Open Repair of Ventral Incisional Hernias

Dan H. Shell IV, MD a, Jorge de la Torre, MD a,*, Patricio Andrades, MD a, b, Luis O. Vasconez, MD a

Division of Plastic Surgery, University of Alabama at Birmingham, 510 20th Street S, Birmingham, AL 35294-3411, USA
Division of Transplant Immunology, University of Alabama at Birmingham, 510 20th Street S, Birmingham, AL 35294-3411, USA

Incisional hernia is a common and often debilitating complication after laparotomy. Despite significant advances in many areas of surgery, correction of incisional hernias continues to be problematic, with recurrence rates ranging from 5% to 63% depending on the type of repair used [1–8]. Recurrence rates are likely underestimated because of a lack of long-term follow-up and objective criteria in the literature to determine true recurrence.

More than 2 million laparotomies are performed annually in the United States, with a reported 2% to 11% incidence of incisional hernia [1,5,9–11]. It is the most common complication after laparotomy by a 2:1 ratio over bowel obstruction and is the most common indication for reoperation by a 3:1 ratio over adhesive small bowel obstruction [12]. Approximately 100,000 hernia repairs are performed annually in the United States [13]. The associated morbidity secondary to incarceration, strangulation, and bowel obstruction is significant. In a retrospective review of 206 patients who underwent incisional hernia repair, Read and Yoder [9,10] found that strangulation or incarceration was the indication for repair in 17% of patients. The gradual enlargement of the hernia over time results in a relative loss of abdominal domain, with adverse effects on postural maintenance, respiration, micturition, defecation, and biomechanical properties, which have a profound impact on patients’ overall physical capacity and quality of life. As patients are forced to alter their lifestyle, their ability to work becomes impaired, which has negative economic consequences. Progressive enlargement of the hernia also results in a cosmetic deformity, which is detrimental to patients’ self-esteem.

* Corresponding author.
E-mail address: jdlt@uab.edu (J. de la Torre).
Incisional hernias are the only abdominal hernias that are iatrogenic [10]. Controversy exists regarding the ideal treatment of incisional hernias. Nowhere in surgery does the phrase “if there are multiple ways of fixing a problem then there is not one good way” hold true more so than with incisional hernia repair. The approach to incisional hernia repair is often based on tradition rather than evidence. Several important contributions to the literature in recent years have helped our understanding of the causes of incisional hernia formation and the important physiologic and functional properties of the abdominal wall. An appreciation for the dynamic function of the abdominal wall has led to technical refinements and the recognition of important principles that are necessary for successful repair.

Etiology

Many patient-related risk factors have been implicated in the development of incisional hernias, including obesity, smoking, aneurismal disease, chronic obstructive pulmonary disease, male gender, malnourishment, corticosteroid dependency, renal failure, malignancy, and prostatism [1–8,10,11,14–23]. Many of these risk factors may contribute to the development of an incisional hernia, but no single factor is so regularly associated that it may be declared as serving a truly etiologic role [22].

In a study by Condon and colleagues [21] of complications associated with closure of 1000 midline laparotomies, no single factor was associated with incisional hernia on univariate analysis. On multivariate analysis, only the combination of reopening and reclosing previous incisions coupled with wound infection influenced the development of incisional hernia. Postoperative wound infection has been found in additional studies to be the single most significant prognostic factor in the development of incisional hernia [1,7,10,14,19,21]. Bucknall and colleagues [1] reported a 23% incidence of incisional hernia formation in patients who developed a wound infection.

Obesity often has been cited as a risk factor, with an incisional hernia rate of 15% to 20% [24–26]. In a prospective, randomized evaluation that compared fascial closure techniques, Brolin [24] found a reduction in incisional hernia occurrence from 18% to 10% with the use of double-stranded #1 PDS placed in continuous fashion compared with #1 Ethibond placed in interrupted figure-of-eight fashion. Aneurysmal disease also has been found in multiple studies to be an independent risk factor in the development of incisional hernias [22,27–29]. A recent multicenter, prospective study by Rafetto and colleagues [22] found a 28.2% incidence of incisional hernia formation in patients undergoing surgery for aortic aneurysm repair. After correcting for other risk factors, this figure represents a ninefold increase in the incidence of incisional hernia formation compared with surgery for aortic occlusive disease. It has been suggested that a defect in collagen metabolism with a decreased ratio of type I to type III procollagen may play a role; however,
further studies are needed before a causal relationship can be established [22,30].

Incisional hernias differ from other abdominal wall hernias in their iatrogenic origin. Surgeon-related technical errors are responsible for most incisional hernias. Closure under tension results in fascial strangulation and hernia formation. Studies have shown that 50% of hernia recurrences are detected in the first postoperative year, 75% are detected at 2 years, and 90% are detected at 3 years, with continued failure rates of 2% per year thereafter [2,5,6,11]. These findings implicate technical factors in early wound failure and patient-related factors in late wound failure. Playforth and colleagues [31] applied radiopaque staples to the margins of incised fascia. Serial radiographs were taken at time intervals up to 1 year. In patients who developed incisional hernias at 1 year, there was separation of the staples at 1 week postoperatively. This finding supports faulty surgical technique as the primary cause of early wound failure. Poole [32] concluded in a comprehensive review that local technical factors were of greater significance than patient-related conditions in the development of incisional hernias. Given these findings, it is incumbent on surgeons to identify and use appropriate techniques and materials to minimize the incidence of incisional hernias.

Controversy exists regarding the optimal closure material and technique used to avoid incisional hernias. Carlson and colleagues [21] compared the incisional hernia rate of midline, transverse, and paramedian incisions. Midline incisions had the highest hernia rate—10.5% compared with 7.5% with transverse incisions and 2.5% with paramedian incisions. A meta-analysis of randomized, controlled trials that compared suture material and technique found that abdominal fascial closure with nonabsorbable monofilament suture in a continuous fashion had a significantly lower rate of incisional hernia [33]. In work that has been reinforced by others, Jenkins [34–36] found that a suture length-to-incision ratio of 4:1 was optimal for fascial closure. To use this length of suture, bites should encompass 1 cm of tissue at 1-cm intervals with attention to simply approximate the fascia. They also found nonabsorbable suture in continuous fashion to be the material and technique of choice.

Presentation and natural history

Patients typically present with a bulge in a portion of the healed surgical incision. Complaints of dull abdominal discomfort and associated nausea are common and are related to stretching of the bowel mesentery as it protrudes through the defect [10,11]. Bowel obstruction may result from incarceration in the hernia sac but is more often caused by twisting of the bowel around adhesions at the lateral margins of the hernia defect [10,11]. The natural history of incisional hernias is gradual enlargement. The linea alba serves as the midline anchor for the aponeurotic insertions of the rectus.
sheath and oblique musculature [37]. Disruption results in gradual enlargement of the hernia defect because of unopposed lateral contraction of the oblique musculature. As the hernia defect widens, task-dependent functions of the abdominal wall musculature are interfered with and significant physiologic derangements occur [11,38,39].

The abdominal wall has important functions in respiration. As the hernia defect widens, the diaphragm loses synergy with the abdominal wall, as evidenced by paradoxical abdominal respiratory motion [37]. Puckree and colleagues [39] demonstrated that the internal oblique and transversus abdominus muscles receive neural impulses from central expiratory neurons. Misuri and colleagues [40] demonstrated by ultrasound assessment that the transversus abdominus muscle is a major contributor to the generation of expiratory forces. Trunk motion abnormalities are common in patients with incisional hernias. Myrinkas and colleagues [41] measured stretch reflexes of the rectus abdominus muscles and found that a crossed monosynaptic communication exists between the right and left rectus muscles, which controls trunk flexion and extension. Trunk rotation results from joint contraction of one external oblique and the contralateral internal oblique. Blondeel and colleagues [42] demonstrated in isokinetic dynamometric studies that displacement of the oblique fibers insertions results in statistically significant reductions in trunk rotation.

The abdominal wall plays an important role in posture maintenance and support of the lumbar spine [43–45]. Patients with large incisional hernias often have significant lumbar lordosis and disabling back pain. Children with prune belly syndrome are functionally impaired by the associated scoliosis [45]. Ramirez and colleagues [46] demonstrated complete relief of back pain after repair of large incisional hernias by restoration of midline myofascial continuity. In a study by Toranto [43], resolution of back pain was observed in 24 of 25 patients after wide rectus plication. This resolution is postulated to result from a restoration of the counterbalancing effect of the abdominal wall muscles with the back musculature. The lateral pull of the internal oblique-transversus abdominus musculature on the lumbo-dorsal fascia is responsible for a reduction in intervertebral joint stress [46].

Expulsive functions are compromised and may become problematic as the hernia enlarges. Contraction of the abdominal wall musculature and generation of intra-abdominal pressure are important in functions such as coughing, micturition, and defecation.

Dermatologic changes may occur as the hernia enlarges. As the overlying skin is stretched, the subcutaneous tissue atrophies and the skin at the apex becomes ischemic, which renders it susceptible to ulceration and infection.

**Repair principles**

The presence of an incisional hernia is an indication for repair; the hernia will only enlarge in size and lead to progressive physiologic derangements.
The actual size of the hernia is defined by the size of the parietal defect to be repaired, which is often significantly larger than the palpable clinical defect. This includes all secondary hernias and zones of weakened fascia [47]. Multiple repair techniques have been used in the past; however, there is lack of a general consensus regarding the optimal technique. Several important principles have been defined to aid in the surgical approach to this difficult problem [48–51]. The goals of hernia repair should be as follows:

1. Prevention of visceral eventration
2. Incorporation of the remaining abdominal wall in the repair
3. Provision of dynamic muscular support
4. Restoration of abdominal wall continuity in a tension-free manner

The high recurrence rates with primary suture repair have led to an increased use of prosthetic mesh to provide for a “tension-free” repair. This approach has resulted in a decline in recurrence rates; however, mesh-related complications, such as infection, extrusion, and fistula formation, are significant problems. Recent emphasis on the importance of restoration of midline myofascial continuity and dynamic abdominal wall support has led to the application of numerous techniques of autologous reconstruction.

Primary suture repair

Until the 1990s, simple suture repair of incisional hernias was the gold standard. Multiple retrospective studies in the literature have demonstrated high recurrence rates (25%–63%) of primary suture repair of even small (< 5 cm) fascial defects [3,4,7,9,11]. Various techniques have been applied; however, the continued presence of tension at the site of repair has led to high recurrence rates (Table 1). Additional hernias and areas of fascial weakening may not be appreciated by the limited exposure of primary suture repair and may result in future recurrences. In a study of recurrent hernias by Girotto and colleagues [55], 50% of patients were noted to have more than one hernia at the time of exploration.

The high recurrence rates of primary suture repair were supported in a large, prospective, randomized trial by Luijendijk and colleagues [3]. In a study that compared mesh and primary suture repair for incisional hernias smaller than 6 cm in greatest dimension, they found a 46% recurrence rate in the primary suture repair group compared with 23% in the mesh repair group [3]. A long-term follow-up of the study by Burger and colleagues [4] revealed a 10-year cumulative rate of recurrence of 63% for the suture repair group compared with 32% for the mesh repair group, which led the authors to conclude that “primary suture repair of incisional hernias should be completely abandoned.” An expert panel on incisional herniorrhaphy concluded that primary suture repair should be used only for small (< 5 cm) hernias and if the repair is oriented horizontally with nonresorbable, monofilament suture with a suture-to-wound length ratio of 4:1 [56].
Mesh repair

High recurrence rates associated with primary suture repair have led to an increased application of prosthetic mesh for the repair of incisional hernias. The use of synthetic mesh in incisional hernia repairs increased from 34.2% in 1987 to 65.5% in 1999 [57]. The American Hernia Society has declared that the use of mesh currently represents the standard of care in incisional hernia repair [58]. Placement of mesh allows for a tension-free restoration of the structural integrity of the abdominal wall. Advantages to the use of mesh include availability, absence of donor site morbidity, and strength of the repair [59]. The ideal prosthetic material should be non-toxic, nonimmunogenic, and nonreactive [59,60]. The ultimate goal when using mesh is for it to become incorporated into the surrounding tissues.

Tensile strength is another important property of the synthetic material. Tensile strength of the abdominal wall may be calculated as the product of tension strength according to LaPlace’s formula ($\Delta P = 2T/r$) and the area of cross-section of the abdomen [59]. In an average-sized human, the maximum required tensile strength to maintain abdominal closure is 16 N/cm [59]. In general, prosthetic materials have a tensile strength more than 32 N/cm [61]. Rarely is there a true failure of the mesh material. Recurrences seen after mesh repair typically occur laterally at the mesh-tissue interface. The physical properties of this interface are important in determining the ultimate strength and durability of the repair.

The two most commonly used permanent prosthetic materials are polypropylene and expanded polytetrafluoroethylene (ePTFE). Polypropylene was first introduced in the 1950s by Usher [62]. The large pore size of the polypropylene mesh allows for macrophage and neutrophil infiltration, which provides greater resistance to infection. Its porosity also allows for better fibrovascular ingrowth and a reduced incidence of seroma formation [59]. ePTFE (Goretex; W.L. Gore and Associates, Flagstaff, Arizona) has a microporous structure that minimizes cellular infiltration and tissue incorporation. Studies have shown ePTFE prosthesis to be stronger than marlex
and equivalent to polypropylene in terms of suture retention strength [63]. As a result of its flexible, soft, and conforming qualities and minimal tissue ingrowth, it can be placed directly on bowel [59]. The disadvantages of ePTFE are related to its microporous structure. The material is virtually impenetrable, which prevents host tissue incorporation and leads to seroma formation. Once infected, ePTFE requires explantation. The micropores range from 3 to 41 \( \mu m \) in size, which are large enough for bacteria (1 \( \mu m \)) to infiltrate but too small for macrophages (> 50 \( \mu m \)) [59].

In an effort to reduce mesh-related complications and more closely duplicate abdominal wall physiology, research has focused on the development of composite materials that combine nonabsorbable and absorbable materials. Well-designed, comparative studies with long-term follow-up are still needed. Knowledge of the structural anatomy and an appreciation of the physiology of the abdominal wall are necessary for successful abdominal wall reconstruction. Recurrence after mesh repair is rarely caused by intrinsic failure of the prosthetic material. Failure to identify healthy fascia and technical error in securing the mesh to the fascia commonly lead to recurrence at the mesh-fascia interface (Table 2).

Several methods of securing the mesh to the fascia have been described, with the most common being mesh onlay, mesh inlay, retrorectus placement, and intraperitoneal underlay. The onlay technique (Fig. 1A) is popular among surgeons because it avoids direct contact with the bowel and imparts less tension on the repair. In a survey of more than 1000 surgeons, Milliken [11] reported that 50% of surgeons use this repair without closing the fascial defect. The disadvantages are that it requires wide tissue undermining, which may predispose to wound-related complications, and that the pressure required to disrupt the mesh from the anterior abdominal wall is less than other repairs. Chevrel and Rath [76,77] reported their results of 389 patients and found a recurrence rate of 18.4% \( (n = 153) \) without the use of mesh compared with 5.5% \( (n = 133) \) with the use of polypropylene onlay mesh and 0.97% \( (n = 103) \) with the use of fibrin glue in addition to the mesh. Their technique consisted of relaxing incisions in the anterior rectus sheath with primary approximation of the linea alba and medial turnover of the anterior rectus sheath followed by mesh placement.

The inlay technique involves excision of the hernia sac and identification of healthy fascial margins (Fig. 1B). This technique provides for a tensionless repair at the time of surgery and avoids the wide undermining of the onlay repair. Without the overlying support of the anterior abdominal wall, activities that increase intra-abdominal pressure impart significant tension to the mesh-fascial interface, which is the weakest point of the repair [76]. High recurrence rates of 10% to 20% have resulted in use of other techniques to optimize strength of the mesh-fascia interface [3,11]. Retrorectus placement of mesh, popularized by Rives and Stoppa, has been used with increasing frequency [11,78,79]. In this technique, the hernia sac is preserved and used as a buffer between the mesh and underlying viscera. The mesh is
placed above the posterior rectus sheath and beneath the rectus muscle (Fig. 1C). Below the arcuate line, the mesh is placed in the preperitoneal space. It is generally recommended to place the mesh with at least 4 cm of contact between the mesh and fascia, which allows for distribution of pressure over a wider area (Pascal’s principle), and the pressure-induced apposition promotes fibrous ingrowth at the mesh-fascial interface [59].

It has also been experimentally demonstrated that prolene may shrink up to 30% after implantation [80,81]. By placing the mesh beneath the abdominal wall, the repair is bolstered by the anterior abdominal wall, which provides for a more secure and physiologic repair. Recurrence rates of less than 10% have been reported with this technique [66,68]. Intraperitoneal underlay placement is a common technique used in open and laparoscopic approaches. Proponents of this technique cite that the ability to place the mesh with a large underlay allows for better tissue ingrowth and a more

<table>
<thead>
<tr>
<th>Author et al</th>
<th>Year</th>
<th>N</th>
<th>Mesh</th>
<th>Technique</th>
<th>Recurrence (%)</th>
<th>Follow-up (mo)</th>
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Adapted from Cassar K, Munro A. Surgical treatment of incisional hernia. Br J Surg 2002;89:534–45; with permission of Blackwell Science Ltd.
secure mesh-fascial interface [11]. Fixation techniques vary from approximation at the fascial margins to full-thickness lateral fixation [82]. Recurrence rates of less than 5% have been reported with this technique [82].

Advances in laparoscopic surgery have led to an increased application of this technology to the treatment of incisional hernias. This technique involves intraperitoneal mesh placement, which is secured with either a tacking device or transabdominal sutures or both. Advocates of this technique cite lower recurrence rates of 2% to 4%, shorter hospital stay, decreased infection rate, and reduced wound complication rates as advantages. Several comparative studies have concluded that it is a superior technique [83–87]. Restoration of dynamic abdominal wall function by midline myofascial approximation and cosmetic improvement of the abdomen by excision of excess tissue and scar are important objectives of hernia repair that are not accomplished by the laparoscopic approach [58].

Although the application of mesh has resulted in a significant improvement in recurrence rates, the use of mesh is associated with specific complications that may range from being relatively minor to life threatening. Infection is one of the most feared complications after mesh placement. The average rate of early and late mesh infections is approximately 7% [8,59,72,88–90] and depends on the type of mesh used. The most common
organisms are *Staphylococcus aureus* and *Staphylococcus epidermidis* [59]. Reports exist in the literature of mesh salvage in the face of infection; however, in most cases mesh removal is required [91]. Law [92] examined the effects of infection on the mesh-fascial interface and found significant weakening, which predisposes to higher recurrence rates. Robertson and colleagues [93–106] demonstrated that isolation of the incision away from the hernia repair through an abdominoplasty approach is associated with lower complication and recurrence rates. It was particularly helpful in obese patients and patients with multiple or recurrent hernias.

Seroma is a common complication after hernia repair and comprises up to 16% of the overall complications [8,88,107]. Reduction of the hernia leaves a potential space for fluid accumulation. Combined with inflammation, disruption of lymphatics, and continued irritation caused by the foreign body reaction from the prosthetic material, this complication results in fluid accumulation [59]. Seromas often resolve with time; however, continued prosthetic irritation may result in persistent seroma requiring surgical drainage.

Inadequate soft tissue coverage may result in mesh extrusion. Less pliable materials, such as marlex, are associated with a higher extrusion rate. When extrusion is noted, most authors agree that mesh removal is indicated. Enteric fistula formation is a potentially devastating complication that occurs when the prosthetic material erodes into the underlying bowel. Leber and colleagues [8] demonstrated that excision of the hernia sac, lack of omental interposition, and the presence of a fascial gap were factors associated with a higher incidence of fistula formation.

**Bioprosthetics**

Justified concern regarding mesh-related complications has led to the search for more biocompatible prosthetic material. Advances in tissue engineering technology have led to the development of biomaterials derived from human and animal tissues. These materials differ in that they heal by a regenerative process rather than by scar tissue formation. The collagen-based extracellular matrix is preserved, which allows for maintenance of mechanical integrity while providing a scaffold for host tissue regeneration. These materials have demonstrated resistance to infection, tolerance of cutaneous exposure, and mechanical stability when used in incisional hernia repair. Disadvantages are the high cost and lack of long-term follow-up studies.

**Components separation technique**

A significant contribution to the repair of incisional hernias was the description by Ramirez and colleagues [46] of the components separation technique (Fig. 2). The evolution of the components separation technique is based on early descriptions by Vasconez and colleagues [108] of transverse
rectus abdominus myocutaneous closure that involves separation of the external and internal oblique musculature and release of the posterior sheath. Ramirez and colleagues [46,51,109,110] noted that the abdominal wall is formed by overlapping muscle layers that may be separated while preserving their innervation and blood supply, specifically, elevation of the external oblique off the internal oblique. (C) Rectus is released form the posterior sheath. (D) Medial advancement of rectus muscle and attached internal oblique–transversus abdominus complex.

Fig. 2. Components separation technique. (A) The abdominal wall formed by overlapping muscle layers that may be separated. (B) Elevation of the external oblique off the internal oblique. (C) Rectus is released form the posterior sheath. (D) Medial advancement of rectus muscle and attached internal oblique–transversus abdominus complex.
oblique off the internal oblique while maintaining the neurovascular supply
to the rectus abdominus, which travels in a segmental fashion between the
internal oblique and transversus abdominus. The rectus then can be released
from the posterior sheath. Once this procedure is accomplished, medial ad-
vancement of a compound flap of rectus muscle and attached internal obli-
que-transversus abdominus complex can be used to cover large midline
abdominal defects. Unilateral advancement of 5 cm in the epigastric region,
10 cm at the umbilicus, and 3 cm in the suprapubic region has been de-
scribed. Fabian and colleagues [111,112] described a modification that in-
volved division of the internal oblique of the anterior rectus sheath, which
allowed for unilateral advancement of 8 to 10 cm in the epigastric area, 10
to 15 cm in the mid abdomen, and 6 to 8 cm in the suprapubic region. A
lower hernia recurrence rate, avoidance of prosthetic material, restoration
of dynamic abdominal wall function, and improvement in back and postural
abnormalities have been cited in the literature (Table 3). Wound-related
complications have been problematic with this technique and are related
to the wide undermining required. Recent work has demonstrated a reduc-
tion in wound-related complications with preservation of periumbilical per-
forators [121].

In a recent review, Ramirez [110] attributed the success of the procedure
to five principles:

1. Translation of the muscular layer of the abdominal wall to enlarge the
tissue surface area.
2. Separation of muscle layers that allows for maximal individual expan-
sion of each muscle unit.
3. Disconnection of the muscle unit from its fascial sheath envelope, which
restricts horizontal motion and thereby facilitates expansion.
4. Abdominal wall musculature in approximately 70% of its surface is cov-
ering hollow viscus, which is more easily compressed than solid
structures.
5. Bilateral mobilization works more efficiently than unilateral advance-
ment by equilibrating forces of the abdominal wall and centralizing
the midline.

Flap reconstruction

Local and distant flaps have been used to reconstruct hernia defects in
which there is significant absolute loss of domain and in lateral defects
that are not amenable to advancement techniques. Fasciocutaneous flaps
may be used to reconstruct partial-thickness defects of the skin and subcu-
taneous tissues and full-thickness defects when used in combination with
mesh. The thoracoepigastric flap is useful for defects of the upper third of
the abdominal wall. The iliolumbar bipedicled flap based on the superficial
circumflex iliac and lumbar perforators may be used for middle third
Table 3
Results of components separation technique

<table>
<thead>
<tr>
<th>Author/year</th>
<th>n</th>
<th>Mean follow-up (mo)</th>
<th>Recurrence n (%)</th>
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<td>13a</td>
<td>11.5</td>
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<td>1 (9)</td>
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<td>Saulis, et al, 2002 [121]</td>
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<td>3 (8)</td>
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<td>Maas, et al, 2002 [122]</td>
<td>5i</td>
<td>10.6</td>
<td>1 (20)</td>
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<tr>
<td>Levine, et al, 2001 [125]</td>
<td>10k</td>
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<td>0</td>
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<tr>
<td>Shestak, et al, 2000 [109]</td>
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<tr>
<td>Thomas, et al, 1993 [133]</td>
<td>7u</td>
<td>18</td>
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</tr>
</tbody>
</table>

a Component separation (CS) alone = 3, CS + mesh = 5, CS + mesh/Alloderm onlay = 5.
b CS = 23, CS + mesh = 2, CS + surgis = 2.
c CS = 12, CS + subfascial tissue expansion (TE) = 6.
d Abdominal wall partitioning (accordion), staggered release of transversalis/external oblique.
e Modified = internal oblique divided, approximation of medial border of posterior sheath to lateral border of anterior sheath.
f Mesh onlay when necessary.
g CS = 4, CS + TE = 3, CS + mesh onlay = 4; modified = rectus sheath incised anteriorly and/or posteriorly or flipped medially (open book) and transversalis incised.
h Standard CS = 25, modified (periumbilical perforator preservation) = 41.
i Endoscopically assisted.
j CS = 41, CS + fascia lata graft = 6, modified periumbilical perforator preservation.
k CS = 9, CS + mesh onlay = 1, modified (±) internal oblique release.
l CS = 24, CS + Goretex graft = 4, CS + lateral abdominal wall flap = 1.
m CS = 21, CS + mesh = 1.
n ± Mesh.
o CS = 20, CS + mesh = 10, endoscopically assisted = 6, endoscopically assisted + mesh = 1.
p CS = 8, CS + mesh onlay = 12.
q Modified = external oblique transected via separate lateral incision.
r Modified = complete rectus release from anterior and posterior sheaths.
s CS = 20, CS + vicryl onlay = 12, CS + Goretex onlay = 3.
t Modified = internal oblique divided, approximation of medial border of posterior sheath to lateral border of anterior sheath.
u CS = 7, CS + transversalis division = 2.

defects. Lower third defects may be covered with a groin flap, which may reach to the umbilicus [49,127,134–137]. Superficial inferior epigastric artery and deep inferior epigastric artery flaps are useful for lower abdominal and groin defects [134,138–140].

Local muscle flaps are useful for musculofascial defects of the lateral abdominal wall (Fig. 3). The rectus abdominus is a commonly used pedicled flap based on either the superior epigastric or deep inferior epigastric arteries. The flap has a large arc of rotation capable of reaching the entire abdomen [134,135,141,142]. The rectus also may be separated completely from the posterior rectus sheath and turned medially based on a medial row of perforators to reconstruct midline defects. This technique has a reported 13% recurrence rate and a 25% incidence of local wound complications [143].

The external oblique flap based on lateral cutaneous branches of the posterior intercostal arteries has been used as a rotational flap to cover upper abdominal wall defects and as an advancement flap to cover paramedian defects. Spear and colleagues [144] reported a 3% recurrence rate at 12-month follow-up with the use of this flap.

Distant muscle flaps as either free flaps or pedicled flaps have been used for musculofascial defects not amenable to closure with local flaps or advancement techniques [145,146]. The tensor fascia lata has been used successfully as a pedicled and free flap and as an autologous fascial patch. It is based on the ascending branch of the lateral femoral circumflex artery and may be used as a muscle, fascial, or fasciocutaneous flap [145,146]. It has the advantage of being dispensable and has a good arc of rotation. It does not provide for a dynamic reconstruction, and its distal third is unreliable with a 20% to 25% rate of necrosis. Its use is complicated by a 15% to 20% incidence of donor site morbidity, including hematoma, seroma, skin

Fig. 3. Flaps in abdominal wall reconstruction. (A) Tensor fascia lata. (B) Anterolateral thigh. (C) Rectus femoris.
graft loss, and lateral knee instability [145,146]. Recurrence rates are also significant and range from 9% to 42% in the literature [145,146].

The anterolateral thigh flap has been used in the reconstruction of lower abdominal wall defects as either a free or pedicled flap based on septocutaneous perforating branches of the transverse and deep branches of the lateral femoral circumflex artery [147]. With the adjunctive use of mesh, this technique has demonstrated low recurrence rates in small series. It also may be used in combination with the tensor fascia lata to provide a composite graft up to $35 \times 20$ cm in dimension. In small series, the use of this technique has demonstrated no recurrences or flap loss in follow-up up to 24 months [134,147,148].

The rectus femoris muscle has been used successfully as either a free flap with preservation of the motor nerve or as a pedicled flap in reconstruction of the lower two thirds of the abdomen. It is a dispensable muscle with a consistent anatomy. Reports have indicated a weakness in terminal knee extension after muscle harvest, which can be minimized by approximating the vastus medialis and lateralis. It is based on the lateral femoral circumflex artery and has a large arc of superior and contralateral rotation. It can be designed as a musculofascial or musculofasciocutaneous flap based on the location and extent of the defect [149–151]. Electromyographic studies have documented motor function of the transferred muscle.

The latissimus dorsi muscle has been used as a musculocutaneous flap for defects of the upper third of the abdomen. It is based on the thoracodorsal pedicle and can be designed as either a pedicled or a free flap. As a pedicled flap, its arc of rotation is limited to coverage of upper abdominal wall defects. The area of coverage can be increased by including the pregluteal and lumbodorsal fascia. In 1979, Bostwick [152] reported the use of the latissimus as a free flap for abdominal wall reconstruction. In 1998, Ninkovic [153] reported the use of a free, innervated latissimus flap in conjunction with prolene mesh for abdominal wall reconstruction. No flap failures were reported, and electromyographic testing demonstrated reinnervation of the muscle.

The gracilis muscle has been used to reconstruct lower third abdominal wall defects. It is a thin, narrow, dispensable muscle based on the ascending branch of the medial circumflex femoral artery. It can be designed as either a muscular or musculofasciocutaneous flap and is limited to small defects because of its size and the poor reliability of its distal skin [154]. The vastus lateralis can be used as a muscular flap for reconstruction of lower third abdominal wall defects. It does not have a fascial component and its use is primarily reserved for salvage situations [155].

Tissue expansion

Tissue expansion has been used to provide well-vascularized, autologous, innervated tissue for abdominal wall reconstruction. Its use has been
demonstrated in the reconstruction of congenital defects and large hernias [156–161]. Expanders may be placed in either the subcutaneous or intermuscular plane. Placement in the avascular plane between the external and internal oblique muscles allows superficial expansion of the external oblique and deep expansion of the internal oblique-tranversus abdominus musculo-fascial layer while preserving innervation and blood supply. Hobar and colleagues [157,158] demonstrated an approximate doubling of the layers of the anterior abdominal wall with normal function and clinically demonstrated innervated composite reconstruction of defects exceeding 50% of the abdominal surface.

Summary

Despite advances in many fields of surgery, incisional hernias still remain a significant problem. There is a lack of general consensus among surgeons regarding optimal treatment. A surgeon’s approach is often based on tradition rather than clinical evidence. The surgeon’s treatment plan should be comprehensive, with attention focused not merely on restoration of structural continuity. An understanding of the structural and functional anatomy of the abdominal wall and an appreciation of the importance of restoring dynamic function are necessary for the successful reconstruction of the abdominal wall.

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