Abdominal Wall Hernia

Abdominal wall hernia (AWH), although not necessarily the most glamorous of surgical subjects, is 1 of the most important for all surgeons who operate on the abdomen. Although the true incidence is unknown, the National Center for Health Statistics estimates that approximately 5 million Americans have an abdominal wall hernia.[1] The majority of these hernias develop in the inguinal region. The topic of inguinal hernia has been recently and extensively addressed in this journal, and therefore our focus will be on other hernias of the anterior abdominal wall, flank, and back.[2]

Based on projected growth from the 1996 National Survey of Ambulatory Surgery and National Center for Health Statistics, there were 360,000 ventral hernia repairs performed in the United States in 2003; 105,000 hernias were incisional and the remainder were comprised of primary ventral hernias.[3] Although such hernias can be small and relatively asymptomatic, most, in fact, do cause patients pain and discomfort and affect their quality of life. Furthermore, a small proportion of these hernias progress to incarceration and even strangulation of bowel and other viscera, which can be life-threatening. Considering also the fact that as many as 1 in 5 patients who undergo a laparotomy will develop an incisional hernia,[4] it is clear that abdominal wall hernias remain a common and serious health care issue in this country. Although it is hard to estimate the full economic burden that AWH imposes on our society, informal industry estimates suggest that related health care costs alone amount to $2.5 to $3 billion per year.

Happily, there have been some positive developments to report on the approach to and treatment of AWH over the past several years. Our understanding of the natural history of ventral and incisional hernias has improved over the past 2 decades. We now know that incisional hernias do not all develop within 6 to 12 months of the primary operation. Bucknall and colleagues[5] have shown that patients must be followed at least 3 and preferably 5 years after laparotomy to get a true sense of the incidence of incisional hernias. We have also learned that when ventral

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and incisional hernias are repaired, they have recurred, historically, at an alarming rate (up to 50%) depending on the surgical techniques employed.[6] Furthermore, the recurrences tend to present sooner than the original ventral hernias, most commonly within a year of the repair.[7,8] It is still difficult to quantify a hernia patient's risk of suffering bowel strangulation.

Of all recent developments in ventral herniorrhaphy, 2, in particular, bear special mention. The surgical shift over the past 10 to 15 years from primary suture repair (initially under tension) to a tension-free repair requiring placement of a biomaterial or mesh has been 1 of the most important trends in herniorrhaphy.

Building on reports of surgeons indicating their early experience with mesh repairs and the resulting dramatic and significant drop in recurrence rates, several well-designed randomized controlled trials on the subject were conducted.[6,8] Most notable among these was a study that provided incontrovertible evidence that mesh repairs of ventral hernias result in significantly fewer recurrences than nonmesh repairs.[4] A second, more recent advance in ventral herniorrhaphy that must be acknowledged is the advent of a minimally invasive or laparoscopic approach to ventral hernia repair. First described in the early 1990s, it is a procedure being increasingly adopted by surgeons across the country.[9,10] To summarize the significant impact of both advances, informal industry reports suggest that approximately 70% of ventral or incisional hernia repairs in the United States are now performed with mesh and 25% to 30% of all such mesh repairs are performed laparoscopically.

In this issue we discuss abdominal wall anatomy, contributing factors to AWH formation, and proposed mechanisms of hernia formation. We also review the principal anatomic subtypes of these hernias and their treatment and outcomes, followed by a discussion of biomaterials and devices/methods of fixation.

Abdominal Wall Anatomy

The abdominal wall consists of a complex fusion of overlapping layers of muscle and connective tissue designed to contain and protect the abdominal viscera while facilitating rotation and approximation of the thorax with respect to the pelvis. The abdominal wall muscles are comprised of 2 central vertical pillars (rectus abdominis [RA]) connected to a triple layer of flat muscles extending laterally to cover a roughly hexagonal area bound superiorly and laterally by the xyphoid process and costal margins and inferiorly and laterally by the pubic symphysis and iliac crests. These muscles encompass a cylindrical abdominal cavity and

in performing their function must be able to withstand pressures generated internally as well as "insults" applied externally.

Rectus Abdominis

The RA muscles broadly originate from the 5th, 6th, and 7th ribs and the xyphoid process. The fleshy upper half of each rectus muscle is wider than the lower area of its tendinous insertion onto the pubis (10 to 12 cm in upper third, 5 to 8 cm near umbilicus, 2 to 3 cm near pubis).

The RA is enveloped within a robust sheath derived from the aponeuroses of the 3 flat muscles. Where these fibers cross and coalesce in the midline, the linea alba is formed.

The Flat Abdominal Wall Muscles

The 3 flat muscles of the abdominal wall in descending order from superficial to deep are the external obliques (EO), the internal obliques (IO), and the transversus abdominis (TA). The EO takes origin on the lower 8 ribs, and its muscular fibers follow an oblique course inferiorly and medially to insert into the rectus sheath (description follows) and more inferiorly into the iliac crest and pubis. Along the way the EO forms an intricate part of the inguinal anatomy, including the superficial inguinal ring. The IO arises more from the anterior half of the iliac crest and lateral half of the inguinal ligament. Its muscular fibers then course anteriorsuperiorly at right angles to those of the EO to insert on the lower 4 ribs and the rectus sheath. The TA is the main muscle used to retain the abdominal contents. It takes origin from both the inner lip of the iliac crest and the lateral one third of the inguinal ligament as well as from the deep surface of the lower 6 rib costal cartilages. The TA muscular fibers course transversely to decussate ultimately in the linea alba.

The Rectus Sheath

It is important for a surgeon to understand the anatomy of the rectus sheath because it relates to incisional hernia repair, laparoscopic inguinal herniorrhaphy, and, in particular, the totally extraperitoneal repair. The anterior lamina of the rectus sheath is comprised largely of fibers from the EO and IO muscles. At the level of the midepigastrium, all aponeurotic fibers from the EO pass into the anterior lamina (as they do the entire length of the sheath), whereas fibers of the IO aponeuroses split to pass into both the anterior and the posterior lamina of the sheath. The TA muscle aponeuroses passes into the posterior lamina of the sheath along with fibers from the IO down to the level of the arcuate line (semicircular line of Douglas). Below this line the aponeuroses of the EO, IO, and TA

muscles all pass into the anterior lamina of the sheath and only the transversalis fascia passes posterior to the RA muscle. The linea semilunaris, a medially concave semilunar line running essentially the length of the lateral bender of the rectus sheath, is well described. Initially van der Spiegel discerned the line to represent the boundary between the muscle body and the anterior aponeuroses of the TA.[11] Where the semicircular and semilunaris lines cross, an area of potential weakness exists, within which the rare Spigelian hernia may arise. The rectus sheath contains the inferior epigastric artery that pierces the transversalis fascia, then runs cephalad posterior to the RA. The inferior epigastric artery, which originates from the external iliac artery, and the superior epigastric artery, which arises from the internal thoracic artery, supply the coverings and contents of the rectus sheath. The flat muscles of the abdominal wall are supplied by intercostals and lumbar arteries as well as by a deep circumflex branch of the iliac artery.[12]

Pathophysiologic Features

The development of abdominal wall hernias is not new, having been described in the written record since the times of the Egyptian Old Kingdom.[13] However, the exact pathogenesis of this entity is not well understood. Primary ventral hernias, most commonly umbilical, may be related to anatomic abnormalities and a host of other problems that cause an increase in intra-abdominal pressure. The variety of factors known to contribute to hernia development includes physiologic change in fascial integrity, proteolysis associated with cigarette smoking, direct mechanical trauma, physical overexertion, and familial genetic tendency.[14]

Hernias are defined as defects in an aponeurotic layer, resulting in the protrusion of an organ out of a cavity in which it normally resides. This occurs as a result of increases in intra-abdominal pressure that exceed abdominal wall counterpressure. Pascal's principle of hydrostatic forces serves as a first approximation of intra-abdominal pressures that result in hernia formation. Pascal's principle states that any change in the pressure applied to a completely enclosed fluid is transmitted undiminished to all parts of the fluid and the enclosing walls. This model assumes uniformity of the abdominal contents as well as the abdominal wall. Although the contents of the abdominal cavity are not uniform and are not a uniform liquid, the model helps to better understand the physiology of hernia formation. According to Pascal's principle, any increased pressure generated within the abdominal cavity is transmitted equally to the walls of that cavity. In response to increased abdominal pressure, the muscular abdominal wall will contract and generate counterpressure. In the event

that intra-abdominal pressure exceeds abdominal wall pressure, the excess pressure results in rupture of the abdominal wall's weakest component, causing herniation. In a series of recent studies, Cobb and colleagues[15,16] characterized these forces by determining the intra-abdominal pressures (IAP) generated in a group of healthy, young adults during the course of several routine activities. They found that when these subjects performed Valsalva sitting and standing, they generated IAP of 64 and 116 mmHg, respectively. Standing and coughing produced an IAP of 141 mmHg. When a subject jumped in place, he or she could generate a remarkable IAP as high as 252 mmHg. They concluded that the maximum and necessary tensile strength of an adult's abdominal wall to sustain such activities would range from 11 N/cm to 27 N/cm.[15,16]

According to Pascal's principle, despite the uniformity of the intra-abdominal pressure, the tension of the abdominal wall will vary. Best illustrating this is the Law of LaPlace, according to which wall tension is directly proportional to the radius of the cylinder. The Law of LaPlace states: $T = PR/2w$, where T is wall tension, P is chamber pressure, R is chamber radius, and w is wall thickness. The wall tension of the abdominal wall will be greatest at the point with the largest radius and the thinnest wall. As a result, once an abdominal wall defect has developed, the radius at this location will increase and the abdominal wall thickness will have decreased, thus increasing the wall tension, which ultimately leads to progression of the hernia. In other words, once a hernia has developed, it will continue to progress in size due to the increase in wall tension at that location.

The most common mechanism of hernia formation in the abdominal midline is in the postoperative setting. This represents the simplest conceptual scenario of hernia development, in which the traumatized tissue loses a portion of its structural integrity, allowing protrusion of an organ or viscera into a region that is not its normal location.

Biochemical Factors

Somewhat surprisingly, research into the biochemical basis of incisional hernia formation is in its infancy. It has long been speculated that a dysfunction of collagen synthesis or deposition may underlie clinical herniation. Initial studies in the 1970s, such as that of Wagh and Read,[17] demonstrated disordered collagen arrangements and increased elasticity in inguinal hernias. However, more sophisticated analysis has recently been undertaken to highlight the nature of hernia defects.

Research has been focused on the extracellular matrix as the dynamic scaffolding that allows appropriate tissue remodeling and healing.[18] It is

now recognized that there is an active role taken by the collagen subtypes as well as fibronectin, laminin, and a host of other glycoproteins. Investigations into regulatory pathways, such as that of the matrix metalloproteinases, has not yet yielded consistent results.[19] In addition, some initial attempts at providing molecular therapy for hernias have not yet proved fruitful.[20]

One study incorporated both immunohistochemistry and Western blot analysis to investigate the ratio of collagen subtypes in patients with and without inguinal hernias.[21] Type I collagen is mature collagen, found in dense bundles, whereas type III collagen is more embryonic and populates smooth muscle. The study found that there was an increased rate of type III collagen synthesis in patients with inguinal hernias, resulting in a significantly altered ratio of type I to type III collagen. This recognition of altered collagen synthesis and its potential impact on cross-linking has significant implications for further research on the biology of hernia formation.

In a separate study, the same investigators demonstrated in an animal model that the specifics of the suture material itself also affect the collagen deposition of the abdominal wall.[22] Interestingly, the ultrastructural composition of the abdominal wall was affected by suture technique and tension beyond the expected time frame for adequate healing. The results of this research suggest that surgical technique clearly alters the body's tissue response on both a molecular as well as a functional level.

Other Factors

A myriad of factors have been associated with incisional ventral hernias and are outlined in Table 1. Unfortunately, strong literature support is often lacking for the significance of the individual risk factors. However, the contributing factors may be considered in 2 categories: those that are patient-related and those that depend on surgical technique.

Aneurysmal disease has long been noted to be associated with hernia formation. In 1 study, a nearly 4-fold increase in incisional hernias was reported in patients who had undergone repair of abdominal aortic aneurysms compared with patients who had undergone abdominal aortic reconstructions for occlusive disease.[23] It has long been postulated that aneurysmal disease represents a fundamental defect in collagen synthesis or deposition. However, little has been accomplished in the realm of potential systemic treatment, and mechanical reinforcement remains the standard of care.

Significant obesity also seems to predispose to incisional herniation. A retrospective review at 1 center found a 20% incidence of incisional

TABLE 1. Risk factors reported to be associated with the development of incisional hernias

Systemic
Abdominal aortic aneurysm
Advanced age
Anemia
Anticoagulation
Benign prostatic hypertrophy
Blood transfusion
Chemotherapy
Cigarette smoking
Chronic pulmonary disease
Diabetes
Early reoperation
Emergency procedure
Experience of the surgeon
Infection
Jaundice
Kidney disease
Renal failure
Polycystic kidney disease
Male gender
Malignancy
Malnutrition
Obesity
Radiotherapy
Steroid use
Local
Fascial closure technique
Continuous versus interrupted
Absorbable suture versus permanent
Suture length to wound length ratio
Location of incision
Postoperative hematoma/seroma
Size of fascial defect

herniation among patients undergoing open gastric bypass.[24] In a separate study, obesity contributed to higher recurrence rates, but the differences were not statistically significant.[6] Because of data such as these, the association between obesity and hernia formation or recurrence has come into question. However, it is nearly universally accepted that morbidly obese patients have a higher risk of wound infection, which, in turn, leads to an increased incidence of incisional hernias. Among patients who develop a wound infection, the rate of clinical herniation is increased nearly 5-fold.[5]

Incisional hernia recurrence has not been impacted by factors associated with decreased healing ability, such as the presence of diabetes mellitus or steroid use, or associated with intermittently increased intra-abdominal

pressure, such as constipation.[5] Studies of comorbidities are plagued by bias, lack of statistical power, and reporting issues. The best current evidence, however, does not suggest comorbidities dramatically affect incisional hernia recurrence.

The size of the hernia defect has important implications for recurrence. Surgical experience would suggest that the larger the hernia defect, the more likely the possibility of recurrence. Studies have borne this out, with a threshold of approximately 4 cm representing a 3-fold risk for recurrence.[5]

Surgical technique has obvious implications for the recurrence rates of hernias. The technical details will be reviewed in the subsequent sections on open and laparoscopic techniques. However, the use of mesh clearly reduces the rate of hernia recurrence and is considered to be the gold standard for any sizable hernia defect.[4] Studies have not demonstrated a difference between continuous and interrupted suturing techniques.[25] Similarly, there has been no recurrence difference noted between vertical and transverse incisions.[26]

Principles of Ventral Herniorrhaphy

The principal techniques of ventral hernia repair have evolved from primary closure of defects with suture material to tension-free repairs using prosthetic materials. The advent of laparoscopic surgery has added an additional modality of repair to the armamentarium of the surgeon. Despite numerous advances in the arena of herniorrhaphy, many questions remain unanswered. There is no clear consensus among surgeons regarding the optimal repair of ventral or incisional hernias. However, there is agreement about the fundamental principles of ventral/incisional management.

Nonoperative Treatment

Conventional surgical wisdom dictates that unless other comorbid conditions preclude safety, the presence of a hernia is an indication for repair. No published prospective randomized trial has compared nonoperative ventral hernia management with elective repair. The rationale for elective repair of ventral and incisional hernias relates to the possibility of incarceration of the hernia with resulting strangulation of the herniated intestine. The true incidence of incarceration is unknown, but it may occur in as many as 10% of all ventral hernias.[27] Patients with incarcerated ventral hernias commonly develop bowel obstructions, and nearly 50% of these patients will develop strangulated hernias.[28] Of those patients with strangulated hernias, nearly 20% will require intestinal

resection, which significantly complicates the postoperative course. Overall complication rates following incarcerated ventral hernia repair are reported to be as high as 25%. Furthermore, postoperative mortality rates following the repair of an incarcerated hernia have been reported as high as 5%, significantly greater than for elective hernia repair.[29] The postoperative mortality rate following repair of a strangulated hernia necessitating bowel resection approaches 20%.[28] Some patient populations such as those receiving peritoneal dialysis may be more susceptible to incarcerated hernias. The incidence of incisional hernia incarceration in this group has been reported to be in excess of 60%.[30]

Patients with significant comorbidities that preclude hernia repair may be managed nonoperatively. These patients should be counseled regarding the signs and symptoms of incarceration, such as nausea, vomiting, and abdominal pain. A primary tenet of nonoperative management requires minimization of activities that increase intra-abdominal pressure. A sudden increase in intra-abdominal pressure may increase the possibility of an acutely incarcerated hernia. Therefore, patients treated nonoperatively should avoid strenuous activities, such as lifting, straining, and jumping. Abdominal binders may serve as an adjunct to the nonoperative management of such hernias. A tightly worn abdominal binder serves to support the abdominal wall at the site of the hernia defect and may decrease the likelihood of incarceration. Buttressing the abdominal wall may also minimize hernia enlargement. It should be noted, however, that patient compliance with abdominal binders is often poor, due to discomfort and difficulty in securing the binder tightly. Despite the theoretical benefits of abdominal binders, no strong evidence is available to support or refute such benefits in the management of ventral hernias.

In determining the role for surgical repair of a ventral hernia, the physician must carefully consider the mortality associated with elective repair as well as with emergency surgery in addition to the likelihood of recurrence, the likely annual risk of incarceration, and the patient's life expectancy. Only by assessing these factors on an individual basis can the surgeon determine the potential benefits and risks of herniorrhaphy.

Ventral/Incisional Hernia Repair

Although ventral herniorrhaphy can largely be classified into 2 categories (primary repair or tension-free repair with prosthetic material), surgeon preferences result in significant technical differences in the execution of such repairs. Primary repairs are typically performed by excising the hernia sac and closing the tissues, using either continuous or interrupted permanent sutures. Approximation of the wound edges

requires placement of sutures at appropriate intervals to minimize the likelihood of wound failure. Postoperative abdominal distension has been shown to increase the length of a surgical wound by as much as 50%.[31] Accordingly, sutures must be at least 1 cm in width with advancement of no more than 1 cm between stitches. This results in an ideal suture to wound length ratio of at least 4:1, thus minimizing the likelihood of wound disruption from sutures pulling through the tissues.[32] Burst abdominal wounds may occur when the suture-to-wound length ratio is less than 2:1. In addition, sutures placed closer than 1 cm to the wound edge will be in the zone of inflammation, which has a decreased ability to hold sutures.[33]

Primary repair typically has been reserved for ventral hernias less than 4 cm in the greatest dimension. Since primary closure of even small incisional hernias has been associated with long-term hernia recurrence rates between 40% and 60%,[4,34] most surgeons have abandoned primary repair of incisional hernias.

Prosthetic materials may be used to repair ventral hernias in a tension-free manner. Numerous techniques used commonly in such repair include mesh overlay, mesh inlay, properitoneal underlay, and intraperitoneal underlay. Repairs differ in type and location as well as the method of fixation of the prosthetic material. Despite these differences, each of these tension-free repairs serves to bridge the hernia defect with the prosthetic material widely overlapping normal healthy tissues. This allows the defect to be repaired without increasing intra-abdominal pressure, which may stress the repair's integrity. Tension-free hernia repairs are associated with recurrence rates of 20% to 30%, significantly lower than the recurrence rate for primary repairs.[34]

When repairing a hernia, it is important to keep in mind Pascal's principle. Intra-abdominal forces will be applied directly to the hernia repair in cases of primary closure. These forces, along with the lateral distraction of the abdominal wall, will lead over time to disruption of the hernia repair and the high rate of hernia recurrence. During tension-free hernia repair, Pascal's principle must also be considered when determining optimal placement of a prosthetic material. Common techniques for prosthetic hernia repair include placement of the prosthetic anterior to the abdominal wall fascia as an onlay, suturing the prosthetic adjacent to the fascial edges as an inlay, or placement of the prosthetic as an underlay in either an intraperitioneal or properitoneal location. Based on Pascal's principle, the placement of mesh in the underlay position has the most theoretic appeal.

Onlay mesh repairs can be performed with or without primary closure

of the fascia. The primary advantage of primary fascia closure with anterior reinforcement of the repair with a prosthetic material is the avoidance of contact between the underlying viscera and the prosthetic material. Closing the hernia defect primarily may result in tension on the hernia, ultimately leading to its recurrence; however, the anteriorly sutured prosthetic serves to reinforce the primary closure. Onlay repairs performed without primary closure of the hernia defect present the potential for mesh exposure to the underlying viscera. Direct exposure between a prosthetic material and the viscera may result in long-term bowel erosion and fistula formation and infection of the prosthetic. Insertion of a prosthetic material in an onlay fashion is associated with an increased incidence of infections compared with primary hernia closure.

The inlay technique for ventral hernia repair involves suturing a prosthetic material to the edges of the fascia without significant overlap of the mesh. This technique does not allow for overlap between the prosthetic material and the fascia adjacent to the hernia defect. Although this repair is also tension-free, increases in intra-abdominal pressure may result in the mesh separating from the fascia at the suture line. This may result in button-hole hernias lateral to the prosthetic material. Recurrence rates with inlay hernia repairs are at least 2-fold higher than onlay repairs and underlay repairs. Accordingly, this type of repair is not encouraged.

Underlay repairs are considered the gold standard for open incisional hernia repairs. In these procedures, the prosthetic material is secured posterior to the abdominal wall musculature either in the preperitoneal space or in an intraperitoneal position. The retrorectus or Stoppa repair is 1 of the more commonly performed underlay hernia procedures. Popularized during the 1990s, this operation involves placing a large prosthetic material into the properitoneal space. The prosthetic is anchored by placing sutures through the full thickness of the abdominal wall by means of separate "clock-face" incisions along the anterior abdominal wall. As a result, the material is anchored circumferentially to the entire thickness of the abdominal wall musculature with the prosthetic overlapping the fascia by approximately 5 cm in all dimensions. The initial report by Stoppa reported a satisfactory result in 85% of patients with a 1.8% mortality and 12% sepsis rate.[48] Since that time, others have reported excellent results with hernia recurrence rates of less than 5% and incidence of mesh infection requiring prosthetic removal between 1% and 4%.

Intraperitoneal placement of prosthetic material is a comparable alternative to the retrorectus repair of Stoppa. Intraperitoneal repair is performed similarly to the Stoppa repair, except that a properitoneal space

TABLE 2. Published comparisons of laparoscopic and open incisional hernia repair using mesh

Author	Year	P/R	Type	n	Defect (cm^2)	Patch (cm^2)	Prior repair (%)
Bencini[35]	2003	R	Lap	42	83	NS	7
			Open	49	122	NS	20
Carbajo[36]	1999	P	Lap	30	140	NS	NS
			Open	30	141	NS	NS
Chari[37]	2000	R	Lap	14	NS	495	NS
			Open	14	NS	97	NS
DeMaria[38]	2000	P	Lap	21	NS	NS	54
			Open	18	NS	NS	17
*Holzman[39]	1997	R	Lap	21	105	NS	38
			Open	16	148	NS	25
*McGreevy[40]	2003	P	Lap	65	NS	NS	40
			Open	71	NS	NS	27
Park[41]	1998	P/R	Lap	56	99	231	29
			Open	49	105	NS	18
*Ramshaw[42]	1999	R	Lap	79	73	287	46
			Open	174	34	47	29
Raftopoulos[43]	2003	R	Lap	50	125	NS	NS
			Open	22	202	NS	NS
Robbins[44]	2001	P	Lap	36	NS	NS	NS
			Open	18	NS	NS	NS
van't Riet[45]	2002	R	Lap	25	NS	NS	32
			Open	76	NS	NS	26
Wright[46]	2002	R	Lap	90	112	224	17
			Open	90	79	172	31
Zanghi[47]	2000		Lap	11	104	227	9
			Open	15	120	NS	7

*Includes some primary repair in open group; P, prospective; R, retrospective; NS, not specified; ePTFE, expanded polytetrafluoroethylene; PP, polypropylene; Y, yes; N, no; Lap, laparoscopic.

does not need to be created. This procedure minimizes the properitoneal dissection, which can be difficult and time-consuming in patients with multiple previous abdominal operations. Placement of the prosthetic material in an intraperitoneal location adjacent to the intestines requires the use of a prosthetic material with an adhesion barrier that will not result in bowel adhesion/erosion and the possibility of enterocutaneous fistula formation.

Laparoscopic ventral hernia repair is an underlay technique that will be discussed in greater detail in the section titled "Laparoscopic Incisional/Ventral Hernia (LIVH) Repair." The repair is modeled after the Stoppa repair but differs in that the prosthetic is placed in an intraperitoneal location. Following laparoscopic adhesiolysis, the prosthetic is placed within the abdomen and sutured circumferentially to the full thickness of the abdominal wall. The prosthetic is anchored with sutures that are

TABLE 2. Continued

Patch material	Transfascial sutures	Complications		Recurrence (%)	Follow-up (mo)
		Total (%)	Seroma (%)		
ePTFE	Y	26	14	0	17
PP	—	44	10	3	18
ePTFE	Y/N	20	13	0	27
ePTFE, PP	—	NS	67	7	27
ePTFE	N	14	NS	0	NS
PP	—	14	NS	0	NS
ePTFE	Y	67	43	5	12–24
PP	—	72	22	0	12–24
PP	N	31	NS	10	20
PP	—	23	NS	13	19
ePTFE	Y	8	3	NS	1
PP	—	21	4	NS	1
ePTFE	Y	18	4	11	24
PP, ePTFE	—	37	2	34	53
ePTFE	Y	19	3	3	21
PP	—	31	7	21	21
ePTFE	Y	28	14	2	21
ePTFE, PP	—	45	14	18	26
ePTFE, PP	Y	16	NS	NS	NS
PP, ePTFE	—	28	NS	NS	NS
PP	Y/N	52	36	16	15
PP	—	44	17	18	17
ePTFE	Y	28	9	1	24
PP	—	42	12	6	32
ePTFE	Y	18	0	0	18
ePTFE, PP	—	60	1	0	40

placed through incisions on the skin of the abdominal wall at the outer circumference of the hernia prosthetic, much like the Stoppa repair. Laparoscopic ventral hernia techniques can be used to repair most hernias, with complications occurring in 5% to 15% of patients. Recurrence rates with laparoscopic hernia repair are less than 5%. Table 2 summarizes published comparisons of both laparoscopic and open herniorrhaphy using mesh, and Table 3 similarly addresses published large series (more than 100 patients) of laparoscopic incisional herniorrhaphy using mesh.

Biomaterial/Fixation Device Overview

The repair of virtually all ventral hernias requires prosthetic material use, due to the unacceptable recurrence rate encountered with the primary closure of incisional hernias. The use of prosthetic materials in ventral hernia repair has resulted in decreased incidence of

TABLE 3. Large series of laparoscopic incisional hernia repair using mesh (>100 cases)

Author	Year	n	Body mass index	Defect (cm^2)	Patch (cm^2)	Prior repair (%)	Conversion (%)
Bageacu[49]	2002	159	NS	NS	NS	23	14
Ben-Haim[50]	2002	100	NS	NS	NS	25	4
Berger[51]	2002	150	29	94	350	13	2
Bower[52]	2004	100	34	124	280	32	1
Carbajo[53]	2003	270	NS	145	300	27	1
Chowbey[54]	2000	202	NS	NS	NS	NS	1
Franklin[55]	2004	384	NS	NS	NS	NS	4
Frantzides[56]	2004	208	NS	173	NS	NS	0
Gillian[57]	2002	100	NS	NS	NS	NS	0
Heniford[58]	2003	850	32	118	344	34	4
Kirshtein[59]	2002	103	34	175	324	41	3
LeBlanc[60]	2003	200	NS	111	258	21	4
Rosen[61]	2003	100	31	96	354	38	12
Toy[62]	1998	144	NS	98	216	26	0
Ujiki[63]	2004	100	33	97	259	24	3

NS, Not specified; PP, polypropylene; PTFE, polytetrafluoroethylene; Y, yes; N, no; LOS, length of stay.

recurrence; however, these implants are not without potential for side effects and complications. Numerous biomaterials—each with distinct advantages and disadvantages—are used clinically (Table 4). The goal in using these materials is to provide the abdominal wall with a permanent repair that is compliant, strong, durable, and resistant to infection and that does not result in adhesion formation. Although there is no ideal prosthetic agent, the unique properties of each biomaterial make all more or less suitable, depending on the individual circumstance. Polypropylene, polyester, and polytetrafluoroethylene (PTFE) meshes are the most commonly used hernia prosthetic materials. Numerous manufacturers have fashioned these meshes in a variety of specifications so that hernia repair can best be facilitated and prosthetic-related complications can be minimized.

Polypropylene mesh is 1 of the most widely used biomaterials in incisional hernia repair. Polypropylene mesh, designed by numerous manufacturers and marketed under different trade names, is available in many different configurations, each of which differs in weight, porosity, thickness, and weave pattern. In general, polypropylene meshes with larger pores and monofilament weave patterns will be less adhesiogenic than multifilament weaves with smaller pores. The incidence of complications with polypropylene meshes is relatively low. The incidence of prosthetic infections with polypropylene mesh is approximately 5%. Intestinal fistulization has been reported to occur

TABLE 3. Continued

Patch material	Transfascial sutures	Complications		LOS (d)	Recurrence (%)	Follow-up (mo)
		Total (%)	Seroma (%)			
PTFE	Y	44	16	3.5	16	49
PTFE	N	24	11	5	2	14
PTFE	Y	97	93	9.1	3	15
PTFE	Y	15	1	NS	2	6.5
PTFE	N	15	12	1.5	4	44
PP	N	30	25	1.8	1	35
PP, PTFE	N	10	3	2.9	3	47
PTFE	N	3	NS	1.4	1	24
Composix	N	7	3	NS	1	NS
PTFE	Y	13	3	2.3	5	20
PTFE	N	6	0	3.1	4	26
PTFE	Y	18	NS	1.3	7	36
PTFE, PP	Y/N	14	4	1.8	17	30
PTFE	Y	26	16	2.3	4	8
PTFE	Y	23	13	2	6	3

with polypropylene mesh, but in less than 2% of patients.[64] Due to the risk of fistulization and also the potential for adhesion and bowel obstruction, polypropylene meshes should be avoided when the hernia repair requires placement of the prosthetic adjacent to the viscera without a protective layer.

Polyester prosthetics are also commonly used in ventral hernia repair. Mersilene (Ethicon, Inc, Somerville, NJ) has been commercially available longer than most other polyester prosthetics and is the most commonly used. It should be noted that Mersilene has been associated with a higher incidence of enterocutaneous fistulas and infections.[65] In polyester prosthetic hernia repairs, in general, hernia recurrence and postoperative bowel obstructions are encountered commonly.[64] However, the increased incidence of fistulas and the higher recurrence rate have been disputed, and despite associated risks, polyester prosthetics are used widely in Europe.

Expanded polytetrafluoroethylene (ePTFE) prosthetics have become increasingly popular due to their unique properties. Current formulations of ePTFE have been developed that may be placed safely adjacent to the abdominal viscera without the risk of intestinal fistula formation. The ePTFE patches have a microporous surface formulated with porosity of less than 3 μm to minimize intra-abdominal adhesion formation. The opposite surface of ePTFE patches has larger porosity to allow for rapid ingrowth into abdominal wall tissues. This prosthetic may be placed in an intraperitoneal location with the microporous surface adjacent to the

TABLE 4. Common prosthetic meshes in abdominal wall hernia repair

Material	Trade name	Year introduced	Manufacturer
Dermis (cadaveric)	Alloderm	1994	LifeCell
Dermis (porcine)	Permacol	1997	Tissue Science Labs
Polyester	Mersilene	1956	Ethicon
	Parietex	1993	Sofradim
Polyglactin	Vicryl	1952	Ethicon
Polyglycolic acid	Dexon	1983	W.L. Gore
Polypropylene	Marlex	1958	Bard
	Prolene		Ethicon
	Surgipro		Tyco/USSC
Polypropylene and collagen	Parietex Composite	1998	Sofradim
Polypropylene and HA-CMC	Sepramesh	2000	Genzyme
Polypropylene and PTFE	Composix	1997	Bard
PTFE	Dualmesh	1983	W.L. Gore
Submucosa	Surgisis	2001	Cook

HA-CMC, hyaluronic acid-carboxymethylcellulose; PTFE, polytetrafluoroethylene.

viscera and the macroporous surface adjacent to the peritoneum. Although, in contrast to other prosthetics, ePTFE patches have little memory and require more manipulation when the graft is positioned, experienced surgeons may quickly master the necessary technical skills. Although the incidence of infection with the ePTFE products is low, when such infection does occur, removal of the ePTFE prosthetic is necessary.[66]

Innovative bilayer prosthetic materials may be used in both open and laparoscopic ventral hernia repair. These materials combine a prosthetic with favorable ingrowth characteristics with a prosthetic that minimizes adhesion formation. The most commonly used bilayer prosthetics are created with polypropylene and PTFE.

Bilayer prosthetic materials from a permanent material, such as polypropylene or polyester, are formulated with 1 surface coated with an absorbable adhesion-preventing substance. In hernia repair, this barrier minimizes adhesion formation while a neomesothelial layer is created on the undersurface of the graft. Because this layer covers the graft before the absorbable adhesion barrier is fully dissolved, the risk of adhesion formation is theoretically decreased.

Xenografts have recently been used in the repair of incisional hernias, most commonly during contaminated procedures. Use of these bioabsorbable tissue scaffolds that are derived from the extracellular matrix of porcine small intestinal mucosa in hernia repair are accompanied by mixed results. In procedures involving contaminated or infected wounds, complications in approximately 40% of patients occurred and included recurrent hernias (17%), early reoperations (32%), partial dehiscenses

(21%), and mesh reactions (11%). However, patients not requiring mesh debridement or removal had only a 6-month hernia recurrence rate of 2%.[67] Intestinal fistulas have also been reported as a complication of this biomaterial.[68]

Allografts, in which decellularized human dermis is a scaffold material to regenerate abdominal wall tissues, are increasingly being used in the repair of hernias in infected and contaminated fields. The material is secured to healthy fascia surrounding the hernia defects and serves as a matrix for tissue ingrowth and regeneration. Allografts have been found to be resistant to infection, erosion, extrusion, and rejection.[69] This material is indicated primarily for procedures in which a permanent prosthetic is contraindicated due to high infection risk. Short-term results are promising,[70] but long-term studies are needed.

Methods of Prosthetic Fixation

Numerous techniques for prosthetic fixation—including suture material, tacking devices, and fibrin glues—are available to the surgeon. Suture material remains the most common method of prosthetic fixation for ventral hernia repair; the long-term durability of such procedure mandates the placement of permanent sutures. Despite ingrowth from the abdominal wall into a prosthetic, permanent sutures are a necessity to prevent hernia recurrence by providing long-term stabilization of the prosthetic. Monofilament sutures are optimal to minimize interstices, which may harbor bacteria that could result in latent prosthetic infections. Failure to secure a prosthetic with circumferential sutures usually leads to mesh migration and hernia recurrence.

Tacking devices serve as an effective adjunct during hernia repair. Most commonly used in laparoscopic repairs, tacking devices generally are able to penetrate the prosthetic mesh, peritoneum, and a short depth of posterior fascia. Tacks are best used between the anchoring sutures to prevent the incarceration of bowel during the period of mesh incorporation. The repair of ventral hernias with tacks alone has been reported to be associated with a high incidence of hernia recurrence.[58]

Fibrin glues may also be used as an adjunct to prosthetic fixation. The fibrin glue may be placed between the prosthetic and the abdominal wall to facilitate incorporation and prevent seroma formation.[71] These sealants are also helpful for obtaining hemostasis following a difficult dissection. However, fibrin glues cannot be recommended as a sole method of prosthetic fixation for ventral hernias. Much like the tacking devices, their role is as an adjunct to the essential sutures.

Specific Hernias

Incisional Hernia

Epidemiology. It is reported that a hernia will develop in 3% to 12% of all laparotomy incisions.[72] The few longitudinal studies that followed and assessed laparotomy patients over a number of years report incisional hernia development in as many as 20% of those individuals.[73] Although there appears to be no diminution in the number of patients with ventral or incisional hernias in the United States to date, the rate may be anticipated to drop with the advent and increasingly widespread adoption of minimally invasive surgery (MIS). As open abdominal aortic aneurysm repairs, bariatric procedures, and colonic surgeries are replaced increasingly by minimally invasive procedures, it would stand to reason that fewer incisional hernias would result. Hernias developing within a 10- or 12-mm trocar incision site are well documented.[74,75] There are no major reports, however, of hernias developing within 5-mm port site incisions, and as laparoscopic instrumentation continues to evolve, the move is increasingly toward 5-mm (or less) diameter devices accommodated by 5-mm trocars. There are no good, long-term data available at present regarding the incidence or natural history of port site hernias.

Patient Presentation and Evaluation. Although discomfort and/or a bulge over the defect are common to all hernia patients, inguinal or otherwise, those with incisional hernias most often present with these complaints. The vast majority of these patients present with chronic symptoms for elective evaluation. Many will describe an aching discomfort that, through the course of their day, will increase, particularly if they are upright or ambulatory for an extended time period. When such patients strain or exert themselves, the discomfort usually worsens and the bulge increases in size. Also commonly described with incisional hernias is sharp pain as well as exacerbation of symptoms following the eating of a large meal. Most patients with long-standing incisional hernias do not report any significant alteration of their bowel habits. A conservative estimate of 25% of the authors' patients were found at operation to have abdominal contents incarcerated to some degree in their hernias. At the time of operation as we liberate the incarcerated contents of some large hernias, we often marvel that the patient has been able to maintain a regular bowel habit.

Not all patients with bowel incarceration within incisional hernias progress to bowel strangulation. A 1% incidence of strangulation among incisional hernia patients is often quoted but hard to substantiate.[72] When

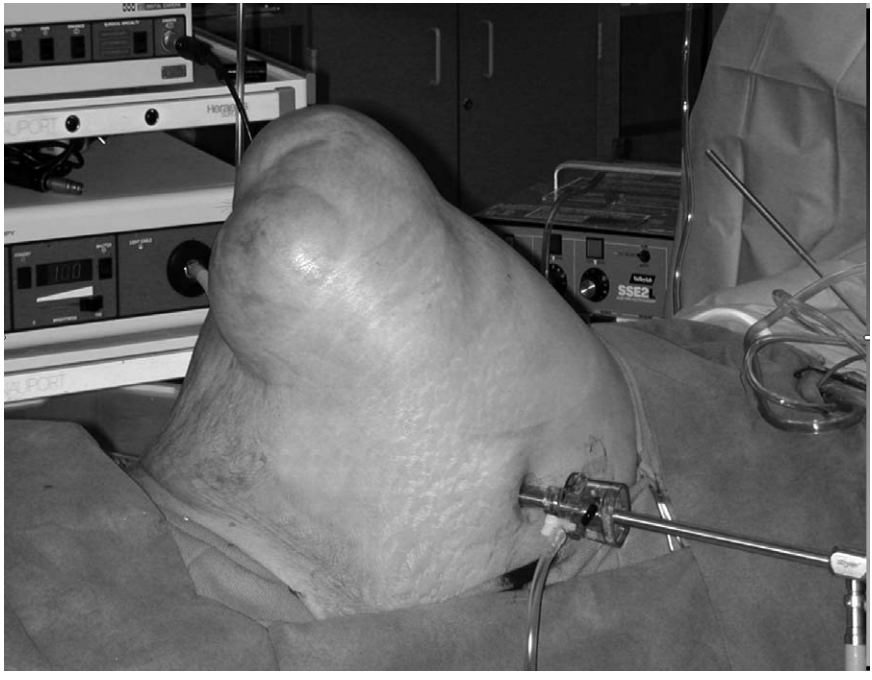

FIG 1. External view of an incisional hernia. The true nature of the abdominal wall fascial defect may not always be appreciated based on the external appearance.

patients present with an incisional hernia, the process of evaluation and the evaluation is fairly straightforward. Determination of whether or not the patient is receiving corticosteroid therapy is important because planning operation to follow a period of steroid taper or "holiday" may be possible. A thorough cardiopulmonary history can be a very important consideration in patients with a large incisional hernia, particularly those who are suffering some "loss of domain" and have borderline pulmonary reserve. If such patients were to undergo mesh hernia repair, the resulting increase, even if transient, in intra-abdominal pressure and resistance to diaphragmatic excursion could render them ventilator-dependent for an extended period of time. Such patients should be referred to a pulmonologist for assessment and preoperative pulmonary function testing.

Most patients with incisional hernias have observable hernias (Fig 1) and easily palpable defects. However, some obese patients or those with smaller defects may present diagnostic dilemmas. In such patients a computed tomography (CT) scan can help to delineate the abdominal wall layers and identify any defect or hernia present (Fig 2). Abdominal

FIG 2. Computed tomography scan demonstrating pronounced ventral hernia defect. Standard cross-sectional imaging provides some indication of the extent of herniation.

ultrasound (US), despite its advantages of lower cost and ionizing radiation avoidance, may be less sensitive for identifying smaller or more subtle defects. Some authors have suggested the use of CT or abdominal US to assess preoperatively the extent of intra-abdominal adhesions.[76,77] It is not our practice to obtain CT scans routinely on our incisional hernia patients.

Every patient who presents to a surgeon with an incisional hernia is not necessarily a candidate for surgical repair. The reasons to repair an incisional hernia can be summarized as follows: (1) the hernia is causing the patient symptoms, most commonly pain or discomfort; (2) the hernia results in an "unsightly bulge" that affects the patient's quality of life; or (3) the hernia poses a "significant" risk of bowel strangulation. The last indication is the most difficult to quantify. A narrow neck and large sac are among the characteristics of a hernia that may predispose it to "strangulation," but predicting such an event in an incisional hernia patient with any certainty, beyond that 1% incidence of strangulation earlier noted, is difficult. The patient who has had increasing difficulty in reducing his hernia or has suffered some recent (even if transient) alteration in bowel habit, attributable to the hernia, is a candidate for repair. However, a patient with a small incisional hernia that is stable in size and causing no symptoms may be well served by an approach of "watchful waiting" and serial reevaluation (6 monthly, yearly, or as

necessary should the hernia become symptomatic). In the event of symptoms of incarceration, a more urgent operation would be required.

Laparoscopic Technique of Repair—Preoperative Preparation. In our practice, those patients deemed candidates for incisional hernia repair receive important instruction as part of their preoperative preparation. One of the first points regards postoperative pain and recovery. If patients undergo LIVH repair with the expectation that they will have little or no pain within a couple of days postoperatively, they are mistaken. These patients do have pain, particularly in the area of the mesh suture fixation sites. Those caught unaware by such discomfort may experience anxiety or fear that something was amiss with their surgery. As long as they are counseled that such pain is to be expected and should diminish steadily several days to 1 week after operation, they usually are reassured sufficiently. Also emphasized is that such mesh suture fixation is indispensable to the long-term durability of the repair.

The second point that we routinely discuss relates to the formation of a seroma postoperatively. Following LIVH repair, a seroma very commonly will develop between the mesh and hernia sac. This is an unavoidable sequela of the operation since, despite efforts over the years to either scarify the sac or raise peritoneal flaps including the sac to cover the mesh, the sac is left in situ. Such seroma formation is almost invariably a transient, self-limited phenomenon. Again, patients are usually fine as long as they are instructed (and later reassured) that this "bulge" is anticipated and does not represent an early hernia recurrence.

Probably the most important issue to discuss preoperatively with the patient is the possibility of inadvertent enterotomy or colotomy, whether observed or "missed." One of the most lethal complications of LIVH repair has proved to be the missed bowel injury. Obviously, the surgeon must make every effort to avoid such an injury during operation and remain vigilant postoperatively for the possibility that such a complication may have occurred. Preoperatively, the patient must have a clear appreciation of the risk involved. In the early days of LIVH repair, incisional hernia patients routinely underwent bowel preparation. Now the indication is to use bowel preparation for patients on an empiric basis if their past surgical history portends a particularly "hostile abdomen."

Our practice is to explain to patients the potential options and treatment algorithms should a recognized enterotomy/colotomy occur. Our patients are told that in the event of an enterotomy with spillage of succus or a colotomy, even without spillage, the bowel will be repaired (usually laparoscopically but if necessary via laparotomy) and the hernia repair will be delayed. The reasons for this, we explain, are that, as with

implanted foreign bodies in general, most biomaterials used in LIVH are poorly resistant to infection and once colonized by bacteria almost always must be explanted. Therefore, the safest and most prudent course following enterotomy with even the possibility of mesh contamination is to repair the injury, complete the adhesiolysis, and postpone the hernia repair for at least 1 week. If a deep seromuscular cut or small enterotomy (immediately recognized and with no spillage) occurs, then immediate enterorrhaphy and completion of the hernia repair may be indicated.

Our patients understand preoperatively that they may awake from their operation without having had their hernia repair completed. Recognizing that their safety and a good surgical outcome is of paramount importance to us, patients are uniformly appreciative of, and not scared off by, such a discussion.

Laparoscopic Incisional/Ventral Hernia (LIVH) Repair. LIVH repair is currently 1 of the fastest growing minimally invasive surgical procedures performed by general surgeons in the United States. There are several reasons for this. Prime among these reasons is the frequency with which incisional hernia patients present to abdominal surgeons, most of whom will have an adequate volume of LIVH cases (Table 3) to establish and maintain the necessary expertise to perform minimally invasive repair. As well, a surgeon who has 2-handed (navigational) laparoscopic skills will be equipped not only to assimilate this procedure into his or her clinical armamentarium but to select cases of increasing difficulty as those skills are further refined.

Although there is some variation in the techniques of tension-free LIVH repair reported in the literature and in practice, there are several elements common to such procedures. Here we describe our technique of LIVH repair. Under general anesthesia the patient is placed supine on the operating room (OR) table with arms tucked by the sides. An orogastric tube and a Foley catheter are inserted. A protective barrier, such as an adhesive drape, is placed over the patient's abdomen. Although there is some debate about the best or safest way to establish pneumoperitoneum, our practice is to introduce a Veress needle through a small (1 or 2 mm) incision in the right or left subcostal region. Many surgeons unfamiliar with the Veress needle prefer to employ an open or Hasson technique of initial port placement and insufflation. It is our preference to establish pneumoperitoneum via Veress needle because the contour of the insufflated abdomen often differs significantly from the noninsufflated abdomen. "Preinsufflation" allows the surgeon to better plan trocar placement as far lateral from the closest hernia defect as comfortably possible. Otherwise an initial trocar placed via cut down into a flat abdomen may

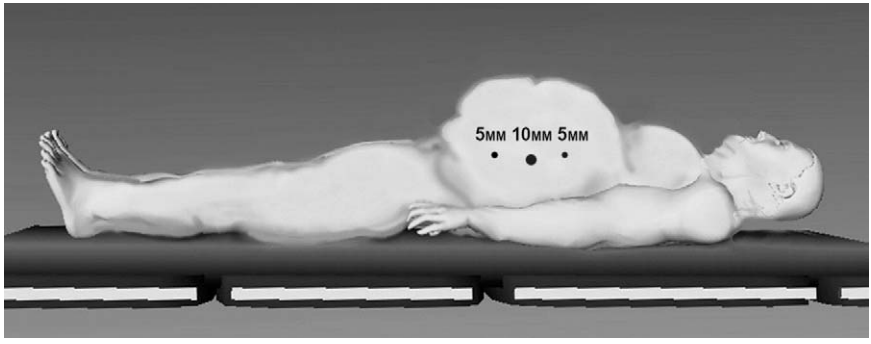

FIG 3. Port placement for laparoscopic repair. All ports are placed away from the defect to optimize the ergonomics of the repair.

"migrate" too medially following insufflation. As with most laparoscopic procedures, judicious port placement for LIVH repair can make the difference between a pleasant operating experience and a few hours of ergonomic torture.

Although there is debate about the means of establishing pneumoperitoneum, there should be none over the fact that each trocar must be inserted under direct visualization either via cutdown or by means of a direct-view trocar. It is our practice to array 3 trocars (one 10-12 mm and two 5 mm) between the iliac crest and costal margin on the side of the patient farthest from the closest hernia defect, whether midline, upper, or lower abdomen (Fig 3). Such trocar locations, with the patient's arms tucked by the sides, allow low displacement of instrument handles to gain "end effector" access to the anterior abdominal wall. We have found it possible to repair all shapes and sizes of hernia using this trocar configuration, with only occasional insertion of an extra 5-mm trocar on the contralateral side to aid in adhesiolysis or mesh fixation. A 5-mm 30° laparoscope is used and can be moved among all trocars as the need arises.

Adhesiolysis is performed to achieve exposure of the hernia and to clear a margin of at least 5 cm around the defect (Fig 4). Great care must be taken to avoid excessive traction on adhesions, particularly those involving bowel. Meticulous sharp dissection is the preferred method of adhesiolysis, seizing on the advantages of enhanced laparoscopic visualization of the planes of dissection and the suspension (by pneumoperitoneum) of structures adhesed to the abdominal wall. Very limited and judicious use of energy sources during initial dissection is recommended. A missed enterotomy can too easily result from inadvertent and unrec-

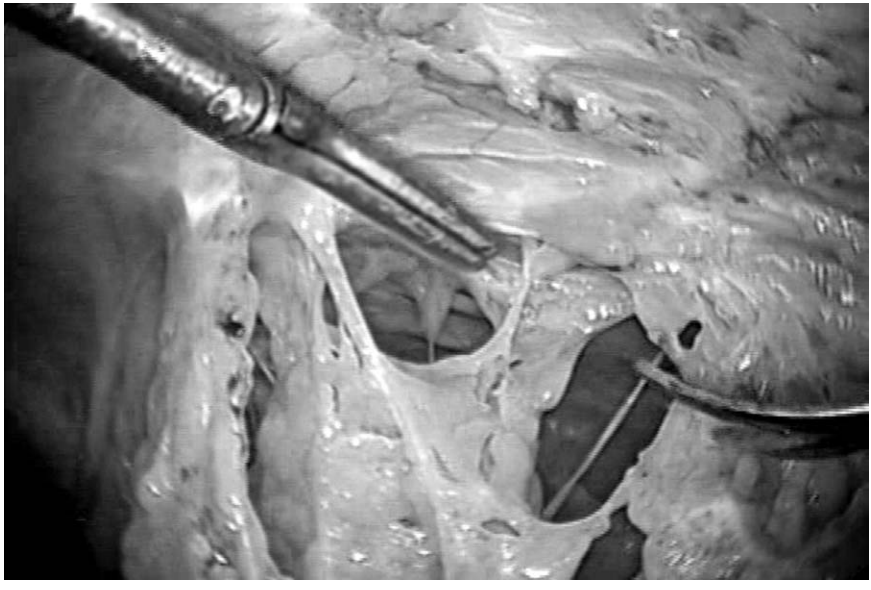

FIG 4. Laparoscopic adhesiolysis to define the defect. Adhesiolysis must be performed with caution due to the risk of inadvertent bowel injury.

ognized thermal injury to the bowel during the use of diathermy or ultrasonic dissection.

Once the hernia has been exposed adequately, it is measured either intracorporeally (Fig 5) or by external palpation, depending on the abdominal wall thickness. A mesh is then selected to overlap all defect margins by at least 5 cm. In our practice Gore Dualmesh Plus (W. L. Gore & Associates, Inc, Flagstaff, AZ), an antimicrobial impregnated ePTFE biomaterial, is used most commonly. It is oriented and marked with symbols or letters to correspond with similar marks on the abdominal wall (Fig 6). These serve to orient the mesh and line it up appropriately once it is introduced into the abdomen. This is particularly helpful in the case of large hernias that require the correct placement of large meshes. Before the mesh is introduced into the abdomen, anchoring sutures (4 on most meshes, occasionally 6 to 8 on a very large mesh) are placed equidistant around its periphery. The mesh and sutures are then furled around a laparoscopic grasper and inserted through the 12-mm trocar. Once intracorporeal the mesh is unfurled and anchor sutures grasped via a suture passer, which is introduced through a small incision that has been placed by 1 of the orienting symbols on the anterior abdominal wall. Each of the pair of sutures is picked up by a separate pass of the suture passer,

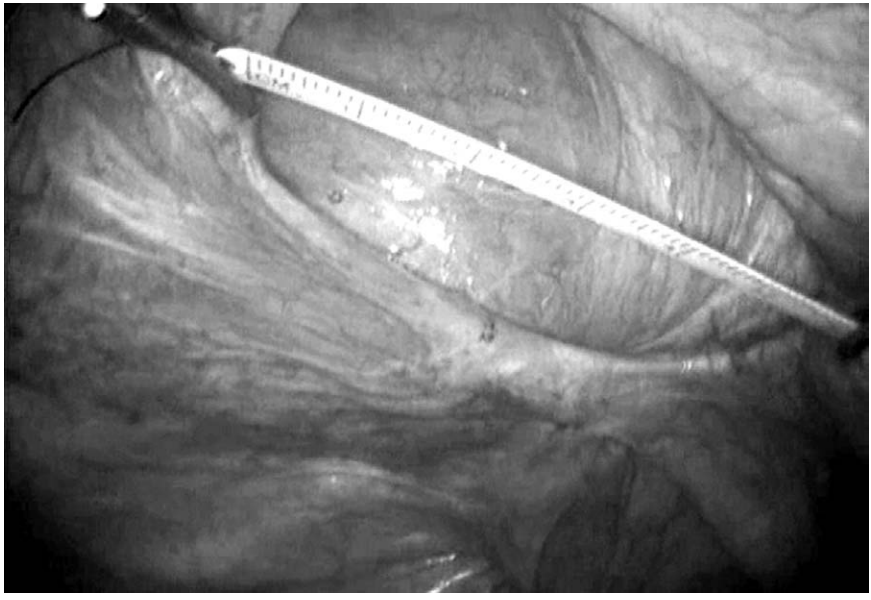

FIG 5. Internal view from laparoscope of fascial defect, with ruler in place.

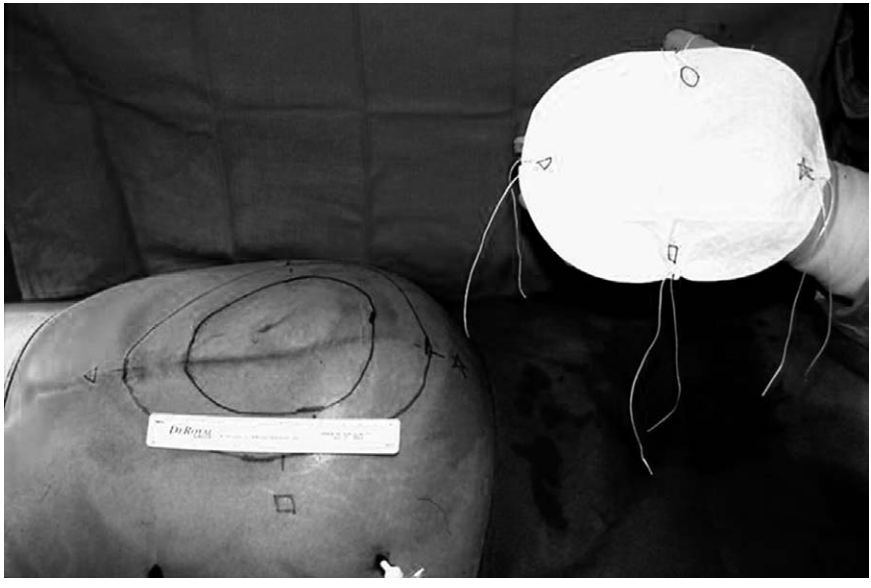

FIG 6. External view of defect, with markings on patient abdomen and orienting marks on mesh. Maintaining orientation of the prosthetic is crucial to the success of the repair.

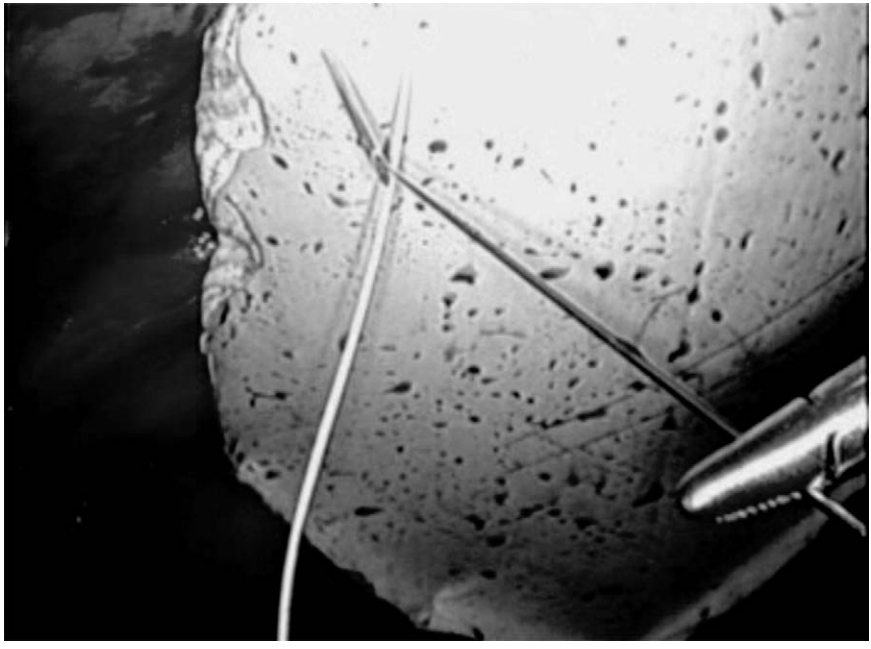

FIG 7. Alternative technique for transfascial suture placement. A spinal needle is inserted through the mesh, and the Keith needle is passed through the bore of the spinal needle.

resulting in a wedge of abdominal wall muscle and fascia encompassed by the suture. The knot is tied and buried subcutaneously. Further sutures are then placed every 5 to 6 cm around the periphery of the patch (Fig 7). As mentioned previously, these contribute significantly to the long-term durability of the repair.[9] Finally a stapler or tacker is used to secure the edge of the mesh at approximately 1-cm intervals (Fig 8). This ensures that while the process of mesh incorporation into the host tissue is under way no bowel or other abdominal contents are trapped above the patch. After a final survey to ensure that hemostasis is secure and that there is no evidence of bowel injury, trocars are removed and the fascia at the 12-mm port site is closed. All trocar and suture sites are injected with local anesthetic. The orogastric tube and (usually) Foley catheter are removed in the OR.

Open Repair. Open repair of ventral hernias has been well described by many authors. The basic principles may be summarized briefly. The soft tissues overlying the hernia defect are incised and the hernia defect is identified by dissection. Once the fascial edges are exposed and the

FIG 8. Internal view of the completed laparoscopic ventral hernia repair. Spiral tacks secure the mesh circumferentially, preventing visceral contents from accessing the potential space above the mesh.

underlying structures are cleaned from the edges of the defect, repair may be undertaken.

In cases of small primary hernias, such as umbilical hernias, primary suture repair may be sufficient. However, in cases of large or recurrent hernias, mesh repair is more effective. In an "onlay" repair the mesh may be placed over a primary repair. Alternately, the mesh may be placed in the same extrafascial position without primary repair of the underlying tissues. The mesh may also be placed below the fascia, which has been termed the "underlay," "inlay," or "subfascial" repair (Fig 9). In addition, 2 pieces of mesh may be used to buttress the defect from both above and below—the "sandwich" technique.

The choice of mesh for open hernia repair remains somewhat controversial. Few advocate use of polypropylene mesh in any position where it may come into contact with the abdominal viscera because of the complications of erosion, infection, and enterocutaneous fistula formation. Occasional series report minimal complications from polypropylene in an intra-abdominal location.[55]

The optimal treatment of the hernia sac, as with the choice of prosthetic material, is still under debate. Some surgeons prefer to reduce the sac whereas others open or excise it. In addition, the degree of overlap of the

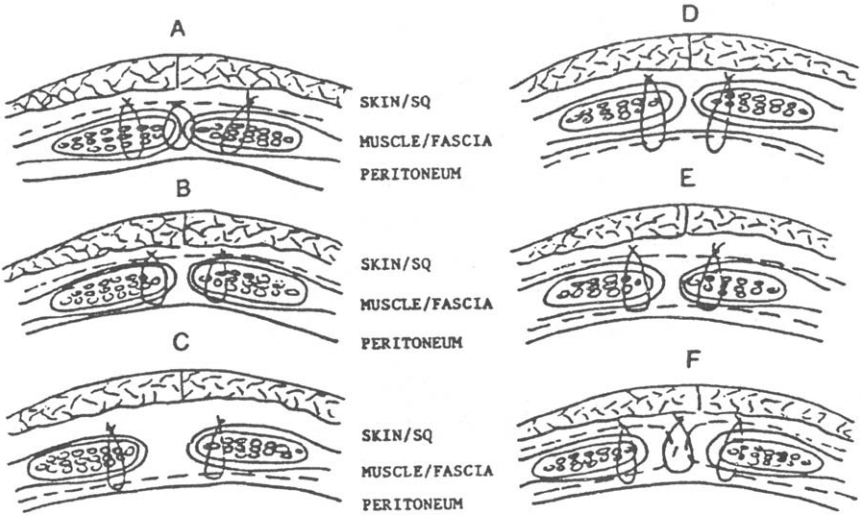

FIG 9. Layers of the abdominal wall with potential areas for placement of mesh. Current concepts of physiologic stress favor placement of prosthetics in the underlay position.[77]

mesh beyond the hernia defect may vary considerably. All surgeons agree that overlap of the fascial edges is appropriate; however, the optimal distance has not yet been determined. Finally, both the type of suture used to secure the mesh and the placement of drains remain at the discretion of the surgeon.

An additional technique is the "components separation" method first introduced by Ramirez and colleagues.[78] In this method, the skin and subcutaneous tissues are mobilized from the abdominal wall. Next, relaxing incisions are made in the external oblique aponeurosis lateral to the rectus sheath bilaterally, from the costal margin to the pubis. The internal and external oblique muscles are then separated through blunt dissection to increase the mobility of the fascia and allow midline approximation.

There have been several modifications of this technique, including variations in the placement of the incisions and the use of a reinforcing mesh. Components separation technique perhaps has been most useful in the setting of contamination, where placing a permanent, nonresorbable mesh is ill-advised. In practiced hands, excellent initial results with minimal long-term recurrence have been reported.[79] Other means of native tissue repairs by providing vascularized fascia, such as rotational flaps, or through the use of tissue expansion have yet to achieve widespread popularity or demonstrable long-term success.[80]

TABLE 5. Selected recent series of open mesh repairs of incisional hernias

Author	Year	n	Follow-up		
			Biomaterial	(months)	Recurrence rate
Ammaturo[86]	2004	24	Parietex	15	4%
Arnaud[87]	1999	250	Dacron	97	3%
Bauer[88]	2002	57	ePTFE, PP	35	2%
Burger[34]	2004	84	PP	120	32%
Chrysos[89]	2000	52	PTFE	—	8%
Koller[82]	1997	26	PTFE	24	13%
Ladurner[90]	2001	57	PP	6–33	2%
Martin-Duce[91]	2001	152	PP	72	1%
Millikan[84]	2003	102	PP/ePTFE	28	0
Paajanen[83]	2004	84	PP	12	5%
Ramshaw[42]	1999	174	PP	21	21%
van't Riet[45]	2002	76	PP	17	18%

PTFE, polytetrafluoroethylene; ePTFE, expanded PTFE; PP, polypropylene.

Open Outcomes. It has been difficult to characterize the outcomes of ventral hernia repairs. Given the wide variability in the details of the technique used with open repair, the complexity of interpreting the literature becomes a challenge. What is clear is that the use of mesh unquestionably has decreased the recurrence rate in incisional hernia repairs. In perhaps the best known trial, Luijendijk and colleagues[4] compared primary repair with polypropylene mesh underlay repair in a multicenter, randomized prospective trial. In this study, the rate of recurrence at 3 years was 24% in the mesh group compared with 43% in the primary repair arm. Although clearly advocating the use of mesh instead of suture repair, it still establishes a baseline recurrence rate of 24% for open incisional hernia repair.[4] Other retrospective series have also found similar results in favor of the use of mesh.[81,82]

Other groups have reported improved results with mesh placed by open surgery. In Finland, 84 consecutive patients were treated with retromuscular preperitoneal polypropylene mesh repairs.[83] At 3-year follow-up, only 5% had recurrence. In a separate U.S. study, no recurrences were found at 28-month follow-up among 102 patients.[84] However, even in the most experienced hands, recurrence rates of 5% to 7% are common[85] (Table 5).

In addition to the primary outcome of recurrence, the short-term morbidity of open incisional hernia repair must be assessed. Wound complications tend to occur in open surgery at rates between 5% to 20% in most series.[92] Ileus, substantial postoperative pain, sepsis, fistulization, and necrotizing fasciitis have all been described as well. One meta-

analysis calculated the overall complication rate at 27% following open repair.[93]

Spigelian Hernia

Spigelian hernias represent anterior abdominal wall hernias of the semilunar line. Named after a Belgian anatomist, Adriaan van den Speigel, they typically occur at the level of the arcuate line lateral to the epigastric vessels.[94] In this region, the Spigelian fascia, or the aponeurosis of the transversus abdominis muscle, is wide and relatively weak, allowing herniation under conditions of elevated intra-abdominal pressure. Since the overlying external oblique aponeurosis is not compromised, this condition (that might represent a partial hernia through the thickness of the abdominal wall) may be difficult to diagnosis.

Most patients with Spigelian hernia present later in life, with a mean age at presentation of older than 60 years.[95] There does not seem to be a strong gender predilection. Many such hernias are clinically detectable as a bulge on physical examination, whereas others are incidental findings. Typically, these hernias are identified and repaired electively. CT and ultrasound have proven useful but not 100% sensitive in preoperative diagnosis.[96]

There are various options for repair of Spigelian hernias. Traditionally, the most common approach has been open repair with dissection of the sac and primary repair of the defect via a transverse incision.[96] For larger hernias, the use of prosthetic mesh is recommended. Some surgeons have even successfully applied specialized meshes designed for inguinal hernias to the abdominal wall defect in Spigelian hernias, although the use of such techniques remains anecdotal.[97]

Spigelian hernias have been treated laparoscopically since the first report in 1992.[98] Since that time, more than 30 case reports and series have appeared and recently been summarized.[99] Typically, a transperitoneal approach is employed, although an extraperitoneal dissection has also been described.[100]

There exists in the literature a single prospective, randomized trial comparing open and laparoscopic techniques for Spigelian hernia repair.[101] In this report of 22 patients undergoing elective procedure, open repair was associated with higher initial morbidity and longer hospital stay. None of the patients, however, presented with hernia recurrences. The authors recommend open repair for emergent cases or cases with complications, the transperitoneal approach if concomitant surgery is indicated, and the extraperitoneal approach as the technique of choice.

Given the relative rarity of this condition, it is unlikely that further trials will be undertaken.

Obturator Hernia

Obturator hernias represent a rare group of pelvic hernias, first described by Arnaud de Ronsil in 1724.[102] Their true incidence is unknown, since asymptomatic hernias are not detectable by routine history and physical examination. There have been fewer than 1000 obturator hernias reported in the literature, with a typical example from 1 tertiary institution being 6 cases in a 28-year span.[103] However, with increasing awareness of this condition among surgeons practicing diagnostic laparoscopy, it is possible that the appreciated incidence of obturator hernia will climb.

The obturator foramen, the largest single foramen in the human body, is formed by the rami of the ischium and pubis. The obturator canal represents the portion of this large opening not covered by fibroaponeurotic membrane. It is a small hiatus located on the superior-lateral aspect of the foramen, which transmits the obturator neurovascular bundle. A herniation, which can include small bowel or colon, may occur through this opening and lead to the expected hernia complications of incarceration, strangulation, and necrosis.

Typically, the obturator foramen is protected from herniation due to the obturator fat pad. However, this adipose tissue may be atrophied, especially in patients who have had significant weight loss.[104] Elderly patients are also at increased risk, due to increased laxity of connective tissues as well as advanced age. In addition, women are at particular risk for the development of an obturator hernia because the dimensions of their obturator foramen are larger, averaging 4 cm.[105]

The physical examination may be deceptively benign; however, several classic findings may suggest the diagnosis. First, a palpable mass in the medial thigh may be appreciated. Alternatively, a prominence may be detected on digital rectal or vaginal examination. The Howship-Romberg sign is said to be present when pain or paresthesia in the proximal thigh is elicited by medial rotation, adduction, or extension of the thigh. Perhaps more sensitive, although less appreciated, is the Hannington-Kiff sign, where the adductor reflex is absent but the patellar reflex is preserved.[106] Finally, the patient may present with obturator neuralgia, manifested by difficulty with adduction of the thigh.

A variety of maneuvers may be employed preoperatively to diagnose an obturator hernia. In limited series, US has been shown to be an effective means of diagnosis in cases of bowel obstruction due to obturator hernia.[107] CT also may play a significant role. It is in common use in

emergency departments to address patients with abdominal pain of uncertain etiology. In 1 series, CT scan was 100% sensitive in 8 cases,[108] and others have shown that use of the CT scan has diagnostic superiority over a physical examination alone.[109]

The management of obturator hernias parallels that of the other hernias: reduction of the hernia contents, resection of nonviable structures, and repair of the defect. Laparoscopic as well as open techniques have been described to accomplish these goals.[110,111] In the obturator canal, primary closure of the defect is not always possible given the relative inflexibility of the surrounding tissues. Various techniques have been described to obliterate the remaining space, using omentum, flaps of peritoneum, the round ligament, or prosthetic mesh.[112]

Given that these hernias are uncommon and tend to manifest in elderly patients, there is minimal objective data available on obturator hernia recurrence. Some authors have suggested a recurrence rate approaching 10% if primary repair is used alone, which may be acceptable in the elderly population.[113] However, it seems prudent to attempt a tension-free repair of the hernia, even in the urgent setting.

Sciatic Hernia

Sciatic hernias are especially rare hernias, with fewer than 90 cases reported in the literature. Certainly, these hernias seldom develop primarily. Moreover, asymptomatic sciatic hernias may be completely clinically silent, contributing to the lack of diagnosis.

The greater and lesser sciatic foramena may be found on the inferior/posterior aspect of the pelvis. The 2 foramena are separated from each other by the sacrotuberous and sacrospinous ligaments. The greater sciatic foramen is then subdivided by the piriformis muscle. Most hernias develop superior to the piriformis muscle, following the superior gluteal artery and nerve. Abnormalities, whether congenital, traumatic, or age-related atrophy, in the piriformis muscle predispose to hernia formation.

As with other AWH, any of the abdominal viscera may become entrapped within the hernia sac. Small bowel, colon, omentum, bladder, ureter, fallopian tubes, and even Meckel's diverticulum have all been described within sciatic hernias.[114] This large variety leads to a plethora of presentations. In fact, there is no "typical" presentation or patient described reliably. The single most common manifestation may be pain radiating to the thigh or sciatica.[115] Bowel or ureteral obstruction may also bring the patient to the attention of the physician. Chronic pelvic pain in women may be caused by unrecognized sciatic hernias. In fact, 1 group

reviewed 1100 women with chronic pelvic pain and determined that sciatic hernias were at the root of 1.8% of the cases.[116]

Diagnosis of hernias is seldom based on physical examination alone; however, in this instance, a bulge in the region of the buttock may suggest the diagnosis. More commonly, sciatic hernia is discovered on CT examination. Ultrasound has also been useful in some circumstances. There is the possibility of reduction of the hernia contents under US guidance, but this remains speculative.[117] Finally, this condition may also be found during laparoscopy or coincidental laparotomy.

Treatment of sciatic hernias must be individualized since there is little guidance in the literature to make broad generalizations. However, reduction of the hernia sac and a durable repair remain the standard of care. As such, a transgluteal approach with local repair may be an option but only if the contents are viable and may be reduced safely.[118] Repair may also be accomplished transabdominally, either through laparoscopic or open means. Laparotomy remains the procedure of choice in cases of suspected or proven bowel ischemia. Repair of the pelvic floor is probably best accomplished using prosthetic mesh; however, no large series are available to guide the precise types of mesh or method of repair.

Lumbar Hernia

A lumbar hernia may be described as a fascial defect in the posterior-lateral abdominal wall that allows the passage of intraperitoneal or extraperitoneal contents into a non-anatomic location. Although lumbar hernias have been described since at least the 18th century, fewer than 300 have been reported in the world's literature. These are classified by anatomic location: the Petit hernia, located in the inferior lumbar triangle, and the Grynfeltt type, situated in the superior lumbar triangle.

Lumbar hernias may also be categorized based on etiology. A detailed review of lumbar hernias discovered that most occur spontaneously, acquired after strenuous exertion, especially in those of advanced age or those who have had substantial weight loss.[119] Many other hernias develop due to trauma, surgical incisions, or lumbar abscess. Blunt traumatic mechanisms may account for an increasingly large proportion of reported hernias, including 1 case of lumbar hernia as a result of seat-belt injury.[120] For a classification, see Table 6.

There is a general consensus that diagnosis of lumbar hernias may be quite difficult, particularly in incisional cases. As opposed to the clarity of most anatomic diagrams, the patient's flank may have a diffuse deficit without specific involvement of a particular organ. Abdominal wall tenderness may guide diagnosis, but discretely palpable masses are

TABLE 6. Classification of traumatic abdominal wall hernia

Type	Subtype	Associated injury	Location
Focal	Direct	<10%	Lower abdomen, lateral to rectus
Focal	Autopenetrating	Low	Periphery
Diffuse	Pressure	30%	Infraumbilical
Diffuse	Shear	60%	Midline

Adapted from Ganchi PA et al. J Trauma 1996;41:1064–6.

uncommon. CT scanning has become the modality of choice for diagnosis in cases of such suspected herniation.[121]

Repair of lumbar hernias is challenging. The region of interest is bounded by bony structures that limit dissection and mesh placement.[122] Furthermore, few surgeons receive specialized training in the abdominal wall, and therefore this region is often unfamiliar to those called on for repair. Traditional open repair is possible and effective when performed using prosthetics and avoidance of tension. Some groups have developed laparoscopic repair techniques, both transperitoneal as well as totally extraperitoneal.[123-125] The laparoscopic approach holds several advantages, similar to those of other minimally invasive procedures: decreased recovery time, decreased reliance on narcotics, and improved cosmesis. However, the most compelling reason may be mesh placement on the side of the defect that allows reinforcement abiding by Pascal's law. Innovative approaches, such as fixation to the iliac crest using bone anchors, may make this repair feasible and effective in the hands of general surgeons.[126] Although comparative studies are rare, it seems likely that laparoscopic techniques may be readily applied to these hernias.

Parastomal Hernia

Parastomal hernias are a subset of incisional hernias in that they occur due to a surgically created fascial defect. Given that a stoma is in essence a deliberate hernia, the incidence of parastomal herniation is, therefore, difficult to determine with precision. Estimates for these hernias have ranged from 0% to 100% in the literature.[127] However, certain types of stomas, such as the loop transverse colostomy, seem more prone to herniation and complications than others.[128]

Although several researchers have attempted to delineate precise risk factors for herniation, definitive data remains elusive. One review summarized the available evidence for various patient and technical factors in the development of parastomal hernias.[129] Among size of the fascial defect, location, intra- or extraperitoneal technique, preoperative stomal therapist consultation, stomal fixation to the fascia, and elective or

TABLE 7. Surgical options in management of parastomal hernia

Nonoperative management
Reversal of stoma
Repair
Local repair
Local repair with synthetic mesh
Laparoscopic repair
Relocation of stoma

emergent creation, only the size of the defect had evidence to support it as a determinant of herniation. Unfortunately, it remains to be determined at what size threshold herniation becomes most likely.

Parastomal hernias have been conceptually categorized into 4 separate subtypes. First, the true parastomal herniation has intra-abdominal contents through the fascia adjacent to the stoma. Second, there is the subcutaneous/intrastomal variety in which the hernia sac extends into the stoma itself. Third, the subcutaneous prolapse is not a true hernia because the fascial ring itself is not compromised. Last is the pseudohernia, in which there is a general fascial weakening in the region of the stoma with an intact fascial ring, producing a bulge similar to a direct inguinal hernia defect.

Parastomal hernias may be quite diverse and have been reported to contain most every intra-abdominal structure from omentum and small bowel to gallbladder.[130] On physical examination, it is often the case that herniation may be readily apparent. However, in some circumstances, the presentation may be subtle. The stoma itself is an abnormal fascial defect, and ample body habitus may obscure a small herniation. Diagnosis may be facilitated by US, if performed by practiced hands. More commonly, CT has proved quite useful in clarifying atypical presentations.[131]

Many patients have no symptoms and may be managed expectantly. A surgical adage contends that it is not possible to improve on an asymptomatic patient. This is particularly true for repair of parastomal hernias, in which operative management may have high rates of morbidity or recurrence. It is estimated that only 10% of parastomal hernias require surgical intervention.[132] There are several options for treatment of parastomal hernias outlined in Table 7. The best option is reestablishment of gastrointestinal continuity with reversal of the stoma. However, this is clearly indicated for only a subset of patients with stomas. If the stoma is required, then surgical repair may be considered. This may be achieved as a local repair of the fascial ring with or without synthetic mesh reinforcement or as a relocation of the stoma.

Local primary repair may be easily accomplished via a laparotomy or through a laterally placed incision.[132] However, unless there was some technical error at the initial stoma creation, recurrent herniation may be expected. Some authors have incorporated prosthetic mesh in the repair and report encouraging preliminary results.[133] Relocation seems to reduce further the likelihood of recurrent herniation but at the expense of increased morbidity.

The techniques of laparoscopic repair of parastomal hernias follow those of incisional and ventral hernia repair. Described in the literature since the late 1990s, multiple case reports have presented successful minimally invasive management of parastomal hernia.[134,135] Unfortunately, others' results have not been as encouraging. In the largest single institution review, collating a total of 9 cases, laparoscopic repair was successful in only 44%.[136] In addition, all of the failures in this series occurred within 6 months of the procedure.

Trauma Abdomen

The surgical treatment of critically injured patients has changed dramatically over the past decade. The advent of damage-control laparotomy has resulted in an increasing number of large open abdominal wounds. Surgeons increasingly use damage-control laparotomy during procedures in which the patient is hemodynamically unstable, acidotic, and hypothermic. During these procedures, the surgeon often will perform life-saving maneuvers with plans to return to the operating room. Frequently, the fascia of the abdominal wall is not closed, due to bowel edema secondary to large-volume resuscitation, retroperitoneal hematomas, use of abdominal packing, and traumatic loss of abdominal wall tissues. After resolution of the patient's life-threatening injuries, abdominal wall closure is frequently attempted. Primary closure may be facilitated by the use of a prosthetic that may be tightened serially at the bedside over a period of days or weeks. Daily pleating of the prosthetic will serve to approximate the edges of the fascia gradually. As the patient's abdominal edema lessens, the fascia edges will be drawn medially until the point at which primary closure becomes feasible. Primary closure of the abdominal wall fascia may be obtained in more than 30% of patients.[137] Patients for whom primary fascial closure is not feasible are candidates for abdominal wall closure in which an absorbable prosthetic material is used and then is followed by delayed skin grafting once an adequate bed of granulation tissue has formed over the mesh. This technique serves to provide temporary coverage of the viscera to prevent evisceration, minimize fluid losses, and decrease the likelihood of

intestinal fistulas, which occur in 5% of patients managed in this fashion.[138] Ultimately, abdominal wall reconstruction may be performed by using the technique of separation of components.[78]

The management of ventral hernias in patients with abdominal sepsis is a challenging problem. The placement of a synthetic material in these cases is associated with an unacceptable morbidity rate resulting from the high incidence of infections. For this reason, these patients are often treated in a staged fashion with delayed hernia repair.[138] However, large contaminated ventral hernias may be repaired in a single-stage operation using the technique of separation of components, with acceptable morbidity and a recurrence rate of less than 10%.[78] In the presence of a contaminated field, nonabsorbable prosthetic materials have been used to repair hernias but are associated with fistula, bleeding, skin erosion, drainage, and chronic infections. Fifty to 90% of patients with permanent mesh placed under contaminated conditions will require mesh explant.[139] Absorbable prosthetic materials are advantageous because they are less likely to promote infection, but as the graft is resorbed, the repair loses its integrity. Autologous fascial grafts have been used in the repair of infected hernias with good results although they have been associated with donor-site morbidity.[140]

Human acellular tissue matrix (LifeCell Corporation, Branchburg, NJ) has been used successfully as a single stage repair of ventral hernias in patients with abdominal contamination.[141] Although long-term data for the use of Alloderm in contaminated procedures is not available, this is a promising material for the single stage repair of hernias in the presence of infection.

Separation of Components Technique

The component separation technique (Fig 10) is a method of abdominal wall reconstruction in patients with large midline hernias that are not amenable to standard primary closure. The technique is based on enlargement of the abdominal wall surface by translation of the muscular layers. In this technique, first described by Ramirez and colleagues in 1990,[78] the abdomen is entered and adhesiolysis is performed between the viscera and the abdominal wall. The skin and subcutaneous tissues are dissected from the anterior sheath of the rectus muscle and the external oblique aponeurosis. The aponeurosis of the external oblique is incised 2 cm lateral to the rectus sheath, extending 5 to 7 cm above the costal margin. The EO muscle is then separated from the IO muscle as far laterally as possible. An additional 2 to 4 cm of medial mobilization can be achieved by incising the posterior rectus sheath from the rectus

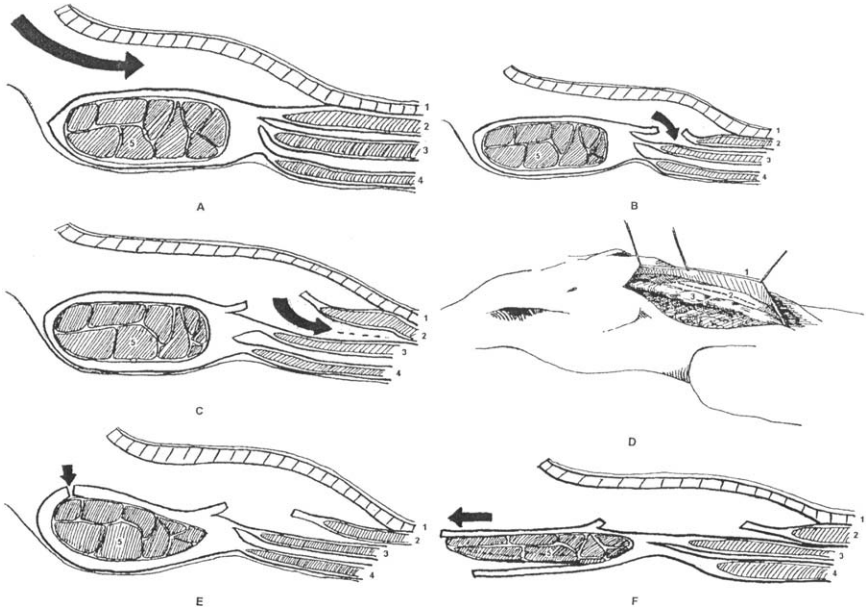

FIG 10. Separation of components technique, as described by Ramirez. This technique allows for mobilization of fascia to bridge gaps as wide as 20 cm. Reproduced with permission.[142]

abdominis muscle. Using the component separation technique, we can obtain midline fascial advancement of 10 cm at the epigastrium, 20 cm at the waistline, and 6 cm in the suprapubic area when separated bilaterally.[78]

Separation of Components Outcomes

Initially, the technique of separation of components of the abdominal wall was performed with good results in 11 patients whose defects ranged from 4 × 4 cm to 18 × 35 cm.[78] Despite that this technique is typically reserved for the most difficult cases, the incidence of hernia recurrence following such repair has been reported at between 5% and 30%,[142-144] which compares favorably with elective prosthetic hernia repairs.[142] Risk factors for hernia recurrence in 1 series included obesity, wound infection, and hernia repair in a contaminated field. Complications unique to this procedure are related to significant undermining and dissection of the abdominal wall. Skin necrosis may occur due to the undermining of the skin flaps. The musculocutaneous perforators of the epigastric artery are typically divided during the dissection. The blood supply to the skin flaps is based solely on the intercostal arteries. As a result, the blood supply to

the midline skin is quite tenuous and may be compromised further by placement of drains, enterostomies, and additional incisions. The incidence of skin necrosis in these patients is reported as high as 20%.[144] Other wound complications related to the large subcutaneous flaps, such as hematomas and seromas, are not uncommon. Intestinal fistulas occurred in 8% of patients in 1 series.[138] Increased intra-abdominal pressures may also be encountered after closure of the hernia, resulting in respiratory insufficiency. A unique complication of this technique is herniation at the site of the incision in the EO aponeurosis. Unintentional division of the IO muscle as well as the EO muscle may dramatically weaken the lateral abdominal wall musculature and result in rupture of the transverses abdominal muscle or in hernia formation. This complication can be minimized by careful surgical technique and buttressing of the incision in the external oblique muscle with a prosthetic mesh.

The separation-of-components technique is useful in the management of difficult hernias. Despite its exclusive use in the most difficult hernia patients, the incidence of complications is acceptable. Prospective trials are still needed to determine the optimal technique for the repair of contaminated ventral hernias.

Ventral Hernia Controversies/Challenges

Seroma Management

Postoperative seromas are a common finding after ventral hernia repairs, whether open or laparoscopic. Some surgeons have categorized these as postoperative findings, rather than as true complications, due to the fact that they represent a nearly universal finding. However, given that they may be debilitating to the patient, their management is briefly considered here. The natural history of seromas is resorption over time. Accordingly, a seroma discovered incidentally may be best managed expectantly.

All patients undergoing repair of significant AWH should be given an abdominal binder during the immediate postoperative period. There is minimal evidence-based literature to guide the duration that a binder should remain in place. Most clinicians recommend maintaining the binder from 2 to 4 weeks postoperatively.

Perhaps more importantly, patients should be counseled preoperatively about the possibility of seroma formation. Specifically, patients should be made aware that the presence of fluid at the site of the repair does not necessarily signal the development of an early recurrence. Having the

patient understand the motivation behind the binder increases the likelihood of compliance.

In the event that the seroma must be drained, there exists a real risk of introducing infection into an otherwise sterile fluid collection. Therefore, aspiration of routine seromas is contraindicated. Similarly, the routine placement of drains intraoperatively may decrease the incidence of early seroma formation at the expense of increased wound and mesh infections.

Loss of Domain

Loss of abdominal domain impedes any hernia repair, and may contribute to difficulties regardless of the surgical approach. Tissue expansion techniques have been developed and promoted by some plastic surgeons, and have recently been reviewed elsewhere.[80] However, such techniques may still result in tension at any potential suture line. In addition, the fear of creating an abdominal compartment syndrome following hernia repair is not unsubstantiated in patients with significantly large hernias that have developed over long periods of time. Recently, a technique has been presented for laparoscopic treatment of patients with substantial loss of domain.[145] In this case, additional ports are placed in an anteromedial position to fix the mesh from above. Although not without its complications, this technique extends the procedure to cases previously considered to be inoperable in the armamentarium of conventional laparoscopic techniques.

Suprapubic Hernias

Suprapubic hernias also provide anatomic challenges for repair. Suprapubic hernias may result from Pfannenstiel incisions at a rate of 2% to 5%, lower midline defects, or even suprapubic tube catheter placement.[146] Like the high epigastric hernias, the bony prominence of the symphysis pubis and the complex anatomy of the inguinal region provide most of the constraints in either laparoscopic or open repair.

The principles of laparoscopic ventral hernia repair do not change from 1 region to the other. Significantly, transfascial sutures and adequate (>5 cm) overlap of the defect are key to an effective and durable repair. Since transfascial suturing is not always possible in the lower midline, the pubic periosteum has been used for successful repair of these low hernias.[147] However, it may be necessary to mobilize the bladder to expose appropriately the fascial edges. The use of polypropylene materials in this region may be contraindicated due to the potential for erosion into the bladder.

High Epigastric Hernias

High epigastric hernias provide a challenge to even the most experienced surgeons. In addition to the constraints of any AWH, the repair must not impinge on the normal mobility of the diaphragm. Furthermore, a mesh repair cannot be secured in any location that puts the pericardium or heart at risk of puncture.

Hernias after sternotomy have been reported to occur at a rate of approximately 4%.[148] Primary, open repairs have been plagued by a high rate of recurrence (up to 80%). A laparoscopic repair technique has been described and has gained some popularity at major institutions. A unique element of this repair involves the mobilization and takedown of the falciform ligament to the level of the diaphragm to facilitate lying down of a larger-than-normal mesh overlap of the defect. Whereas 5-cm overlap is usually indicated in placing a mesh, in this circumstance a 7- to 9-cm cephalad overlap is recommended.

In the event of a high epigastric hernia, sutures may need to be anchored to the posterior rib. If this situation is encountered laparoscopically, intracorporeal suturing is mandated. Given the technical complexity that these hernias present, there is insufficient literature to make broad generalizations concerning the appropriateness of laparoscopic or open repair.

Collagen Vascular Disease

Collagen vascular disease represents a special case, 1 as complex as it is rare. Perhaps not surprisingly, little has been written on abdominal wall hernias in these patients. The only statistical evidence in the literature is based on a Dutch survey in 1996, which determined a risk ratio for inguinal herniation of 3.7 for patients with Ehlers-Danlos.[149] Others have identified umbilical herniation as a common component of specific Ehlers-Danlos subtypes.[150,151] Despite its rarity, collagen vascular disease is a diagnosis that may be entertained in patients who fail multiple attempts at AWH repair.[152]

Conclusion

Hernias are very common. Although hernia defects are correctable by surgical intervention, there is often recurrence even with meticulous operative repair. The etiology of hernia defects is multifactorial and includes problems at the molecular and biochemical level as well as patient factors, such as obesity and smoking.

The management of abdominal wall hernias represents a fusion of surgical tradition and an evolving understanding of pathophysiology

based on current research. Primary tissue closures have largely been abandoned due to high recurrence rates. This has resulted in an increased emphasis on tension-free repairs using prosthetic mesh. Over the last decade the advent and widespread adoption of MIS techniques has resulted in increased numbers and studies of laparoscopic repairs. Reports on hernia repair using these less invasive methods demonstrate low complication and recurrence rates. Laparoscopic techniques are applicable not only in straightforward hernia repairs but also in more difficult and uncommon hernia cases. Despite the commonality of laparoscopic repairs, there is still a role for conventional, open incisional hernia repair. This is primarily in patients with complex hernias, infected wounds, or multiply recurrent hernias with loss of intra-abdominal domain.

A number of novel surgical supplies, devices, and techniques are now available to the abdominal surgeon. In addition, new technologies in hernia prosthetics significantly impact the future of hernia repair. Still it is through reflection on the best available evidence as well as adherence to time-honored surgical principles that surgeons may hope to minimize the impact of abdominal wall hernias and improve the lives of our patients.

REFERENCES

1. National Center for Health Statistics. Vital and health statistics of the Centers for Disease Control and Prevention. Advance Data 1998;300:7.
2. Read RC. Recent advances in the repair of groin herniation. Curr Probl Surg 2003;40:13-80.
3. Rutkow IM. Demographics and socioeconomic aspects of hernia repair in the United States in 2003. Surg Clin North Am 83:1045-51.
4. Luijendijk RW, Hop WC, van den Tol MP, de Lange DCD, Braaksma MMJ, Ijzermans JNM, et al. A comparison of suture repair with mesh repair of incisional hernia. N Engl J Med 2000;343:392-8.
5. Bucknall TE, Cox PJ, Ellis H. Burst abdomen and incisional hernia: a prospective study of 1129 major laparotomies. BMJ 1982;284:931-3.
6. Hesselink VJ, Luijendijk RW, deWilt JH. An evaluation of risk factors in incisional hernia recurrence. Surg Gynecol Obstet 1993;176:228-34.
7. Langer S, Christiansen J. Long-term results after incisional hernia repair. Acta Chir Scand 1985;151:217-9.
8. van der Linden FT, van Vroonhoven TJ. Long-term results after surgical correction of incisional hernia. Neth J Surg 1988;40:127-9.
9. LeBlanc K, Booth WV. Laparoscopic repair of incisional abdominal hernias using expanded polytetrafluoroethylene: preliminary findings. Surg Laparosc Endosc 1993;3:39-41.
10. Park A, Gagner M, Pomp A. Laparoscopic repair of large incisional hernias. Surg Laparosc Endosc 1996;6:123-8.
11. Flament JB, Avisse C, Delattre JF. Anatomy of the abdominal wall. In: Bendavid

R, Abrahamson J, Arregui ME, Flament JB, Phillips EH, editors. Abdominal Wall Hernias. Principles and Management. New York: Springer; 2000:39-63.
12. Basmajian JV, editor. Anterior abdominal wall and scrotum. In: Grant's Method of Anatomy. 10th ed. Baltimore: Waverly Press; 1980:123-35.
13. Kavic MS, Kavic SM. History. In: LeBlanc KA, editor. Laparoscopic Hernia Surgery: An Operative Guide. New York: Arnold; 2004;33-40.
14. Read RC. Why do human beings develop groin hernias? In: Fitzgibbons RJ Jr, Greenburg AG, editors. Nyhus and Condon's Hernia. Vol 5. Philadelphia: Lippincott Williams & Wilkins; 2001:3-7.
15. Cobb WS, Kercher KW, Heniford BT. The argument for lightweight polypropylene mesh in hernia repair. Surg Innov 2005;12:63-9.
16. Cobb WS, Burns JM, Kercher KW, Mathews BD, Norton HJ, Heniford BT. Normal intraabdominal pressure in healthy adults. J Surg Res 2005;129:231-5.
17. Wagh PV, Read RC. Defective collagen synthesis in inguinal herniation. Am J Surg 1972;124:819-22.
18. Jansen PL, Mertens PR, Klinge U, Schumpelick V. The biology of hernia formation. Surgery 2004;136:1-4.
19. Abci I, Bilgi S, Altan A. Role of TIMP-2 in fascia transversalis on development of inguinal hernias. J Invest Surg 2005;18:123-8.
20. Korenkov M, Yuecel N, Koebke J, Schierholz J, Morsczeck C, Tasci I, et al. Local administration of TGF-beta 1 to reinforce the anterior abdominal wall in a rat model of incisional hernia. Hernia 2005;9:252-8.
21. Klinge U, Zheng H, Si ZY, Bhardwaj R, Klosterhalfen B, Schumpelick V. Altered collagen synthesis in fascia transversalis of patients with inguinal hernia. Hernia 1999;4:181-7.
22. Höer JJ, Junge K, Schachtrupp A, Klinge U, Schumpelick V. Influence of laparotomy closure technique on collagen synthesis in the incisional region. Hernia 2002;6:93-8.
23. Liapis CD, Dimitroulis DA, Kakisis JD, Nikolaou AN, Skandalakis P, Daskalopoulos M, et al. Incidence of incisional hernias in patients operated on for aneurysm or occlusive disease. Am Surg 2004;70:550-2.
24. Sugerman HJ, Kellum JM Jr, Reines HD, DeMaria EJ, Newsome HH, Lowry JW. Greater risk of incisional hernia with morbidly obese than steroid-dependent patients and low recurrence with prefascial polypropylene mesh. Am J Surg 1996;171:80-4.
25. Fagniez PL, Hay JM, Lacaine F, Thomsen C. Abdominal midline incision closure. A multicentric randomized prospective trial of 3,135 patients, comparing continuous versus open interrupted polyglycolic sutures. Arch Surg 1985;120:1351-3.
26. Ellis H, Coleridge-Smith PD, Joyce AD. Abdominal incisions—vertical or transverse? Postgrad Med J 1984;60:407-10.
27. Courtney CA, Lee AC, Wilson C, O'Dwyer PJ. Ventral hernia repair: a study of current practice. Hernia 2003;7:44-6.
28. Kulah B, Duzgun AP, Moran M, Kulacoglu IH, Ozmen MM, Cokun F. Emergency hernia repairs in elderly patients. Am J Surg 2001;182:455-9.
29. Sowula A, Groele H. Treatment of incarcerated abdominal hernia. Wiad Lek 2003;56:40-4.
30. Cherney DZ, Siccion Z, Chu M, Bargman JM. Natural history and outcome of

incarcerated abdominal hernias in peritoneal dialysis patients. Adv Perit Dial 2004;20:86-9.
31. Jenkins TP. The burst abdominal wound: a mechanical approach. Br J Surg 1976;63:873-6.
32. van't Riet M, Steyerberg EW, Nellesteyn J, Bonjer HJ, Jeekel J. Meta-analysis of techniques for closure of midline abdominal incisions. Br J Surg 2002;89:1350-6.
33. Carlson MA. Acute wound failure. Surg Clin North Am 1997;77:607-36.
34. Burger JWA, Luijendijk RW, Hop WCJ, Halm JA, Verdaasdonk EGG, Jeekel J. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 2004;240:578-85.
35. Bencini L, Sanchez LJ, Boffi B, Farsi M, Scatizzi M, Moretti R. Incisional hernia repair. Retrospective comparison of laparoscopic and open techniques. Surg Endosc 2003;17:1546-51.
36. Carbajo MA, Martin del Olmo JC, Blanco JI, de la Cuesta C, Toledano M, Martin F, et al. Laparoscopic treatment vs open surgery in the solution of major incisional and abdominal wall hernias with mesh. Surg Endosc 1999;13:250-2.
37. Chari R, Chari V, Eisenstat M, Chung R. A case controlled study of laparoscopic incisional hernia repair. Surg Endosc 2000;14:117-9.
38. DeMaria EJ, Moss JM, Sugerman HJ. Laparoscopic intraperitoneal polytetrafluoroethylene (PTFE) prosthetic patch repair of ventral hernia: prospective comparison to open prefascial polypropylene mesh repair. Surg Endosc 2000;14:326-9.
39. Holzman MD, Purut CM, Reintgen K, Eubanks S, Pappas T. Laparoscopic ventral and incisional hernioplasty. Surg Endosc 1997;11:32-5.
40. McGreevy JM, Goodney PP, Birkmeyer CM, Finlayson SR, Laycock WS, Birkmeyer J. A prospective study comparing the complication rates between laparoscopic and open ventral hernia repairs. Surg Endosc 2003;17:1778-80.
41. Park A, Birch DW, Lovrics P. Laparoscopic and open incisional hernia repair: a comparison study. Surgery 1998;124:816-22.
42. Ramshaw BJ, Esartia P, Schwab J, Mason EM, Wilson RA, Duncan TD, et al. Comparison of laparoscopic and open ventral herniorrhaphy. Am Surg 1999;65:827-31.
43. Raftopoulos I, Vanuno D, Khorsand J, Kouraklis G, Lasky P. Comparison of open and laparoscopic prosthetic repair of large ventral hernias. J Soc Laparoendosc Surg 2003;7:227-32.
44. Robbins SB, Pofahl WE, Gonzalez RP. Laparoscopic ventral hernia repair reduces wound complications. Am Surg 2001;67:896-900.
45. van't Riet M, Vrijland WW, Lange JF, Hop WCJ, Jeekel J, Bonjer HJ. Mesh repair of incisional hernia: comparison of laparoscopic and open repair. Eur J Surg 2002;168:684-9.
46. Wright BE, Niskanen BD, Peterson DJ, Ney AL, Odland MD, Vancamp J, et al. Laparoscopic ventral hernia repair: Are there comparative advantages over traditional methods of repair? Am Surg 2002;68:291-6.
47. Zanghi A, DiVita M, Lomemzo E, DeLuca A, Cappellani A. Laparoscopic repair versus open surgery for incisional hernias: a comparison study. Ann Ital Chir 2000;71:663-7.
48. Louis D, Stoppa R, Henry X, Verhaeghe P. Postoperative eventration. Apropos of 247 surgically treated cases. [French] J Chir 1985;122:523-7.
49. Bageacu S, Blanc P, Breton C, Gonzales M, Porcheron J, Chabert M, et al.

Laparoscopic repair of incisional hernia. A retrospective study of 159 patients. Surg Endosc 2002;16:345-8.
50. Ben-Haim M, Kuriansky J, Tal R, Zmora O, Mintz Y, Rosin D, et al. Pitfalls and complications with laparoscopic intraperitoneal expanded polytetrafluoroethylene patch repair of postoperative ventral hernia. Surg Endosc 2002;16:785-8.
51. Berger D, Bientzle M, Müller A. Postoperative complications after laparoscopic incisional hernia repair. Incidence and treatment. Surg Endosc 2002;16:1720-3.
52. Bower CE, Reade CC, Kirby LW, Roth JS. Complications of laparoscopic incisional-ventral hernia repair. Surg Endosc 2004;18:672-5.
53. Carbajo MA, Martin del Olmo JC, Blanco JI, Toledano M, de la Cuesta C, Ferreras C, et al. Laparoscopic approach to incisional hernia. Lessons learned from 270 patients over 8 years. Surg Endosc 2003;17:118-22.
54. Chowbey PK, Sharma A, Khullar R, Mann V, Baijal M, Vashistha A. Laparoscopic ventral hernia repair. J Laparoendosc Adv Surg Tech 2000;10:79-84.
55. Franklin ME Jr, Gonzalez JJ Jr, Glass JL, Manjarrez A. Laparoscopic ventral and incisional hernia repair: an 11-year experience. Hernia 2004;8:23-7.
56. Frantzides CT, Carlson MA, Zografakis JG, Madan AK, Moore RE. Minimally invasive incisional herniorrhaphy. A review of 208 cases. Surg Endosc 2004;18:1488-91.
57. Gillian GK, Geis WP, Grover G. Laparoscopic incisional and ventral hernia repair (LIVH): an evolving outpatient technique. J Soc Laparoendosc Surg 2002;6:315-22.
58. Heniford BT, Park A, Ramshaw BJ, Voeller G. Laparoscopic repair of ventral hernias: nine year's experience with 850 consecutive cases. Ann Surg 2003;238:391-9.
59. Kirshtein B, Lantsberg L, Avinoach E, Bayme M, Mizrahi S. Laparoscopic repair of large incisional hernias. Surg Endosc 2002;16:1717-19.
60. LeBlanc KA, Whitaker JM, Bellanger DE, Rhynes VK. Laparoscopic incisional and ventral hernioplasty: lessons learned from 200 patients. Hernia 2003;7:118-24.
61. Rosen M, Brody F, Ponsky J, Walsh RM, Rosenblatt S, Duperier F, et al. Recurrence after laparoscopic ventral hernia repair. A five-year experience. Surg Endosc 2003;17:123-8.
62. Toy FK, Bailey RW, Carey S, Chappuis CW, Gagner M, Josephs LG, et al. Prospective multicenter study of laparoscopic ventral hernioplasty. Preliminary results. Surg Endosc 1998;12:955-9.
63. Ujiki MB, Weinberger J, Varghese TK, Murayama KT, Joehl RJ. One hundred consecutive laparoscopic ventral hernia repairs. Am J Surg 2004;188:593-7.
64. Leber GE, Garb JL, Alexander AI, Reed W. Long-term complications associated with prosthetic repair of incisional hernias. Arch Surg 1998;133:378-82.
65. DeBord JR. Groin hernia surgery. The historical development of prosthetics in hernia surgery. Surg Clin North Am 1998;78:973-1006.
66. Deysine M. Pathophysiology, prevention, and management of prosthetic infections in hernia surgery. Surg Clin North Am 1998;78:1105-15.
67. Helton WS, Fisichella PM, Berger R, Horgan S, Espat NJ, Abcarian H. Short-term outcomes with small intestinal submucosa for ventral abdominal hernia. Arch Surg 2005;140:549-60.
68. Franklin ME Jr, Gonzalez JJ Jr, Glass JL. Use of porcine small intestinal

submucosa as a prosthetic device for laparoscopic repair of hernias in contaminated fields: a 2-year follow-up. Hernia 2004;8:186-9.
69. Buinewicz B, Rosen B. Acellular cadaveric dermis (Alloderm): a new alternative for abdominal hernia repair. Ann Plast Surg 2004;52:188-94.
70. Korenkov M, Saurland S, Arndt M, Bogard L, Neugebaur EA, Troidl H. Randomized clinical trial of suture repair, polyprophylene mesh or autodermal hernioplasty for incisional hernia. Br J Surg 2002;89:50-6.
71. Spotnitz WD, Flastrom JK, Rodeheaver GT. The role of sutures and fibrin sealant in wound healing. Surg Clin North Am 1997;77:651-9.
72. Santora TA, Roslyn JJ. Incisional hernia. Surg Clin North Am 1993;73:557-70.
73. Mudge M, Hughes L. Incisional hernia: a 10-year prospective study of incidence and attitudes. Br J Surg 1985;72:70-1.
74. Lowry PS, Moon TD, D'Alessandro A, Nakada SY. Symptomatic port-site hernia associated with a non-bladed trocar after laparoscopic live-donor nephrectomy. J Endourol 2003;17:493-4.
75. Komuta K, Haraguchi M, Inoue K, Furui J, Kanematsu T. Herniation of the small bowel through the port site following removal of drains during laparoscopic surgery. Dig Surg 2000;17:544-6.
76. Arnaud JP, Hennekinne-Mucci S, Pessaux P, Tuech JJ, Aube C. Ultrasound detection of adhesion after intraperitoneal ventral hernia treatment: a comparative study of protected versus unprotected meshes. Hernia 2003;7:85-8.
77. Tu FF, Lamvu GM, Hartmann KE, Steege JF. Preoperative ultrasound to predict infraumbilical adhesions: a study of diagnostic accuracy. Am J Obstet Gynecol 2005;192:74-9.
78. Ramirez OM, Ruas E, Dellon AL. "Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study. Plast Reconstr Surg 1990;86:519-26.
79. van Geffen HJAA, Simmermacher RKJ, van Vroonhoven TJMV, van der Werken C. Surgical treatment of large contaminated abdominal wall defects. J Am Coll Surg 2005;201:206-12.
80. van Geffen HJAA, Simmermacher RKJ. Incisional hernia repair: abdominoplasty, tissue expansion, and methods of augmentation. World J Surg 2005;29:1080-5.
81. Schumpelick V, Conze J, Klinge U. Preperitoneal mesh-plasty in incisional hernia repair. A comparative retrospective study of 272 operated incisional hernias. Chirurgie 1996;67:1028-35.
82. Koller R, Miholic J, Jakl RJ. Repair of incisional hernias with expanded polytetrafluoroethylene. Eur J Surg 1997;163:261-6.
83. Paajanen H, Hermunen H. Long-term pain and recurrence after repair of ventral incisional hernias by open mesh: clinical and MRI study. Langenbecks Arch Surg 2004;389:366-70.
84. Millikan KW, Baptista M, Amin B, Deziel DJ, Doolas A. Intraperitoneal underlay ventral hernia repair utilizing bilayer expanded polytetrafluoroethylene and polypropylene mesh. Am Surg 2003;69:287-9.
85. Wantz GE, Chevrel JP, Flament JB, Kingsnorth A, Schumpelick V, Verhaeghe P. Incisional hernia: the problem and the cure. J Am Coll Surg 1999;188:429-47.
86. Ammaturo C, Bassi G. Surgical treatment of large incisional hernias with an intraperitoneal Parietex Composite mesh: our preliminary experience of 26 cases. Hernia 2004;8:242-6.

87. Arnaud JP, Tuech JJ, Pessaux P, Hadchity Y. Surgical treatment of postoperative incisional hernias by intraperitoneal insertion of Dacron mesh and an aponeurotic graft: a report on 250 cases. Arch Surg 1999;134:1260-2.
88. Bauer JJ, Harris MT, Gorfine SR, Kreel I. Rives-Stoppa procedure for repair of large incisional hernias: experience with 57 patients. Hernia 2002;6:120-3.
89. Chrysos E, Athanasakis E, Saridaki Z, Kafetzakis A, Dimitriadou D, Koutsoumpas V, et al. Surgical repair of incisional ventral hernias: tension-free technique with prosthetic materials (expanded polytetrafluoroethylene Gore-Tex Dual Mesh). Am Surg 2000;66:679-82.
90. Ladurner R, Trupka A, Schmidbauer S, Hallfeldt K. The use of an underlay polypropylene mesh in complicated incisional hernias: successful French surgical technique. Minerva Chir 2001;56:111-7.
91. Martin-Duce A, Noguerales F, Villeta R, Hernandez P, Lozano O, Keller J, et al. Modifications to Rives technique for midline incisional hernia repair. Hernia 2001;5:70-2.
92. Cassar K, Munro A. Surgical treatment of incisional hernia. Br J Surg 2002;89:534-45.
93. Goodney PP, Birkmeyer CM, Birkmeyer JD. Short-term outcomes of laparoscopic and open ventral hernia repair. Arch Surg 2002;137:1161-5.
94. Bell RL, Longo WE. Spigelian hernia. J Am Coll Surg 2004;199:161.
95. Vos DI, Scheltinga MRM. Incidence and outcome of surgical repair of Spigelian hernia. Br J Surg 2004;91:640-4.
96. Larson DW, Farley DR. Spigelian hernias: repair and outcome for 81 patients. World J Surg 2002;26:1277-81.
97. Campanelli G, Pettinari D, Nicolosi F, Avesani EC. Spigelian hernia. Hernia 2005;9:3-5.
98. Carter JE, Mizes C. Laparoscopic diagnosis and repair of Spigelian hernia: report of a case and technique. Am J Obstet Gynecol 1992;167:77-8.
99. Martell EG, Singh NN, Zagorski SM, Sawyer MAJ. Laparoscopic repair of a Spigelian hernia: a case report and literature review. J Soc Laparoendosc Surg 2004;8:269-74.
100. Moreno-Egea A, Aguayo JL, Girela E. Treatment of Spigelian hernia using totally extraperitoneal laparoscopy ambulatory surgery. Surg Endosc 2002;16:1806.
101. Moreno-Egea A, Carrasco L, Girela E, Martin J-G, Aguayo JL, Canteras M. Open vs laparoscopic repair of Spigelian hernia. Arch Surg 2002;137:1266-8.
102. Green BT. Strangulated obturator hernia: still deadly. South Med J 2001;94:81-3.
103. Naude G, Bongard F. Obturator hernia is an unsuspected diagnosis. Am J Surg 1997;174:72-5.
104. Spector SA, Rosenthal RA. Abdominal wall hernia in the elderly. In: Rosenthal RA, Zenilman ME, Katlic MR, editors. Principles and Practice of Geriatric Surgery. New York: Springer-Verlag; 2001:662-76.
105. Gray SW, Skandalakis JE, Soria RE, Rowe JS Jr. Strangulated obturator hernia. Surgery 1974;75:20-7.
106. Hannington-Kiff JG. Absent thigh adductor reflex in obturator hernia. Lancet 1980;1:180.
107. Yokoyama T, Munakata Y, Ogiwara M, Kamijima T, Kitamura H, Kawasaki S. Preoperative diagnosis of strangulated obturator hernia using ultrasonography. Am J Surg 1997;174:76-8.

108. Ijiri R, Kanamaru H, Yokoyama H, Shirakawa M, Hashimoto H, Yoshino G. Obturator hernia: the usefulness of computed tomography in diagnosis. Surgery 1996;119:137-40.
109. Kammori M, Mafune K, Hirashima T, Kawahara M, Hashimoto M, Ogawa T, et al. Forty-three cases of obturator hernia. Am J Surg 2004;187:549-52.
110. Haith LR Jr, Simeone MR, Reilly KJ, Patton ML, Moss BE, Shotwell BA. Obturator hernia: laparoscopic diagnosis and repair. J Soc Laparoendosc Surg 1998;2:191-3.
111. Shapiro K, Patel S, Choy C, Chaudry G, Khalil S, Ferzli G. Totally extraperitoneal repair of obturator hernia. Surg Endosc 2004;18:954-6.
112. Losanoff JE, Richman BW, Jones JW. Obturator hernia. J Am Coll Surg 2002;194:657-63.
113. Schmidt PH, Bull WJ, Jeffery KM, Martindale RG. Typical versus atypical presentation of obturator hernia. Am Surg 2001;67:191-5.
114. Ghahremani GG, Michael AS. Sciatic hernia with incarcerated ileum: CT and radiographic diagnosis. Gastrointest Radiol 1991;16:120-2.
115. Servant CT. An unusual cause of sciatica. A case report. Spine 1998;23:2134-6.
116. Miklos JR, O'Reilly MJ, Saye WB. Sciatic hernia as a cause of chronic pelvic pain in women. Obstet Gynecol 1998;91:998-1001.
117. Yu P-C, Ko S-F, Lee T-Y, Ng S-H, Huang C-C, Wan Y-L. Small bowel obstruction due to incarcerated sciatic hernia: ultrasound diagnosis. Br J Radiol 2002;75:381-3.
118. Cali RL, Pitsch RM, Blatchford GJ, Thorson A, Christensen MA. Rare pelvic floor hernias. Report of a case and review of the literature. Dis Colon Rectum 1992;35:604-12.
119. Burt BM, Afifi HY, Wantz GE, Barie PS. Traumatic lumbar hernia: report of cases and comprehensive review of the literature. J Trauma 2004;57:1361-70.
120. McCarthy MC, Lemmon GW. Traumatic lumbar hernia: a seat belt injury. J Trauma 1996;40:121-2.
121. Salameh JR, Salloum EJ. Lumbar incisional hernias: diagnostic and management dilemma. J Soc Laparoendosc Surg 2004;8:391-4.
122. Moreno-Egea A, Torralba-Martinez JA, Morales G, Fenandez T, Girela E, Aguayo-Albasini JL. Open vs laparoscopic repair of secondary lumbar hernias: a prospective nonrandomized study. Surg Endosc 2005;19:184-7.
123. Woodward AM, Flint LM, Ferrara JJ. Laparoscopic retroperitoneal repair of recurrent postoperative lumbar hernia. J Laparoendosc Adv Surg Tech A 1999;9:181-6.
124. Grauls A, Lallemand B, Krick M. The retroperitoneoscopic repair of a lumbar hernia of Petit. Case report and review of literature. Acta Chir Belg 2004;104:330-4.
125. Meinke AK. Totally extraperitoneal laparoendoscopic repair of lumbar hernia. Surg Endosc 2003;17:734-7.
126. Carbonell AM, Kercher KW, Sigmon L, Matthews BD, Sing RF, Kneisl JS, et al. A novel technique of lumbar hernia repair using bone anchor fixation. Hernia 2005;9:22-5.
127. Rubin MS, Bailey HR. Parastomal hernias. In: Mackeigan JM, Cataldo PA, editors. Principles, Techniques and Management. Intestinal Stomas. St. Louis: Quality Medical Publishing; 1993:245-67.
128. Edwards DP, Leppington-Clarke A, Sexton R, Heald RJ, Moran BJ. Stoma-related

complications are more frequent after transverse colostomy than loop ileostomy: a prospective randomized clinical trial. Br J Surg 2001;88:360-3.
129. Carne PWG, Robertson GM, Frizelle FA. Parastomal hernia. Br J Surg 2003;90:784-93.
130. St.Peter SD, Heppell J. Surgical images: soft tissue. Incarcerated gallbladder in a parastomal hernia. Can J Surg 2005;48:46.
131. Williams JG, Etherington R, Hayward MWJ, Hughes LE. Paraileostomy hernia: a clinical and radiological study. Br J Surg 1990;77:1355-7.
132. Amin SN, Armitage NC, Abercrombie JF, Scholefield JH. Lateral repair of parastomal hernia. Ann R Coll Surg Engl 2001;83:206-8.
133. Jänes A, Cengiz Y, Israelsson LA. Randomized clinical trial of the use of a prosthetic mesh to prevent parastomal herniation. Br J Surg 2004;91:280-2.
134. Deol ZK, Shayani V. Laparoscopic parastomal hernia repair. Arch Surg 2003;138:203-5.
135. Hansson BM, van Nieuwenhoven EJ, Bleichrodt RP. Promising new technique in the repair of parastomal hernia. Surg Endosc 2003;17:1789-91.
136. Safadi B. Laparoscopic repair of parastomal hernias: early results. Surg Endosc 2004;18:676-80.
137. Howdieshell TR, Proctor CD, Sternberg E, Cue JI, Mondy JS, Hawkins ML. Temporary abdominal closure followed by definitive abdominal wall reconstruction of the open abdomen. Am J Surg 2004;188:301-6.
138. Jernigan TW, Fabian TC, Croce MA, Moore N, Pritchard EE, Minard G, et al. Staged management of giant abdominal wall defects: acute and long- term results. Ann Surg 2003;238:349-55.
139. Dayton MT, Buchele BA, Shirazi SS, Hunt LB. Use of an absorbable mesh to repair contaminated abdominal-wall defects. Arch Surg 1986;121:954-60.
140. Silverman RP, Singh NK, Li EN, Disa JJ, Girotto JA, Slezak S, et al. Restoring abdominal wall integrity in contaminated tissue-deficient wounds using autologous fascia grafts. Plast Reconstr Surg 2004;113:673-5.
141. Hirsch EF. Repair of an abdominal wall defect after a salvage laparotomy for sepsis. J Am Coll Surg 2004;198:324-8.
142. De Vries Reilingh TS, van Goor H, Rosman C, Bemelmans MHA, de Jong D, van Nieuwenhoven EJ, et al. "Components separation technique" for the repair of large abdominal wall hernias. J Am Coll Surg 2003;196:32-7.
143. Vargo D. Components separation in the management of the difficult abdominal wall. Am J Surg 2004;188:633-7.
144. Lowe JB, Garza JR, Bowman JL, Rohrich RJ, Strodel WE. Endoscopically assisted "components separation" for closure of abdominal wall defects. Plast Reconstr Surg 2000;105:720-9.
145. Baghai M, Ramshaw BJ. Technique of laparoscopic ventral hernia repair can be modified to successfully repair large defects in patients with loss of domain [poster]. Scientific Session of the Society of American Gastrointestinal and Endoscopic Surgeons, Orlando, FL, April 13-16, 2005.
146. Luijendijk RW, Jeekel J, Storm RK, Schutte PJ, Hop WC, Drogendijk AC, et al. The low transverse Pfannenstiel incision and the prevalence of incisional hernia and nerve entrapment. Ann Surg 1997;225:365-9.
147. Carbonell AM, Kercher KW, Matthews BD, Sing RF, Cobb WS, Heniford BT. The laparoscopic repair of suprapubic ventral hernias. Surg Endosc 2005;19:174-7.

148. Davidson BR, Bailey JS. Incisional herniae following median sternotomy incisions: their incidence and aetiology. Br J Surg 1986;73:995-6.
149. Liem MSL, van der Graaf Y, Beemer FA, van Vroonhoven TJMV. Increased risk for inguinal hernia in patients with Ehlers-Danlos syndrome. Surgery 1997;122:113-5.
150. Abdul Wahab A, Janahi IA, Eltohami A, Zeid A, Ul Haque NF, Teebi AS. A new type of Ehlers-Danlos syndrome associated with tortuous systemic arteries in a large kindred in Qatar. Acta Paediatr 2003;92:456-62.
151. Malfait F, De Coster P, Hausser I, van Essen AJ, Franck P, Colige A, et al. The natural history, including orofacial features of three patients with Ehlers-Danlos syndrome, dematosparaxis type (EDS type VIIC). Am J Med Genet A 2004;131:18-28.
152. Girotto JA, Malaisrie SC, Bulkely G, Manson PN. Recurrent ventral herniation in Ehlers-Danlos syndrome. Plast Reconstr Surg 2000;106:1520-6.