Evidence-Based Abdominal Wall Reconstruction: The Maxi-Mini Approach

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Summary: Complex abdominal wall reconstruction is a high-risk procedure, but it can be performed safely if a systematic approach is followed. In this article, the authors present their evidence-based technique for abdominal wall reconstruction. This approach aims at reducing rates of complications and hernia recurrence, starting with critical patient selection; preoperative patient optimization; adherence to intraoperative principles including preservation of vascular perforators through maintenance of composite tissue with limited undermining; direct supported mesh reinforcement of midline musculofascial reappraisal; use of percutaneous transfascial suture mesh fixation; careful attention to dead space obliteration in any plane; and aggressive soft-tissue resection of marginal, undermined, or tenuous skin and subcutaneous tissue. Postoperative strategies to decrease complications are also used. The authors’ surgical technique is described in detail, and pilot data are presented to support the authors’ approach. (Plast. Reconstr. Surg. 136: 1312, 2015.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

PREOPERATIVE PATIENT OPTIMIZATION

Proper patient selection and optimization are at least as important as the surgical technique for determining the final outcome. All patients seeking elective abdominal wall reconstruction for incisional hernias are seen at least twice preoperatively by a multidisciplinary team including a reconstructive surgeon, a general surgeon, and, if needed, a smoking-cessation specialist and a pain specialist familiar with neuraxial blocks. An individualized reconstructive plan is formulated and discussed at length with each patient.

Risk stratification is performed to estimate the risk of surgical-site occurrences, such as

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infection, seroma, dehiscence, enterocutaneous fistula, and hernia recurrence. There are several useful grading schemes, including the Ventral Hernia Working Group system, the Ventral Hernia Risk Score, and the Carolinas Equation for Determining Associated Risks. Another useful grading scheme, devised by Kanters et al., stratifies patients into three grades: grade 1 patients are those with no comorbidities and no prior or current wound infection; grade 2 patients are those with comorbidities that increase the risk of surgical-site occurrences and those with a history of wound infection; and grade 3 patients are those with active wound infection or violation of the gastrointestinal tract. This grading scheme is predictive of the risk of surgical-site occurrences (14 percent in grade 1, 27 percent in grade 2, and 46 percent in grade 3), thus guiding the choice of mesh: synthetic mesh is acceptable for grade 1 and most grade 2 patients, but is usually inappropriate in complex grade 2 and grade 3 patients, who may benefit from biological mesh instead, especially if the mesh is intraperitoneal.

The first step of patient optimization is abstention from smoking for at least 4 weeks preoperatively and postoperatively. Tobacco impairs wound healing, decreases blood flow to tissues, and doubles infection risk in abdominal wall reconstruction. Preoperative and postoperative smoking cessation decreases complications. We do not perform elective surgery on active smokers, and patients with a history of smoking are tested within 2 weeks of surgery for nicotine metabolites. If test results are positive, surgery is postponed.

The second step is tight glucose control in patients with diabetes mellitus. Preoperative and postoperative hyperglycemia increases surgical-site infections and dehiscence. We defer elective abdominal wall reconstruction if the hemoglobin A1c value is above 7.5 percent, and we maintain postoperative blood glucose levels below 200 mg/dl to reduce wound complications.

The third step is preoperative and postoperative nutritional optimization. Protein malnutrition increases the risk of surgical-site occurrences and death. Nutritional optimization decreases surgical infectious and non-infectious complications, including sepsis and death. We defer elective abdominal wall reconstruction if the albumin value is below 3.0 g/dl, or if the prealbumin value is below 15 mg/dl or has a downward trend.

Patients undergoing abdominal wall reconstruction are at high risk for venous thromboembolism, with Caprini scores commonly above 7 because of immobility, increased intraabdominal pressure, and venous stasis. In addition, many are sedentary at baseline because of generalized deconditioning, and should be screened for venous thromboembolism preoperatively using lower extremity duplex Doppler examination. In patients on chronic anticoagulation, warfarin is discontinued 5 days preoperatively and therapeutic enoxaparin is administered until the international normalized ratio is 1.6 or lower.

Obesity increases surgical-site occurrences and other major complications, including death. Using morphometric measurements based on computed tomography, several groups found higher rates of surgical-site infections with increasing subcutaneous fat, and higher mortality with decreasing lean core muscle. We perform elective abdominal wall reconstruction in patients with a body mass index below 40, but have a “yellow flag” between 40 and 42 and a “red flag” above 42. Those patients are asked to lose weight first, and are often referred for bariatric surgery before abdominal wall reconstruction. This is based on data that show 2-year hernia recurrence rates of 8 percent in those with a body mass index between 30 to 39, 25 percent in those with a body mass index between 40 and 49, and 45 percent in those with a body mass index greater than 50.

In patients with skin graft on viscera, we defer hernia repair until the formation of a “glide plane,” confirmed using a pinch test (i.e., when pinching the graft between one’s thumb and index finger, and rolling the index on the thumb, the graft glides easily on itself). (See Video, Supplemental Digital Content 1, which demonstrates the glide plane between the skin graft and the underlying viscera, confirmed using a pinch test, http://links.lww.com/PRS/B495.)

Video 1. Supplemental Digital Content 1 demonstrates the glide plane between the skin graft and the underlying viscera, confirmed using a pinch test, http://links.lww.com/PRS/B495.
underlying viscera, confirmed using a pinch test, http://links.lww.com/PRS/B495.) This facilitates abdominal reentry and decreases the risk of iatrogenic deserosalization and enterotomy.

**SURGICAL PRINCIPLES**

The maxi-mini approach relies on five evidence-based principles: (1) minimizing perforator disruption, (2) direct supported mesh reinforcement of primary fascial reapproximation, (3) criterion standard transfascial suture mesh fixation, (4) dead space obliteration, and (5) aggressive resection of marginal soft tissue.

**Minimizing Perforator Disruption**

Blood supply to the abdominal skin is derived mostly from perforators from the deep epigastric vessels, the largest of which are within 3 cm of the umbilicus. Traditional component separation involves wide undermining laterally, with sacrifice of most perforators, decreasing blood supply to the midline skin, and increasing the risk of surgical-site occurrences 2.3-fold when more than 2 cm of undermining is performed.

The ultimate perforator-sparing technique is laparoscopic hernia repair, in which no skin flaps are elevated, resulting in low rates of surgical-site occurrences. A perforator-sparing endoscopic technique for open hernia repair was initially described by Lowe et al. in 2000. Another technique was subsequently popularized in 2002 by Saulis and Dumanian, who accessed the linea semilunaris using two subcutaneous tunnels. Another technique was devised by Butler and Campbell in 2011, using one subcutaneous tunnel just below the costal margin to reach the linea semilunaris. These minimally invasive techniques for open hernia repair have achieved fewer wound complications than traditional component separation, and their surgical-site occurrence rate has approached that of laparoscopic repair.

**Mesh Reinforcement of Primary Fascial Reapproximation**

The major goal of abdominal wall reconstruction is the prevention of hernia recurrence, through a strong, durable repair. There are two prerequisites to this end: (1) most repairs should be reinforced with mesh, and (2) musculofascial reapproximation should be obtained.

In a randomized controlled trial, Luijendijk et al. compared suture-only fascial repair to additional reinforcement using mesh. Mesh reinforcement decreased hernia recurrence by half. Other studies have confirmed that mesh should be used regardless of defect size.

Another prerequisite to durability is provision of a dynamic abdominal wall, through primary musculofascial reapproximation, which resists stress and strain better than adynamic repairs, and increases truncal flexion force. Although most laparoscopic repairs consist of mesh interposition without fascial reapproximation, such “bridged” repairs have a much higher risk of recurrence and bulge than reinforced musculofascial reapproximation. Reapproximation of well-vascularized, well-innervated muscle and fascia in the midline minimizes the risk of muscle atrophy, bulge, and hernia. If the gap if too large for fascial reapproximation, defect size reduction should be performed by component separation to decrease recurrence.

For fascial repair, braided sutures have higher rates of surgical-site infection than monofilament, and slowly absorbable sutures have fewer recurrences than rapidly absorbable sutures. In addition, nonabsorbable sutures result in more suture sinuses. Large bites (>10 mm from the wound edge) cause fascial ischemia, a higher surgical-site infection rate, and a higher recurrence rate than small bites (5 to 8 mm). Moreover, continuous sutures result in fewer infections and hernias than interrupted sutures. Based on these studies, our sutures of choice for fascial repair are slowly absorbable monofilament, such as polyglyconate (Maxon; Covidien, Mansfield, Mass.) and polydioxanone (PDS II; Ethicon, Inc., Somerville, N.J.), used in running fashion, with bites no farther than 8 mm from the fascial edge.

**Criterion-Standard Transfascial Suture Mesh Fixation**

Existing evidence demonstrates that the lowest rates of surgical-site occurrences and recurrence are obtained when mesh is placed in retrorectus or underlay positions. Mesh fixation in those two positions while ensuring adequate overlap between mesh and fascia can be technically difficult. Our preferred technique for mesh fixation was adapted from laparoscopic hernia repair, using transfascial sutures, which cause less pain and less bowel injury compared with spiral tacks, and have low recurrence rates. We therefore consider retrorectus, preperitoneal, or intraperitoneal underlay placement of mesh with wide overlap (4 to 5 cm in all directions), and percutaneous-transfascial suture fixation, to be the criterion standard. Butler and Campbell have previously described the use of transfascial...
sutures in open hernia repair. We have borrowed from this technique, but have placed the transfascial sutures more laterally, beyond the semilunar line, to achieve wide overlap between mesh and fascia, which reduces the potential for devascularization of the rectus muscle in the sutures. This was made possible by the use of the laparoscopic Carter-Thomason suture passer (CooperSurgical, Inc., Trumbull, Conn.), as described later in this article.

Dead Space Obliteration

Fluid must not be allowed to accumulate between mesh and fascia, or under any skin flaps, as it may cause seromas or abscesses (Fig. 1). Many synthetic meshes are porous and allow fluid egress. However, biological meshes are impervious to fluid and susceptible to fluid collection. Moreover, close apposition of biological mesh to well-vascularized tissue is essential for mesh revascularization.

Traditional component separation creates large potential spaces susceptible to fluid accumulation. Minimally invasive modifications involve less skin elevation, but still create some potential spaces between mesh and fascia, in the tunnels over the external oblique aponeurotomies, and in the midline subcutaneous plane.

Butler and Campbell have demonstrated excellent outcomes with the use of closed-suction drains and quilting sutures between mesh and fascia and in the subcutaneous plane. We have previously described the use of progressive tension sutures, rather than quilting sutures, in abdominal wall reconstruction to prevent subcutaneous fluid collections. Progressive tension sutures were adapted from cosmetic surgery, namely, “drainless abdominoplasty.” Later in this article, we describe a new technique that we have devised and termed central suspension sutures, aimed at preventing subrectus fluid collections (Fig. 1) and at ensuring apposition of the mesh against the overlying reapproximated musculofascia.

Aggressive Resection of Marginal Soft Tissue

With limited skin flap undermining, most perforators to the skin are preserved. Nevertheless, in patients with multiple prior operations, perfusion to the midline may be marginal. Any tenuous skin in the midline must be aggressively resected, to reduce surgical-site occurrences, effectively constituting a vertical panniculectomy. In addition, in patients with a large pannus, a horizontal or fleur-de-lis panniculectomy is performed to eliminate any skin with poor perfusion. Layered closure should be performed to reduce tension on the skin.65–67

**SURGICAL TECHNIQUE: THE MAXI-MINI APPROACH**

Any skin graft on viscera is resected, if applicable, and then the intraabdominal portion of the procedure is completed, including lysis of adhesions with dissection into the space of Retzius and division of the falciform ligament, if needed. Care is taken to perform as minimal undermining of the skin as possible (<2 cm), just to expose the medial rectus fascia for later suture reapproximation.

The baseline peak and plateau inspiratory pressures of the patient are recorded. The defect is analyzed. If the fascia can be reapproximated, we plan for primary fascial repair with placement of mesh in a retrorectus position, or as a wide intraperitoneal underlay if already intraabdominal (fistula/ostomy takedown, full-thickness oncologic defect). If the fascia cannot be easily reapproximated, unilateral or bilateral minimally invasive component separation is performed, similar to the description by Butler and Campbell. A 5- to 6-cm-wide subcutaneous tunnel is dissected 5 cm below the costal margin to reach the linea semilunaris (Fig. 2), which is readily identified by pushing the rectus muscle against it to accentuate its indentation (Fig. 3). Limited subcutaneous tunnels are then dissected superiorly over the costal margin and inferiorly to the inguinal ligament using a Deaver retractor and a spreader-dissector. An external oblique aponeurotomy is performed 2 cm lateral to the linea semilunaris, and a plastic, nonconducting Yankauer suction tip (without applied suction) is used to enter the avascular plane between the external and internal oblique...
muscles (Fig. 4). It is swept medially to the linea semilunaris to confirm proper position, and electrocautery is used to perform the aponeurotomy directly on top of the suction tip. (See Video, Supplemental Digital Content 2, which demonstrates a minimally invasive external oblique aponeurotomy through a small subcutaneous tunnel. After the plane deep to the external oblique is developed bluntly using the Yankauer suction, electrocautery is used to incise the external oblique aponeurosis directly on top of the Yankauer suction, approximately 2 cm lateral to the linea semilunaris, http://links.lww.com/PRS/B496.) This is extended approximately 6 cm above the costal margin, canting medially to facilitate epigastric rotation-advancement.

The mesh is then prepared for implantation. No. 1 polyglyconate sutures are preplaced into the mesh in a horizontal mattress U-stitch fashion, taking 1-cm-wide bites located 1 cm from the edge of the mesh, and spaced at 1-cm intervals (Fig. 5). One of four types of mesh is usually used: if retrorectus repair is performed, a self-adhering polyester-based mesh is selected (ProGrip; Covidien, Mansfield, Mass.) without need for sutures; if posterior component separation is performed with posterior fascial reapproximation, a medium-weight uncoated polypropylene mesh is selected; if a wide intraperitoneal underlay technique is used, a skirted barrier-coated synthetic mesh is chosen (Parietex; Covidien), with sutures placed...
at the junction of the skirted and flat portions; and if there are significant comorbidities, biological mesh (non–cross-linked porcine acellular dermal matrix) is used.\(^6\)

A laparoscopic Carter-Thomason suture passer is used to pass the sutures in a percutaneous-transfascial fashion. (See Video, Supplemental Digital Content 3, which demonstrates the placement of the percutaneous-transfascial mesh fixation sutures using the laparoscopic Carter-Thomason suture passer, http://links.lww.com/PRS/B497.) The sutures are placed lateral to the semilunar line, to avoid devascularization of the rectus abdominis muscle. A no. 11 blade is used to make 2-mm stab incisions at the anticipated suture exit sites. Under direct vision, the suture passer is inserted into each stab incision through all layers of the abdominal wall, piercing the peritoneum at least 4 to 5 cm from the hernia edge. The two tails of each suture are retrieved through separate peritoneal punctures (Fig. 6). The transfascial sutures are then tied, sliding the knot through the stab incision onto the underlying fascia (Fig. 7). Redundancies in the mesh indicate that the sutures were not placed far enough from the hernia edges.

With a protective malleable retractor in place, four to six central suspension sutures are placed using no. 1 polyglyconate sutures. These are three-point sutures, taking a bite from one edge of the fascia lateral to the anticipated fascial closing suture, then full-thickness through the midline of the mesh, then through the other edge of the fascia, again lateral to the anticipated fascial closing suture (Fig. 8). Those sutures are tagged with hemostats. A 15-French drain is placed between the mesh and the fascia, draining both sides through a question mark configuration (Fig. 9).

The fascia is then closed, using a looped running no. 0 polyglyconate or polydioxanone suture (Fig. 10). The preplaced central suspension
sutures are then tied over the closed midline fascia to appose the mesh to the undersurface of the musculofascia, obliterate dead space, and provide direct mesh support to the abdominal wall. (See Video, Supplemental Digital Content 4, which demonstrates the tying of the preplaced central suspension sutures. This is performed after closing the fascia on top of the mesh. The central suspension sutures ensure close apposition of the

Fig. 7. After the percutaneous-transfascial sutures are tied, the mesh should be flat and taut. The sutures create puckers at the skin.

Fig. 8. Central suspension sutures are placed from one side of the fascia to the other, passing through the midline of the mesh. Those sutures should be lateral to the anticipated fascial closing suture.

Fig. 9. A 15-French drain is placed in a question mark configuration between the intraperitoneal mesh and the posterior rectus sheath to drain both sides.

Fig. 10. The fascia is closed on top of the mesh using a running polyglyconate suture, whereas the central suspension sutures are still tagged with hemostats and untied.
mesh against the underside of the closed fascia, http://links.lww.com/PRS/B498. Unlike previously described techniques for anchoring mesh to the underside of the fascia, the central suspension sutures are preplaced, take full-thickness bites in the midline of the mesh, and are tied after the midline fascia is closed.

The inspiratory pressure is checked again. The patient may be at risk for abdominal compartment syndrome if the peak airway pressure increases by 12 mmHg or more from baseline, or if the plateau pressure increases by 6 cmH$_2$O (4.4 mmHg) or more.

Any tenuous midline skin is resected. A 19-French drain is placed in the subcutaneous space. If needed, progressive tension sutures are used to tack any minor skin flaps to underlying fascia using 2-0 braided polyglactin, advancing the skin toward the midline with each bite to reduce tension. (See Video, Supplemental Digital Content 5, which demonstrates the placement of progressive tension sutures to obliterate dead space between the skin flap and the rectus fascia, http://links.lww.com/PRS/B499.)

Meticulous layered closure is performed (Fig. 11). Interrupted 2-0 polyglactin sutures are placed in the Scarpa layer, incorporating the rectus fascia in three-point fashion to obliterate dead space. Buried 3-0 poliglecaprone sutures are placed in the deep dermis, making sure to evert skin to accelerate dermal healing. Then, 4-0 poliglecaprone is run in a subcuticular fashion, followed by 2-octyl-cyanoacrylate glue as an impervious dressing. The skin at the sites of the percutaneous-transfascial sutures is released from the underlying subcutaneous tissue to eliminate any puckering. (See Video, Supplemental Digital Content 6, which demonstrates the puckers from the percutaneous-transfascial sutures, which are released using a hemostat. The skin is elevated off the underlying subcutaneous tissue, http://links.lww.com/PRS/B500.) Drain sites are dressed with chlorhexidine-impregnated patches to minimize ascending contamination. An abdominal binder is applied to decrease postoperative pain.

Postoperative Management

Adequate postoperative pain control is essential, as uncontrolled pain impairs immune function and delays wound healing.
function and increases infection risk. Para-
vertebral, thoracic epidural, and transversus
abdominis plane blocks are often used, because
they provide excellent pain control, accelerate
time to ambulation, decrease nausea, and
decrease sympathetic-mediated vasodilation and
hypotension.

Patients are started on incentive spirometry in
the recovery unit to decrease pulmonary compli-
cations. Venous thromboembolism prophylaxis
is multimodal, consisting of sequential compres-
sion devices worn at all times when sedentary, enoxaparin
daily starting 6 to 8 hours postoperatively
during discharge, and ambulation five times
daily starting the evening of surgery. In patients
with no signs of infection, antibiotics are provided
for only 24 hours perioperatively. Closed-suction
drains are stripped frequently to maintain a high
pressure gradient, with bulbs compressed side-
to-side and emptied when 50 percent full.

As soon as patients can tolerate oral intake,
you are started on a high-protein diet to reduce
wound healing problems and major complica-
tions. If they cannot tolerate oral intake after 5
to 6 days, parenteral nutrition is considered until
bowel function returns.

### PILOT CLINICAL RESULTS

The maxi-mini approach using all the above
principles and techniques has been applied in
44 consecutive patients with complex abdominal
wall defects. The average follow-up was 335 days,
with 18 patients having follow-up greater than
1 year. In addition, 27.3 percent of the patients
were Kanters grade 1, 61.4 percent were grade 2,
and 11.3 percent were grade 3. Four patients did
not undergo mesh implantation, and 40 patients
did. Mesh was placed as a wide intraperitoneal
underlay (50 percent), retrorectus (27 percent),
or interposition bridge (23 percent). Among
patients with mesh, biological mesh was used in
47.8 percent (including all patients with Kanters
grade 3, and over half of the patients with Kant-
ers grade 2), and synthetic mesh was used in 52.2
percent; 54.5 percent of patients required compo-
nent separation for fascial reapproximation and
45.5 percent did not.

The 30-day surgical-site occurrence rate was
18.2 percent. The greatest predictor of surgical-
site occurrences was the Kanters grade (8.3 per-
cent in grade 1, 14.8 percent in grade 2, and 60.0
percent in grade 3) (Table 1). Our rate of surgi-
cal-site occurrences is lower than that published
by Kanters et al. (18.2 percent versus 34.1 per-
cent; \( p = 0.03 \)), and similar to that published by
Butler and Campbell (18.2 percent versus 26.3
percent; \( p = 0.37 \)).

The overall hernia recurrence rate was 4.5
percent. Component separation, mesh use, mesh
position, mesh type, and Kanters grade were not
found to be predictive of, or protective from,
recurrence.

### CONCLUSIONS

Starting with careful patient selection and
optimization, and using evidence-based principles
of perforator preservation, mesh reinforcement
of primary fascial repair, criterion-standard mesh
fixation, obliteration of dead space, and resection

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**Table 1. Pilot Clinical Data for Patients Undergoing Open Hernia Repair Using the Maxi-Mini Approach**

<table>
<thead>
<tr>
<th>Kanters Grade*</th>
<th>No. of Patients</th>
<th>Abscess (%)</th>
<th>Cellulitis (%)</th>
<th>Delayed Wound Healing (%)</th>
<th>EC Fistula (%)</th>
<th>Seroma</th>
<th>All SSO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>8.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8.3</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>7.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14.8</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>44</td>
<td>9.1</td>
<td>2.3</td>
<td>4.5</td>
<td>2.3</td>
<td>0</td>
<td>18.2</td>
</tr>
</tbody>
</table>

EC, enterocutaneous; SSO, surgical-site occurrences.
of marginal tissue, our approach to complex abdominal wall reconstruction is reliable and reproducible and results in low rates of surgical-site occurrences. A prospective study evaluating the long-term effects of our approach on surgical-site occurrences and hernia recurrence is currently ongoing.

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