Complex Open Abdominal Wall Reconstruction: Management of the Skin and Subcutaneous Tissue

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Summary: Optimal skin and soft tissue management in complex open abdominal wall reconstruction is an integral element of the operation to achieve optimal outcomes. Failure to provide stable, well-vascularized soft tissue coverage over the hernia repair can jeopardize the reconstruction through association with nonhealing wounds, mesh exposure, and even possible hernia recurrence. The literature has shown that careful attention to the skin and soft tissue, especially when part of a multidisciplinary approach to complex abdominal wall reconstruction, improves patient outcomes significantly. (*Plast. Reconstr. Surg.* 142: 125S, 2018.)

The optimal approach to abdominal wall reconstruction has 2 major components: reconstruction of the musculofascia (with or without mesh) and stable soft tissue coverage. Both components are interdependent and equally important. In particular, the lack of stable soft tissue coverage can lead to failure of the musculofascial reconstruction and mesh exposure through the "vicious cycle" described by Holihan et al.[1]

In this article, we discuss evidence-based strategies to avoid surgical-site occurrences, which include dehiscence, delayed would healing, and seroma, in abdominal wall reconstruction. We then discuss techniques for the management of marginal skin and soft tissue. Finally, we discuss strategies to improve mesh incorporation.

AVOIDING SURGICAL-SITE OCCURRENCES

Incisional dehiscence usually occurs due to inadequate tissue vascularity, seroma, excessive tension, or poor closure technique.

Optimizing Tissue Vascularity

During the dissection, every effort should be made to preserve as many vascular perforators to the skin and subcutaneous tissue as possible, especially the periumbilical perforators, typically located within 3 cm of the umbilicus.[2] Preservation of vascular perforators has been shown to reduce the risk of wound healing complications.[3] Therefore, residual subcutaneous undermining (after resection of any marginal or previously undermined tissue) should be limited to 2 cm or less circumferentially because undermining in excess of 2 cm increases the risk of surgical-site occurrences 2.3-fold.[4]

When performing anterior components separation (external oblique release), the use of minimally invasive techniques has been shown to result in fewer wound healing complications than traditional, open anterior components separation.[5–8] Minimally invasive anterior components separation begins by dissecting one 5- to 6-cm–wide subcutaneous tunnel in between the costal margin and umbilicus. This tunnel is extended to approximately 2 cm lateral to the semilunar line, and

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allows access to the anatomically precise external oblique aponeurotomy superiorly and inferiorly with limited subcutaneous dissection and perforator disruption or killed.[7] **See Video, Supplemental Digital Content 1**, which demonstrates the technique for minimally invasive anterior components separation, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C947***.

When using a posterior components separation (transversus abdominis release), there is no skin undermining. This has led to decreased surgical-site occurrence rates relative to other open techniques, which emphasizes the advantages of perforator-sparing techniques in complex abdominal wall reconstruction.[6–9]

When using transfascial sutures to secure mesh in the retromuscular or intraperitoneal underlay positions (regardless of type of components separation), it is not necessary to undermine the skin because the use of advanced techniques allows suture placement without undermining. We have previously described this suture placement technique in detail with associated improved outcomes[9]: the technique uses a Carter-Thomason laparoscopic instrument (CooperSurgical, Inc., Trumbull, Conn.) to pass the 2 tails of each suture in a transfascial, percutaneous fashion, thereby obviating the need for skin undermining which characterized the original descriptions of components separation. (**See Video, Supplemental Digital Content 2**, which demonstrates the placement of transfascial, percutaneous sutures for mesh fixation using the Carter-Thomason laparoscopic suture passer, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C948***.)

Despite the surgeon's best efforts, undermined or tenuous skin may still be present. This is often due to skin attenuation due to the underlying hernia sac itself dissecting a subcutaneous pocket.[10] Once the hernia sac is resected, this attenuated skin and subcutaneous layer may be of marginal viability given its random pattern blood supply (largely based on subdermal plexus), and if kept, it would result in fat necrosis and dehiscence. Attenuated and marginal skin and subcutaneous fat must be resected back to healthy, well-vascularized tissue to minimize surgical-site occurrences. We present more detail about resection of marginal tissue in the next section.

Avoiding Seromas

During abdominal wall reconstruction, dead space may be present in the subcutaneous plane,

Video 1. Supplemental Digital Content 1, demonstrating the technique for minimally invasive anterior components separation, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C947***.

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in the external oblique aponeurotomy site (when anterior components separation in performed), or over the mesh (when mesh is placed in the retromuscular or intraperitoneal planes). Fluid must be prevented from collecting in these dead spaces because this can lead to issues with tissue adherence, mesh incorporation, or abscess.[11] Therefore, closed-suction drains should be placed when any of those dead spaces are present.[12] In addition, those drains should be managed appropriately both intraoperatively and postoperatively as described by Khansa et al[13]: internal drain tubing length should be maximized, external drain tubing length should be minimized, 15 or 19 French drains should be favored over small drain sizes, tubing should be stripped frequently to avoid clotting and emptied when 25%–50% full, bulbs should be charged using "side-to-side" technique

Table 1. Evidence-Based Strategies to Optimize Closed-Suction Drain Performance

Increase intracavitary drain tube length
Decrease extracavitary drain tube length
Increase drain tube diameter
Use perforated drain (rather than fluted)
Use 100 or 400 cc bulb (rather than spring evacuator)
Squeeze bulb side-side-side rather than bottom-up
Empty bulb when 25% full

rather than "thumbs up," and the drains should be removed based on volume-dependent, rather than time-dependent, criteria (Table 1).[14]

In abdominoplasty, the use of progressive tension sutures has been shown to decrease dead space in the subcutaneous plane.[15–17] The same principle has been extrapolated to abdominal wall reconstruction by Janis[18] with statistically significant decreases in postoperative drainage (mean 600 cc less in first 3 days; $P = 0.0198$) (**see Video, Supplemental Digital Content 3**, which demonstrates the placement of progressive tension sutures in the subcutaneous plane, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C949***).[8,19] In addition to obliterating subcutaneous dead space, progressive tension sutures help advance the skin flaps toward the incision to decrease incisional tension, which otherwise can lead to suboptimal outcomes.

Minimizing Tension

The surgeon must strike a careful balance between 2 competing forces: minimizing subcutaneous undermining with the goal of preserving vascularity and minimizing tension on the closure.[20] In cases where some subcutaneous undermining is necessary to achieve skin reapproximation, the dead space that is created by the undermining should be obliterated by progressive tension sutures, as described above. Another function of progressive tension sutures is to advance the skin flap toward the incision with every suture, thereby distributing the tension over a large surface area (**see Video, Supplemental Digital Content 3**, ***http://links.lww.com/PRS/C949***).

Optimal Closure Technique

Meticulous multilayered closure should be performed. This includes the placement of dissolvable sutures in Scarpa's fascia and the deep dermis[8] with skin edge eversion.[20–24]

In patients who are at high risk for dehiscence or infection, incisional negative-pressure wound therapy has been shown to lower complication rates, including seroma, dehiscence, and infection.[25–29] Incisional negative pressure wound therapy (NPWT) has also been shown to improve blood flow around the incision, decrease edema, improve lymphatic clearance, and splint the incision (Fig. 1).[30]

Another option on high-risk patients is the "French fry, string-of-pearls technique"[31–33]: this technique takes advantage of both traditional NPWT and incisional NPWT. Five-centimeter portions of the incision are closed intermittently with absorbable sutures in Scarpa's fascia and the deep dermis, and these closed portions are separated by 5-cm open portions (Fig. 2, *center*). Nonadherent gauze, such as Perform (Covidien, Mansfield, Mass.), is applied over the closed portions, and struts of polyurethane foam are placed into the open portions (Fig. 2, *above* and *below*). The struts are connected outside the skin with a horizontal crossbar

Video 3. Supplemental Digital Content 3, which demonstrates the placement of progressive tension sutures in the subcutaneous plane, is available in the "Related Videos" section of the Full-Text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C949***.

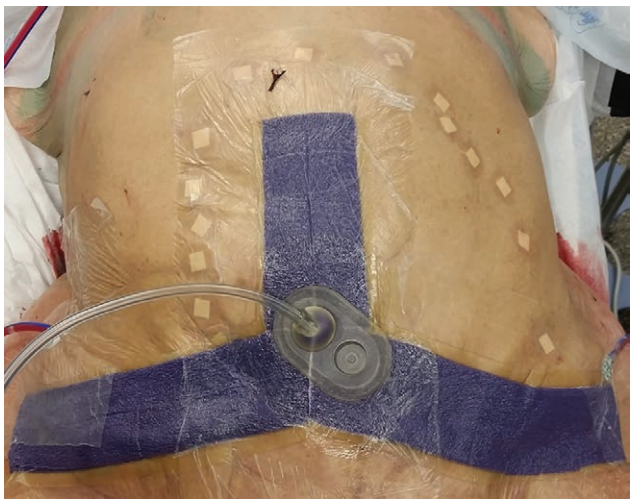

Fig. 1. The use of incisional negative-pressure wound therapy in abdominal wall reconstruction.

Fig. 2. The string-of-pearls technique for partial wound closure. (*Above*) Vertical struts of polyurethane foam are cut, in addition to a horizontal crossbar. (*Center*) Portions of the incision are closed, interspersed with open portions. (*Below*) The vertical struts are inserted into the open portions, and the horizontal crossbar connected the struts outside the skin. Nonadherent gauze separates the closed portions of the incision from the horizontal crossbar. *C* indicates closed; *O*, open.

of foam. The continuous negative pressure (125 mm Hg) is then applied. In wounds that are not amenable to closure due to contamination, this technique transforms a large wound into multiple smaller wounds, which can heal much faster.

MANAGING MARGINAL SKIN AND SUBCUTANEOUS TISSUE

Despite the surgeon's best efforts to minimize skin undermining during the operation, such undermining is often present and must be addressed. Before closure, the surgeon should assess the vascularity of the skin edges. Usually, simply assessing the color of the skin and observing for dermal bleeding are sufficient. Marginal skin and soft tissue with poor blood supply must be excised sharply to avoid dehiscence, fat necrosis, and nonhealing wounds. Particularly, in patients with excessive, redundant skin and subcutaneous tissue, the weight of the excess skin can produce distracting forces on the incision, thereby increasing the risk of dehiscence.[8,34] In those situations, performing aggressive skin flap removal before closure will reduce the excess skin. This must be performed with techniques that minimize undermining. Depending on the pattern of the skin excess, either a vertical or horizontal panniculectomy can be performed. In most cases, when the incision is a vertical midline incision, performing a teardrop-shaped skin resection pattern, rather than an elliptical or lenticular resection pattern, is the optimal approach to remove excess tissue in areas of most redundancy (usually in the inferior third of the abdomen rather than central third). To avoid overresection, precise estimation of the amount of skin to be resected is critical. **See Video, Supplemental Digital Content 4**, in which we show 2 techniques for precise resection of excess skin: the staple-assisted tailor tacking technique and the towel clamp-assisted double-crown technique, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C950***. Of particular importance is our application of the double-crown technique, which was initially described by Aly et al[35] (**see Video, Supplemental Digital Content 5**, which demonstrates the double-crown technique as applied to vertical panniculectomy, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C951***).

In some patients, a large, low-hanging panniculus generates significant distracting forces on the incision, and a horizontal panniculectomy is necessary. When combined with a vertical laparotomy incision, such a horizontal panniculectomy would result in a fleur-de-lis pattern (Fig. 3, *above*), which includes a T-junction that is prone to delayed wound healing (Fig. 3, *center*). A modification of this fleur-de-lis panniculectomy is the "Mercedes" panniculectomy (Fig. 3, *below*), initially described by Butler and Reis.[36] The Mercedes pattern is achieved by placing the T-junction in a more superior location along the vertical incision. This results in shorter upper triangular flaps with improved blood supply (given that they are axial,

Video 4. Supplemental Digital Content 4, which shows 2 techniques for precise resection of excess skin: the staple-assisted tailor tacking technique, and the towel clamp-assisted double-crown technique, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C950***.

Video 5. Supplemental Digital Content 5, which demonstrates the double-crown technique as applied to vertical panniculectomy, is available in the "Related Videos" section of the Full-Text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C951***.

rather than random, and supplied by the superficial inferior epigastric artery), a more obtuse, rather than acute, confluence point, and a confluence point located more cephalad and outside the pubic area, which can have preexisting or current hygiene issues that can lead to infection.

Overall, obese patients undergoing abdominal wall reconstruction are known to have higher rates of surgical-site occurrences.[37,38] Concurrent panniculectomy has been shown to improve wound healing outcomes in patients with excess skin who have lost weight, but not those who are obese at the time of surgery.[39,40]

MANAGING DEFICIENT SKIN

Regional flaps, especially from the thigh, can play a major role in replacing deficient abdominal

Fig. 3. The Mercedes panniculectomy technique. (*Above*), In a traditional fleur-de-lis panniculectomy, the upper triangular flaps are long and have a 90-degree angle at the apex. In addition, the T-junction is located in the pubic area. (*Center*) In a traditional fleur-de-lis panniculectomy, the T-junction is prone to wound breakdown and fat necrosis. (*Below*) The Mercedes panniculectomy technique has several advantages over the traditional fleur-de-lis panniculectomy: the upper triangular flaps are shorter and have a more obtuse apex, and the T-junction is located more cephalad, outside the pubic area.

skin. These flaps are usually based on the descending branch of the lateral circumflex femoral artery and may encompass most of the anterior thigh, including the vastus lateralis, rectus femoris, and tensor fasciae latae muscles, if needed.[41,42] If these flaps can reach their intended recipient site without

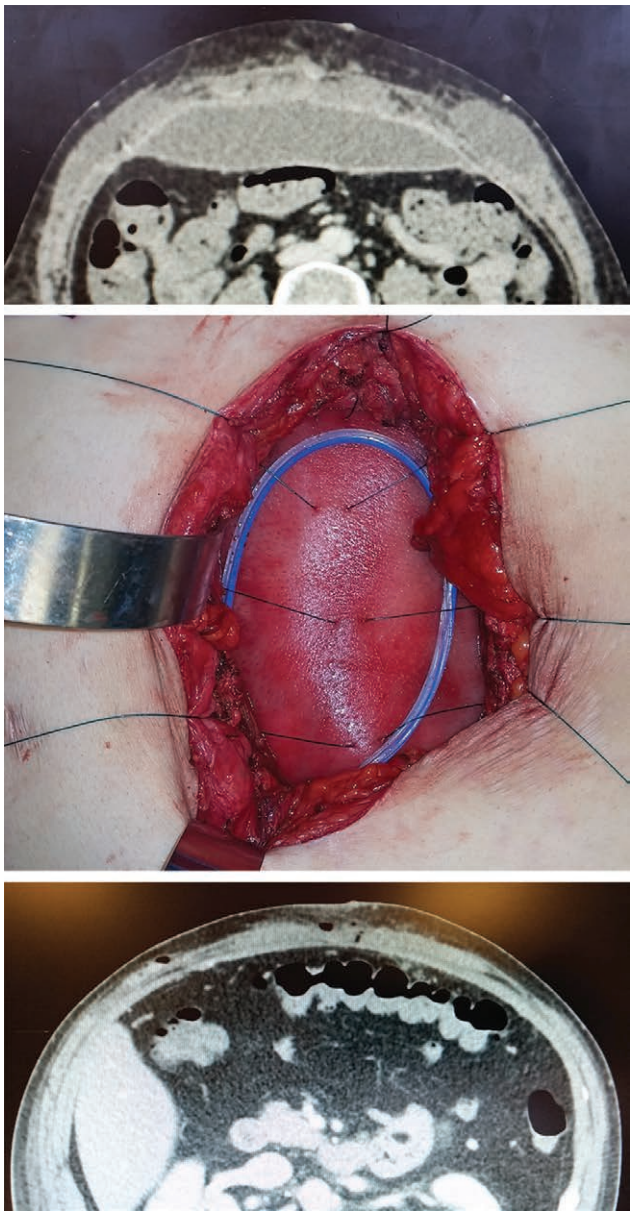

Fig. 4. Achieving close apposition between intraperitoneal mesh and the peritoneum. (*Above*) When placed in a wide intraperitoneal underlay position, mesh tends to bowstring into a flat conformation, and fluid may collect between the mesh and the peritoneum, thereby impeding mesh incorporation. (*Center*) The placement of central suspension sutures ensures close apposition of the mesh against the underside of the peritoneum. A closed-suction drain over the mesh also decreases fluid accumulation. (*Below*) With the use of central suspension sutures, closed-suction drains, and mesh perforation (described in **Video, Supplemental Digital Content 5, *http://links.lww.com/PRS/C951***), close apposition of the mesh against the underside of the peritoneum can be achieved.

undue tension, they may be left as pedicled flaps. Transposition of the flap under the rectus femoris can gain additional pedicle length. These flaps can also be transferred microsurgically as free flaps.

Video 6. Supplemental Digital Content 6, which demonstrates that the perforation of biologic mesh allows fluid egress, preventing seroma formation between the mesh and the peritoneum when the mesh is used in the intraperitoneal underlay position, is available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C952***.

In addition to local flaps, regional flaps, and free flaps, reconstructive surgeons should keep tissue expansion in their armamentarium. Tissue expansion can only be performed in certain situations when the reconstruction is elective. The surgeon must carefully plan the reconstruction by placing appropriately sized tissue expanders in the subcutaneous plane, and overexpanding beyond the soft tissue need. The musculofascial reconstruction is then performed at the time of tissue expander removal and flap advancement.

OPTIMIZING MESH INCORPORATION

Meshes (regardless of type) incorporate to surrounding tissues by close contact and tight apposition with well-vascularized tissue. Fluid accumulation around the mesh would prevent such contact, just as would wrinkles, infolds, or laxity, which would impede mesh incorporation (Fig. 4, *above*).[10] To optimally address this, meticulous technique of mesh placement must be employed, including placement of flat, taut, wrinkle-free mesh[43] and suture techniques that can approximate the mesh to vascularized tissue and obliterate potential spaces in which fluid can accumulate (Fig. 4, *below*).[9]

The ideal planes for mesh placement are the retromuscular and intraperitoneal underlay plane.[44] In the retromuscular plane, the mesh is between the muscle and peritoneum. This plane therefore "sandwiches" the mesh between 2 well-vascularized tissues and avoids direct contact with the viscera. Closed-suction drains can be placed over the mesh in this plane to maximize mesh contact against

the muscle. In the intraperitoneal underlay plane, the mesh is between the peritoneum and viscera. Intraperitoneal meshes tend to bowstring into a flat shape, and not conform to the concavity of the peritoneum (Fig. 4, *above*) unless certain measures are taken: closed-suction drain placement between the mesh and the peritoneum (Fig. 4, *center*),[10] the use of central suspension sutures that suspend the mesh to the underside of the fascia (Fig. 4, *center*),[8] and mesh perforation to allow fluid egress (**see Video, Supplemental Digital Content 6**, which demonstrates that the perforation of biologic mesh allows fluid egress, preventing seroma formation between the mesh and the peritoneum when the mesh is used in the intraperitoneal underlay position, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, at ***http://links.lww.com/PRS/C952***).

CONCLUSIONS

Soft tissue management techniques can be used in complex open abdominal wall reconstruction in patients with excessive, tenuous, or deficient skin and subcutaneous tissue. Multidisciplinary cooperation between general surgery and plastic surgery in those cases can help optimize patient outcomes and decrease complication rates.

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