to be explained by these causes alone. Placement of the stoma lateral to the rectus sheath is widely touted as a cause of parastomal hernia, but high-quality scientific evidence to support this claim is not available. Obesity, malnutrition, advanced age, collagen abnormalities, postoperative sepsis, abdominal distention, constipation, obstructive uropathy, steroid use, and chronic lung disease are also contributing factors.

Various techniques for stoma construction, such as extraperitoneal tunneling, have had little impact on the incidence of parastomal hernia. Fortunately, patients tolerate these hernias well, and life-threatening complications, such as bowel obstruction and strangulation, are rare. Most, in fact, are asymptomatic. Routine repair, therefore, is not recommended; repair is appropriate only when there is an absolute or relative indication, such as a concurrent ventral hernia [see Table 10]. If repair is considered, patients must be informed that there is a significant chance that the hernia will recur.

Three general types of parastomal hernia repairs are traditionally performed: (1) fascial repair, (2) stoma relocation, and (3) prosthetic repair. Fascial repair involves local exploration around the stoma site, with primary closure of the defect. This approach should be considered of historical interest only because the results are so poor. We reserve this approach for elderly patients or in emergent situations as a bridge to a future definitive repair. Stoma relocation yields much better results and is considered the procedure of choice by many surgeons. This approach is especially appropriate for patients who have other stoma problems, such as skin excoriation or suboptimal stoma construction. Stoma relocation is a significantly more invasive procedure and subjects patients to a triple threat of hernia recurrence:

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**Table 10** Indications for Repair of Parastomal Hernia

<table>
<thead>
<tr>
<th>Indications</th>
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<tr>
<td>Absolute indications</td>
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<tr>
<td>Obstruction</td>
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<tr>
<td>Incarceration with strangulation</td>
</tr>
<tr>
<td>Relative indications</td>
</tr>
<tr>
<td>Incarceration</td>
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<tr>
<td>Prolapse</td>
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<tr>
<td>Intractable dermatitis</td>
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<tr>
<td>Difficulty with appliance management</td>
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<tr>
<td>Large size</td>
</tr>
<tr>
<td>Cosmesis</td>
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<tr>
<td>Pain</td>
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</tbody>
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(1) at the old stoma site, (2) at the new stoma site, and (3) in the laparotomy incision used to move the stoma. Given these risks, we typically place a large sheet of mesh prophylactically in the retrorectus position. This mesh is keyholed around the new stoma site and is used to reinforce the old stoma site and the midline closure. In a series of 48 parastomal repairs using our aforementioned approach, we documented five (11%) recurrences, three requiring reoperation. Randomized, controlled, prospective studies with long-term follow-up have also begun to show that use of prophylactic mesh placement during stoma creation appears to significantly reduce recurrence rates (13 to 22%).

Interestingly, the study by Janes and colleagues used macroporous lightweight polypropylene mesh for reinforcement with no long-term infectious complications or bowel erosion. As previously mentioned, the use of synthetic mesh in this scenario is controversial and should be done with extreme caution. Future studies elucidating the safety of synthetic mesh in contaminated fields will corroborate these findings.

The extraperitoneal approach seems logical but can be technically demanding in that it is sometimes difficult to define the entire extent of the hernia defect. Moreover, the considerable undermining involved can lead to seroma formation, eventual infection, or peristomal skin necrosis. As an alternative, an intra-abdominal prosthetic approach has been described that is theoretically attractive because it avoids the local complications of the extraperitoneal operation and incorporates the mechanical advantage gained by placing the prosthesis on the peritoneal side of the abdominal wall. Intra-abdominal pressure then serves to fuse the prosthetic material to the abdominal wall rather than being a factor in recurrence. The use of ePTFE is particularly advantageous given the lack of ingrowth around bowel, but polypropylene or polyester barrier meshes can also be used. One technique is to slit the prosthesis and create a keyhole in its center and then suture this directly around the peritoneal side of the stoma so that it widely overlaps the hernia defect. Sugarbaker’s practice is to mobilize the bowel thoroughly and then lateralize it with the prosthesis, in effect creating a long tunnel in addition to covering the hernia defect. The detractors of the intra-abdominal approach argue that the risk of complications (e.g., adhesive bowel obstruction and fistula formation) outweighs the advantages. The intra-abdominal approach is particularly well suited for adaptation to laparoscopic methods.

**Spigelian Hernia**

A spigelian hernia, first described 400 years ago by the Flemish anatomist Adriaan van den Spiegel, is a hernia through a defect in the spigelian fascia. Above the arcuate line, the fused internal oblique and transversus abdominus aponeuroses split to form anterior and posterior rectus sheaths, encasing the rectus muscle before reconvening at the linea alba. Below the arcuate line, all aponeuroses pass anterior to the rectus muscle. This transition abates the posterior rectus sheath and creates an area of weakness in the linea semilunaris, allowing for herniation. This region, known as the spigelian belt, is a band between the iliac crest and a line drawn 6 cm above the umbilicus. A hernia sac can protrude through transversus abdominus and internal
oblique aponeuroses with the overlying external oblique layer remaining intact, making clinical recognition of a spigelian hernia difficult. These rare hernias are being reported with increasing frequency: there are more than 100 cases in the surgical literature.

A spigelian hernia may present as a bulge lateral to the rectus. However, because many of these hernias are interparietal, they may not be clinically apparent; often they are picked up incidentally during laparoscopy. A significant percentage of patients present with an incarcerated or strangulated hernia. If such a hernia is interparietal, the diagnosis is normally not made until a laparotomy is done for treatment of the acute process.

The standard treatment is operative repair. For open repairs, a transverse incision is made over the bulge. The anterior rectus sheath is incised transversely, and the sac is dissected as far as its neck and either excised or inverted. A prosthetic reinforcement is placed in the retromuscular position. The defect is then repaired with a continuous suture of nonabsorbable material. Laparoscopic methods are increasingly being employed to repair spigelian hernias, with equivalent success.

**Richter Hernia**

A Richter hernia is unique in that part of the bowel wall herniates through the defect without causing an obstruction of the associated lumen. Incarceration can potentially lead to ischemia and gangrenous bowel, and the overlying skin may be discolored. The herniated bowel wall is exposed by opening the sac, and the neck of the sac is enlarged to allow delivery of the bowel into the wound. The gangrenous patch is excised, and the bowel wall is reconstituted. The hernia is then repaired.

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