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 reapproximation; 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.

Complex abdominal hernias constitute a formidable challenge. They often coexist with comorbidities, such as obesity, smoking, diabetes, and malnutrition, that lower the surgical success rate.[1,2] Therefore, careful patient selection, patient optimization, and the use of evidence-based techniques are essential to achieve the best possible outcome during the initial attempt at definitive abdominal wall reconstruction.[3]

The senior author (J.E.J.) has developed a reliable approach to abdominal wall reconstruction, which borrows evidence-based techniques from both open (maximally invasive) and laparoscopic (minimally invasive) hernia repair, and has thus been termed the "maxi-mini approach." The approach aims to combine the durability of open hernia repairs with the low rates of wound healing complications of laparoscopic hernia repairs.[4] In this article, we describe our preoperative patient optimization, followed by a review of the evidence behind the five principles on which the maxi-mini approach is based. We then present a step-by-step description of the surgical technique, followed by our postoperative strategies. Pilot clinical data are presented.

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Received for publication February 23, 2015; accepted June 9, 2015.

DOI: 10.1097/PRS.0000000000001831

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

Disclosure: *Dr. Janis is a consultant for LifeCell, has received a prior honorarium from Pacira and Bard, and receives royalties from Quality Medical Publishing/CRC Press. Dr. Khansa has no relevant financial disclosures.*

Supplemental digital content is available for this article. Direct URL citations appear in the text; simply type the URL address into any Web browser to access this content. Clickable links to the material are provided in the HTML text of this article on the *Journal*'s Web site (www.PRSJournal.com).

infection, seroma, dehiscence, enterocutaneous fistula, and hernia recurrence. There are several useful grading schemes, including the Ventral Hernia Working Group system,[5] the Ventral Hernia Risk Score,[6] and the Carolinas Equation for Determining Associated Risks.[7] Another useful grading scheme, devised by Kanters et al.,[8] 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,[9] and doubles infection risk in abdominal wall reconstruction.[1] Preoperative and postoperative smoking cessation decreases complications.[10] 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.[11–13] 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.[14]

The third step is preoperative and postoperative nutritional optimization. Protein malnutrition increases the risk of surgical-site occurrences[2] and death.[15,16] Nutritional optimization decreases surgical infectious[17] and noninfectious complications,[18] including sepsis and death.[19] 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[20] 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.[21] Using morphometric measurements based on computed tomography, several groups found higher rates of surgical-site infections with increasing subcutaneous fat,[22] and higher mortality with decreasing lean core muscle.[23] 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.[24]

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

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.[25,26] Traditional component separation involves wide undermining laterally, with sacrifice of most perforators,[27] 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.[5]

The ultimate perforator-sparing technique is laparoscopic hernia repair, in which no skin flaps are elevated, resulting in low rates of surgical-site occurrences.[4,28–32] A perforator-sparing endoscopic technique for open hernia repair was initially described by Lowe et al. in 2000.[33] Another technique was subsequently popularized in 2002 by Saulis and Dumanian,[34] who accessed the linea semilunaris using two subcutaneous tunnels. Another technique was devised by Butler and Campbell in 2011,[35] 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,[36] 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.[37] Mesh reinforcement decreased hernia recurrence by half. Other studies have confirmed that mesh should be used regardless of defect size.[38–41]

Another prerequisite to durability is provision of a dynamic abdominal wall, through primary musculofascial reapproximation, which resists stress and strain better than adynamic repairs,[42] and increases truncal flexion force.[43] Although most laparoscopic repairs consist of mesh interposition without fascial reapproximation,[44] such "bridged" repairs have a much higher risk of recurrence and bulge than reinforced musculofascial reapproximation.[4,45–49] 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.[50]

For fascial repair, braided sutures have higher rates of surgical-site infection than monofilament,[51,52] and slowly absorbable sutures have fewer recurrences than rapidly absorbable sutures.[53] 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).[54] Moreover, continuous sutures result in fewer infections and hernias than interrupted sutures.[55] Based on those 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.[48,56] 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[57–60] and less bowel injury compared with spiral tacks,[61] and have low recurrence rates.[62] 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.[35] 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.[63] Minimally invasive modifications involve less skin elevation,[33–35] 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.[35] We have previously described the use of progressive tension sutures, rather than quilting sutures, in abdominal wall reconstruction to prevent subcutaneous fluid collections.[59] Progressive tension sutures were adapted from cosmetic surgery, namely, "drainless abdominoplasty."[64] 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.

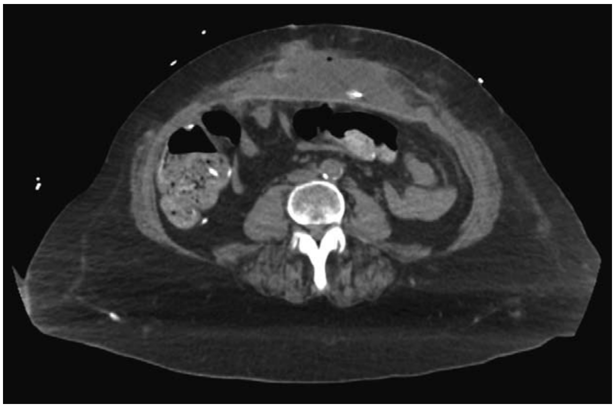

Fig. 1. Abscess formation between an intraperitoneal underlay biological mesh and the posterior rectus sheath. This complication gave rise to the idea of the central suspension sutures.

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.[35] 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

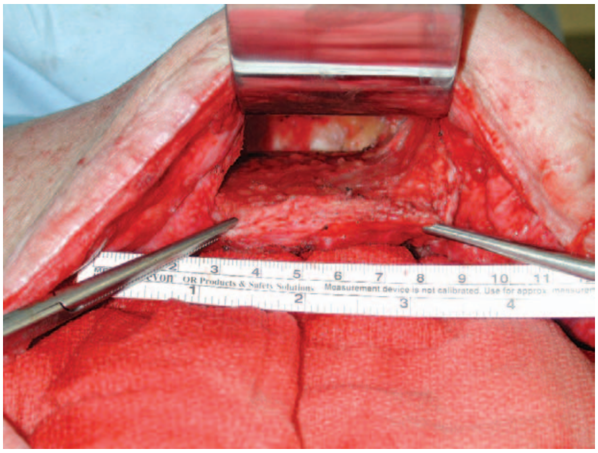

Fig. 2. Subcutaneous access tunnel for minimally invasive component separation.

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

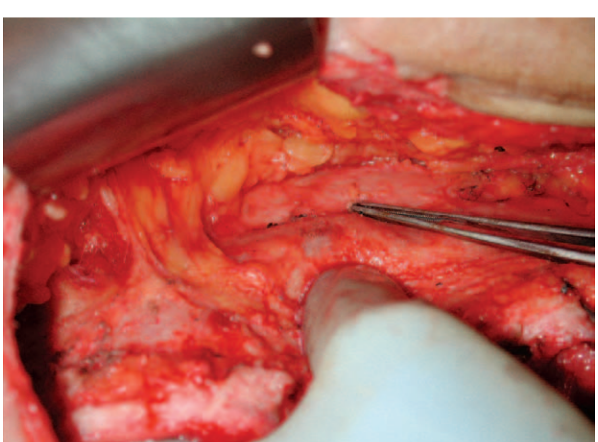

Fig. 3. Identification of the linea semilunaris through the limited subcutaneous tunnel, by means of the "tube of toothpaste" technique: the rectus muscle is pushed laterally against the linea semilunaris, thus accentuating its indentation.

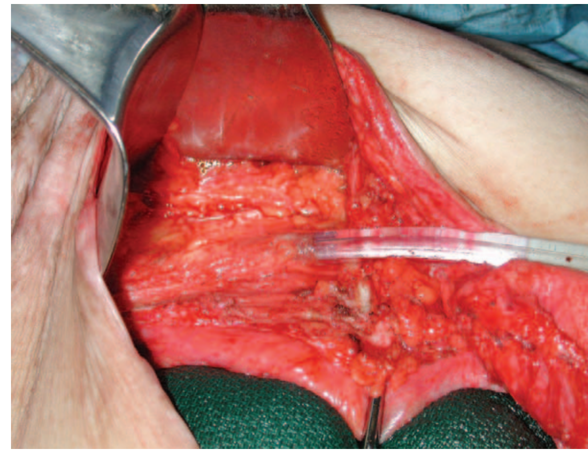

Fig. 4. After a small external oblique aponeurotomy is started approximately 2 cm lateral to the linea semilunaris, a Yankauer suction tip is inserted into the plane deep to the external oblique and used to bluntly develop that plane. Electrocautery is then used directly on top of the nonconducting suction tip to complete the aponeurotomy.

Video 2. Supplemental Digital Content 2 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***.

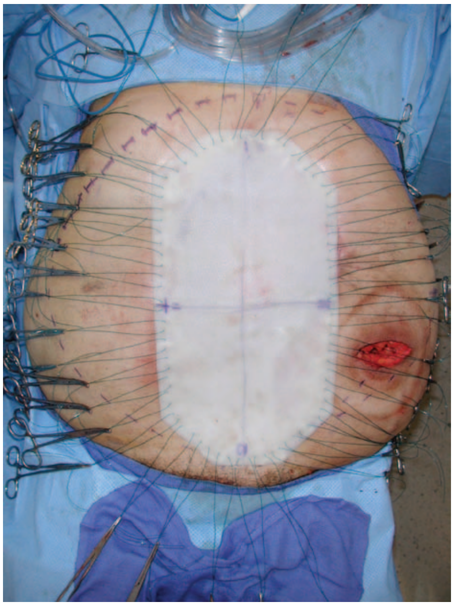

Fig. 5. Polyglyconate sutures are preplaced into the porcine acellular dermal matrix, in preparation for passing them in a percutaneous-transfascial fashion using a laparoscopic Carter-Thomason suture passer.

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

Video 3. Supplemental Digital Content 3 demonstrates the placement of the percutaneous-transfascial mesh fixation sutures using the laparoscopic Carter-Thomason suture passer, ***http://links.lww.com/PRS/B497***.

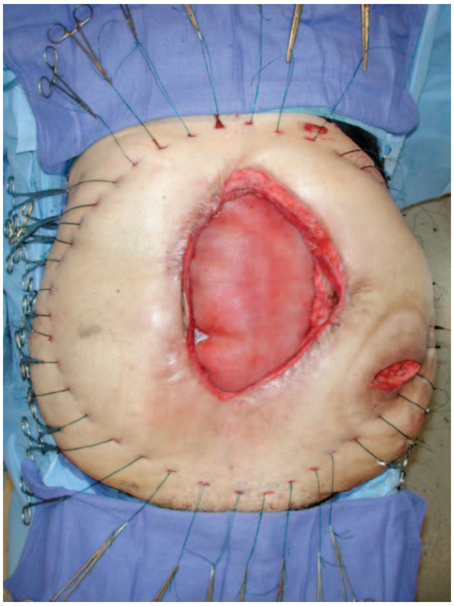

Fig. 6. The percutaneous-transfascial sutures are tagged with hemostats before being tied.

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

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

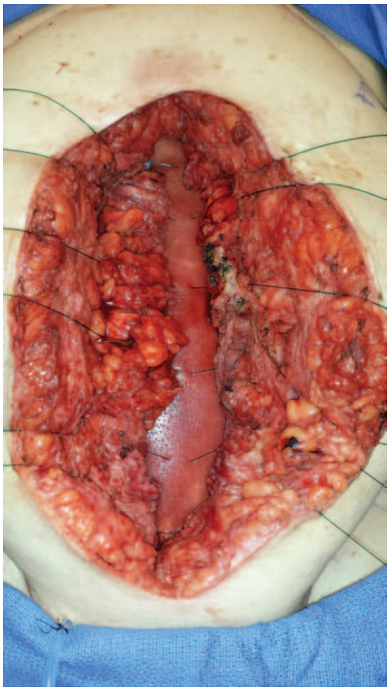

Fig. 8. Central suspension sutures are placed from one side of the fascia to the other, passing through the midline of the mesh. Those sutures should be lateral to the anticipated fascial closing suture.

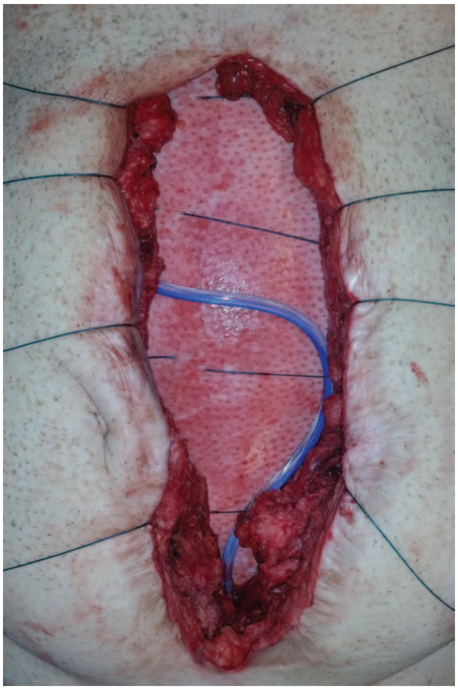

Fig. 9. A 15-French drain is placed in a question mark configuration between the intraperitoneal mesh and the posterior rectus sheath to drain both sides.

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. 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.

Video 4. Supplemental Digital Content 4 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 mesh against the underside of the closed fascia, ***http://links.lww.com/PRS/B498***.

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,[35] 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,[35] or if the plateau pressure increases by 6 cmH_2O (4.4 mmHg) or more.[68]

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.[69] (**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.[65] Then, 4-0 poliglecaprone is run in a subcuticular fashion, followed by 2-octyl-cyanoacrylate glue as an impervious dressing.[66,67] 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.[70] An abdominal binder is applied to decrease postoperative pain.[71]

Video 5. Supplemental Digital Content 5 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***.

Postoperative Management

Adequate postoperative pain control is essential, as uncontrolled pain impairs immune

Fig. 11. Appearance of the patient after excision of marginal midline skin and final complex closure. The skin at the old colostomy site is left open to heal by secondary intention with packing.

Video 6. Supplemental Digital Content 6 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***.

function[72] and increases infection risk.[73] Paravertebral, thoracic epidural, and transversus abdominis plane blocks are often used, because they provide excellent pain control,[74] accelerate time to ambulation, decrease nausea, and decrease sympathetic-mediated vasodilation and hypotension.[75,76]

Patients are started on incentive spirometry in the recovery unit to decrease pulmonary complications.[77] Venous thromboembolism prophylaxis is multimodal, consisting of sequential compression devices worn at all times when sedentary,[78] enoxaparin daily starting 6 to 8 hours postoperatively until discharge,[79] 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,[80] with bulbs compressed side-to-side and emptied when 50 percent full.[81]

As soon as patients can tolerate oral intake, they are started on a high-protein diet to reduce wound healing problems and major complications.[82,83] 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 Kanters grade 2), and synthetic mesh was used in 52.2 percent; 54.5 percent of patients required component 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 percent in grade 1, 14.8 percent in grade 2, and 60.0 percent in grade 3) (Table 1). Our rate of surgical-site occurrences is lower than that published by Kanters et al.[8] (18.2 percent versus 34.1 percent; $p = 0.03$), and similar to that published by Butler and Campbell[35] (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

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

		30-Day Complications					
Kanters Grade*	No. of Patients	Abscess (%)	Cellulitis (%)	Delayed Wound Healing (%)	EC Fistula (%)	Seroma	All SSO (%)
1	12	8.3	0	0	0	0	8.3
2	27	7.4	0	7.4	0	0	14.8
3	5	20	20	0	20	0	60
Total	44	9.1	2.3	4.5	2.3	0	18.2

EC, enterocutaneous; SSO, surgical-site occurrences.
*Kanters AE, Krpata DM, Blatnik JA, Novitsky YM, Rosen MJ. Modified hernia grading scale to stratify surgical site occurrence after open ventral hernia repairs. *J Am Coll Surg.* 2012;215:787–793.

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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REFERENCES

1. Finan KR, Vick CC, Kiefe CI, Neumayer L, Hawn MT. Predictors of wound infection in ventral hernia repair. *Am J Surg.* 2005;190:676–681.
2. Dunne JR, Malone DL, Tracy JK, Napolitano LM. Abdominal wall hernias: Risk factors for infection and resource utilization. *J Surg Res.* 2003;111:78–84.
3. Flum DR, Horvath K, Koepsell T. Have outcomes of incisional hernia repair improved with time? A population-based analysis. *Ann Surg.* 2003;237:129–135.
4. Liang MK, Berger RL, Li LT, Davila JA, Hicks SC, Kao LS. Outcomes of laparoscopic vs open repair of primary ventral hernias. *JAMA Surg.* 2013;148:1043–1048.
5. Breuing K, Butler CE, Ferzoco S, et al. Incisional ventral hernias: Review of the literature and recommendations regarding the grading and technique of repair. *Surgery* 2010;148:544–558.
6. Berger RL, Li LT, Liang MK, et al. Development and validation of a risk-stratification score for surgical site occurrence and surgical site infection after open ventral hernia repair. *J Am Coll Surg.* 2013;217:974–982.
7. Ramshaw BJ. 16(th) Annual Hernia Repair, Las Vegas. *Hernia* 2014;18:931–933.
8. Kanters AE, Krpata DM, Blatnik JA, Novitsky YM, Rosen MJ. Modified hernia grading scale to stratify surgical site occurrence after open ventral hernia repairs. *J Am Coll Surg.* 2012;215:787–793.
9. Sørensen LT. Wound healing and infection in surgery: The pathophysiological impact of smoking, smoking cessation, and nicotine replacement therapy: A systematic review. *Ann Surg.* 2012;255:1069–1079.
10. Møller AM, Villebro N, Pedersen T, Tønnesen H. Effect of preoperative smoking intervention on postoperative complications: A randomised clinical trial. *Lancet* 2002;359:114–117.
11. Latham R, Lancaster AD, Covington JF, Pirolo JS, Thomas CS Jr. The association of diabetes and glucose control with surgical-site infections among cardiothoracic surgery patients. *Infect Control Hosp Epidemiol.* 2001;22:607–612.
12. Endara M, Masden D, Goldstein J, Gondek S, Steinberg J, Attinger C. The role of chronic and perioperative glucose management in high-risk surgical closures: A case for tighter glycemic control. *Plast Reconstr Surg.* 2013;132:996–1004.
13. Ramos M, Khalpey Z, Lipsitz S, et al. Relationship of perioperative hyperglycemia and postoperative infections in patients who undergo general and vascular surgery. *Ann Surg.* 2008;248:585–591.
14. Patel KL. Impact of tight glucose control on postoperative infection rates and wound healing in cardiac surgery patients. *J Wound Ostomy Continence Nurs.* 2008;35:397–404; quiz 405.
15. Khuri SF, Daley J, Henderson W, et al. Risk adjustment of the postoperative mortality rate for the comparative assessment of the quality of surgical care: Results of the National Veterans Affairs Surgical Risk Study. *J Am Coll Surg.* 1997;185:315–327.
16. Kudsk KA, Tolley EA, DeWitt RC, et al. Preoperative albumin and surgical site identify surgical risk for major postoperative complications. *JPEN J Parenter Enteral Nutr.* 2003;27:1–9.
17. Jie B, Jiang ZM, Nolan MT, et al. Impact of nutritional support on clinical outcome in patients at nutritional risk: A multicenter, prospective cohort study in Baltimore and Beijing teaching hospitals. *Nutrition* 2010;26:1088–1093.
18. The Veterans Affairs Total Parenteral Nutrition Cooperative Study Group. Perioperative total parenteral nutrition in surgical patients. *N Engl J Med.* 1991;325:525–532.
19. Mullen JL, Buzby GP, Matthews DC, Smale BF, Rosato EF. Reduction of operative morbidity and mortality by combined preoperative and postoperative nutritional support. *Ann Surg.* 1980;192:604–613.
20. Pannucci CJ, Dreszer G, Wilkins E, et al. Postoperative enoxaparin prevents symptomatic venous thromboembolism in high-risk plastic surgery patients. *Plast Reconstr Surg* 2011;128:1093–1103.
21. Engelman DT, Adams DH, Rizzo RJ, et al. Impact of body mass index and albumin on morbidity and mortality after cardiac surgery. *J Thorac Cardiovasc Surg.* 1999;118:866–873.
22. Levi B, Zhang P, Kuzon WM. Use of morphometric assessment of body composition to quantify risk of surgical-site infection in patients undergoing component separation ventral hernia repair. *Plast Reconstr Surg.* 2014;133:559e–566e.
23. Englesbe MJ, Lee JS, He K, et al. Analytic morphomics, core muscle size, and surgical outcomes. *Ann Surg.* 2012;256:255–261.
24. Vargo DJ. Personal communication. University of Utah Health Care. 2011.
25. Patel KM, Bhanot P. Complications of acellular dermal matrices in abdominal wall reconstruction. *Plast Reconstr Surg.* 2012;130(Suppl 2):216S–224S.
26. Schaverien M, Saint-Cyr M, Arbique G, Brown SA. Arterial and venous anatomies of the deep inferior epigastric perforator and superficial inferior epigastric artery flaps. *Plast Reconstr Surg.* 2008;121:1909–1919.
27. Ramirez OM, Ruas E, Dellon AL. “Components separation” method for closure of abdominal-wall defects: An anatomic and clinical study. *Plast Reconstr Surg.* 1990;86:519–526.
28. LeBlanc KA. Incisional hernia repair: Laparoscopic techniques. *World J Surg.* 2005;29:1073–1079.
29. Sauerland S, Walgenbach M, Habermalz B, Seiler CM, Miserez M. Laparoscopic versus open surgical techniques for ventral or incisional hernia repair. *Cochrane Database Syst Rev.* 2011;3:CD007781.
30. Wright BE, Beckerman J, Cohen M, Cumming JK, Rodriguez JL. Is laparoscopic umbilical hernia repair with mesh a reasonable alternative to conventional repair? *Am J Surg.* 2002;184:505–508; discussion 508.
31. Colon MJ, Kitamura R, Telem DA, Nguyen S, Divino CM. Laparoscopic umbilical hernia repair is the preferred approach in obese patients. *Am J Surg.* 2013;205:231–236.
32. Othman IH, Metwally YH, Bakr IS, Amer YA, Gaber MB, Elgohary SA. Comparative study between laparoscopic and open repair of paraumbilical hernia. *J Egypt Soc Parasitol.* 2012;42:175–182.
33. Lowe JB, Garza JR, Bowman JL, Rohrich RJ, Strodel WE. Endoscopically assisted “components separation” for closure of abdominal wall defects. *Plast Reconstr Surg.* 2000;105:720–729; quiz 730.

34. Saulis AS, Dumanian GA. Periumbilical rectus abdominis perforator preservation significantly reduces superficial wound complications in "separation of parts" hernia repairs. *Plast Reconstr Surg.* 2002;109:2275–2280; discussion 2281.
35. Butler CE, Campbell KT. Minimally invasive component separation with inlay bioprosthetic mesh (MICSIB) for complex abdominal wall reconstruction. *Plast Reconstr Surg.* 2011;128:698–709.
36. Ghali S, Turza KC, Baumann DP, Butler CE. Minimally invasive component separation results in fewer wound-healing complications than open component separation for large ventral hernia repairs. *J Am Coll Surg.* 2012;214:981–989.
37. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. *N Engl J Med.* 2000;343:392–398.
38. Burger JW, Luijendijk RW, Hop WC, Halm JA, Verdaasdonk EG, Jeekel J. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. *Ann Surg.* 2004;240:578–583; discussion 583.
39. Stabilini C, Stella M, Frascio M, et al. Mesh versus direct suture for the repair of umbilical and epigastric hernias: Ten-year experience. *Ann Ital Chir.* 2009;80:183–187.
40. Khansa I, Janis JE. Modern reconstructive techniques for abdominal wall defects after oncologic resection. *J Surg Oncol.* 2015;111:587–598.
41. Butler CE, Baumann DP, Janis JE, Rosen MJ. Abdominal wall reconstruction. *Curr Probl Surg.* 2013;50:557–586.
42. Ger R, Duboys E. The prevention and repair of large abdominal-wall defects by muscle transposition: A preliminary communication. *Plast Reconstr Surg.* 1983;72:170–178.
43. Shestak KC, Edington HJ, Johnson RR. The separation of anatomic components technique for the reconstruction of massive midline abdominal wall defects: Anatomy, surgical technique, applications, and limitations revisited. *Plast Reconstr Surg.* 2000;105:731–738; quiz 739.
44. LeBlanc KA, Booth WV. Laparoscopic repair of incisional abdominal hernias using expanded polytetrafluoroethylene: Preliminary findings. *Surg Laparosc Endosc.* 1993;3:39–41.
45. Booth JH, Garvey PB, Baumann DP, et al. Primary fascial closure with mesh reinforcement is superior to bridged mesh repair for abdominal wall reconstruction. *J Am Coll Surg.* 2013;217:999–1009.
46. Patton JH Jr, Berry S, Kralovich KA. Use of human acellular dermal matrix in complex and contaminated abdominal wall reconstructions. *Am J Surg.* 2007;193:360–363; discussion 363.
47. Bluebond-Langner R, Keifa ES, Mithani S, Bochicchio GV, Scalea T, Rodriguez ED. Recurrent abdominal laxity following interpositional human acellular dermal matrix. *Ann Plast Surg.* 2008;60:76–80.
48. Albino FP, Patel KM, Nahabedian MY, Sosin M, Attinger CE, Bhanot P. Does mesh location matter in abdominal wall reconstruction? A systematic review of the literature and a summary of recommendations. *Plast Reconstr Surg.* 2013;132:1295–1304.
49. Booth JH, Garvey PB, Baumann DP, et al. Primary fascial closure with mesh reinforcement is superior to bridged mesh repair for abdominal wall reconstruction. *J Am Coll Surg.* 2013;217:999–1009.
50. Itani KM, Rosen M, Vargo D, Awad SS, Denoto G III, Butler CE; RICH Study Group. Prospective study of single-stage repair of contaminated hernias using a biologic porcine tissue matrix: The RICH Study. *Surgery* 2012;152:498–505.
51. Bucknall TE. Factors influencing wound complications: A clinical and experimental study. *Ann R Coll Surg Engl.* 1983;65:71–77.
52. Osterberg B. Enclosure of bacteria within capillary multifilament sutures as protection against leukocytes. *Acta Chir Scand.* 1983;149:663–668.
53. van 't Riet M, Steyerberg EW, Nellensteyn J, et al. Meta-analysis of techniques for closure of midline abdominal incisions. *Br J Surg.* 2002;89:1350–1356.
54. Millbourn D, Cengiz Y, Israelsson LA. Effect of stitch length on wound complications after closure of midline incisions: A randomized controlled trial. *Arch Surg.* 2009;144:1056–1059.
55. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: A meta-analysis. *Ann Surg.* 2000;231:436–442.
56. Rosen MJ, Denoto G, Itani KM, et al. Evaluation of surgical outcomes of retro-rectus versus intraperitoneal reinforcement with bio-prosthetic mesh in the repair of contaminated ventral hernias. *Hernia* 2013;17:31–35.
57. Brill JB, Turner PL. Long-term outcomes with transfascial sutures versus tacks in laparoscopic ventral hernia repair: A review. *Am Surg.* 2011;77:458–465.
58. LeBlanc KA, Whitaker JM, Bellanger DE, Rhynes VK. Laparoscopic incisional and ventral hernioplasty: Lessons learned from 200 patients. *Hernia* 2003;7:118–124.
59. Nguyen SQ, Divino CM, Buch KE, et al. Postoperative pain after laparoscopic ventral hernia repair: A prospective comparison of sutures versus tacks. *JSLS* 2008;12:113–116.
60. Bansal VK, Misra MC, Kumar S, et al. A prospective randomized study comparing suture mesh fixation versus tacker mesh fixation for laparoscopic repair of incisional and ventral hernias. *Surg Endosc.* 2011;25:1431–1438.
61. Haltmeier T, Groebli Y. Small bowel lesion due to spiral tacks after laparoscopic intraperitoneal onlay mesh repair for incisional hernia. *Int J Surg Case Rep.* 2013;4:283–285.
62. Chelala E, Thoma M, Tatete B, Lemye AC, Dessily M, Alle JL. The suturing concept for laparoscopic mesh fixation in ventral and incisional hernia repair: Mid-term analysis of 400 cases. *Surg Endosc.* 2007;21:391–395.
63. Girotto JA, Ko MJ, Redett R, Muehlberger T, Talamini M, Chang B. Closure of chronic abdominal wall defects: A long-term evaluation of the components separation method. *Ann Plast Surg.* 1999;42:385–394; discussion 394.
64. Pollock H, Pollock T. Progressive tension sutures: A technique to reduce local complications in abdominoplasty. *Plast Reconstr Surg.* 2000;105:2583–2586; discussion 2587.
65. Weinzweig J, Weinzweig N. Plastic surgery techniques. In: Guyuron B, Eriksson E, Persing JA, eds. *Plastic Surgery: Indications and Practice.* Vol. I. Philadelphia: Saunders; 2009:37–44.
66. Ando M, Tamaki T, Yoshida M, et al. Surgical site infection in spinal surgery: A comparative study between 2-octyl-cyanoacrylate and staples for wound closure. *Eur Spine J.* 2014;23:854–862.
67. Scott GR, Carson CL, Borah GL. Dermabond skin closures for bilateral reduction mammaplasties: A review of 255 consecutive cases. *Plast Reconstr Surg.* 2007;120:1460–1465.
68. Blatnik JA, Krpata DM, Pesa NL, et al. Predicting severe postoperative respiratory complications following abdominal wall reconstruction. *Plast Reconstr Surg.* 2012;130:836–841.
69. Janis JE. Utilization of progressive tension sutures in components separation: Merging cosmetic surgery techniques with reconstructive surgery outcomes. *Plast Reconstr Surg* 2012;130:851–855.
70. Degnim AC, Scow JS, Hoskin TL, et al. Randomized controlled trial to reduce bacterial colonization of surgical drains after breast and axillary operations. *Ann Surg.* 2013;258:240–247.
71. Rothman JP, Gunnarsson U, Bisgaard T. Abdominal binders may reduce pain and improve physical function after major abdominal surgery: A systematic review. *Dan Med J.* 2014;61:A4941.
72. Weissman C. The metabolic response to stress: An overview and update. *Anesthesiology* 1990;73:308–327.

73. Baratta JL, Schwenk ES, Viscusi ER. Clinical consequences of inadequate pain relief: Barriers to optimal pain management. *Plast Reconstr Surg.* 2014;134(Suppl 2):15S–21S.
74. Sforza M, Andjelkov K, Zaccheddu R, Nagi H, Colic M. Transversus abdominis plane block anesthesia in abdominoplasties. *Plast Reconstr Surg.* 2011;128:529–535.
75. Hadzic A, Kerimoglu B, Loreio D, et al. Paravertebral blocks provide superior same-day recovery over general anesthesia for patients undergoing inguinal hernia repair. *Anesth Analg.* 2006;102:1076–1081.
76. Momoh AO, Hilliard PE, Chung KC. Regional and neuraxial analgesia for plastic surgery: Surgeon's and anesthesiologist's perspectives. *Plast Reconstr Surg.* 2014;134(Suppl 2):58S–68S.
77. Zoremba M, Dette F, Gerlach L, Wolf U, Wulf H. Short-term respiratory physical therapy treatment in the PACU and influence on postoperative lung function in obese adults. *Obes Surg.* 2009;19:1346–1354.
78. Hartman JT, Pugh JL, Smith RD, Robertson WW Jr, Yost RP, Janssen HF. Cyclic sequential compression of the lower limb in prevention of deep venous thrombosis. *J Bone Joint Surg Am.* 1982;64:1059–1062.
79. Murphy RX Jr, Alderman A, Gutowski K, et al. Evidence-based practices for thromboembolism prevention: Summary of the ASPS Venous Thromboembolism Task Force Report. *Plast Reconstr Surg.* 2012;130:168e–175e.
80. Grobmyer SR, Graham D, Brennan MF, Coit D. High-pressure gradients generated by closed-suction surgical drainage systems. *Surg Infect (Larchmt.)* 2002;3:245–249.
81. Carruthers KH, Eisemann BS, Lamp S, Kocak E. Optimizing the closed suction surgical drainage system. *Plast Surg Nurs.* 2013;33:38–42; quiz 43.
82. The Veterans Affairs Total Parenteral Nutrition Cooperative Study Group. Perioperative total parenteral nutrition in surgical patients. *N Engl J Med.* 1991;325:525–532.
83. Jie B, Jiang ZM, Nolan MT, et al. Impact of nutritional support on clinical outcome in patients at nutritional risk: A multicenter, prospective cohort study in Baltimore and Beijing teaching hospitals. *Nutrition* 2010;26:1088–1093.