

# Management of skin and subcutaneous tissue in complex open abdominal wall reconstruction

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## Abstract

**Purpose** Open abdominal wall reconstruction is often a complex endeavor, usually performed on patients with multiple risk factors and co-morbidities.

**Methods** In this article, we review soft tissue management techniques that can optimize the skin and subcutaneous tissue, with the goal of reducing surgical-site occurrences.

**Results** Regardless of the hernia repair technique used, outcomes can be highly dependent on the appropriate management of the skin and subcutaneous tissue. Indeed, dehiscence and surgical-site infection can jeopardize the entire reconstruction, especially in cases where synthetic mesh might become exposed and/or infected, setting up a “vicious cycle” (Holihan et al. in *J Am Coll Surg* 221:478–485, 2015).

**Conclusion** Multidisciplinary cooperation between the general and plastic surgeon is useful in cases of tenuous blood supply to the abdominal skin, in cases of redundant, marginal or excessive skin, and in cases of deficient skin.

**Keywords** Abdominal wall reconstruction · Perforator preservation · Panniculectomy · Wound healing · Incisional negative pressure wound therapy · Progressive tension sutures

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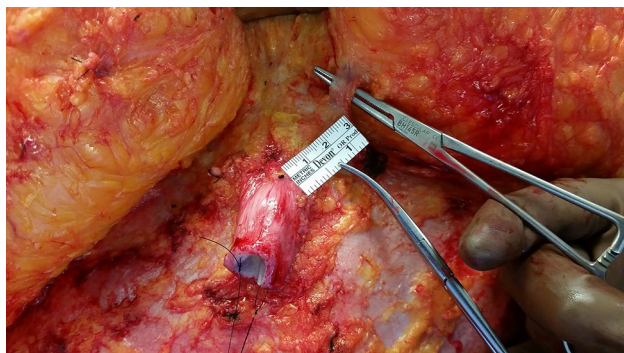
## Introduction

In abdominal wall reconstruction, special attention must be paid to the soft tissue to avoid wound healing problems that can lead to mesh infection and hernia recurrence [1]. In this article, we review evidence-based techniques which can be employed to preserve blood supply to the skin and subcutaneous tissue, manage redundant, undermined and marginal skin, obtain soft tissue coverage in cases of deficient skin, obliterate dead space to prevent fluid accumulation, and optimize incisional closure.

## Preservation of vascular perforators

Blood supply to the abdominal wall skin and subcutaneous tissue is primarily derived via vascular perforators from the deep inferior and superior epigastric vessels [2]. A large proportion of these perforators are concentrated within 3 cm of the umbilicus (Fig. 1) [3].

Whenever mesh is used as part of hernia repair, at least 4 cm of overlap between fascia and mesh on every side is essential [4], and therefore, mesh inset usually requires access to the lateral abdominal wall [5]. In the case of onlay mesh, significant subcutaneous undermining is necessary to place the mesh and achieve adequate overlap between mesh and fascia. Even when the mesh is placed in the retromuscular or intraperitoneal positions, inset may require transfascial sutures, which are traditionally placed under direct visualization after extensive lateral skin undermining. However, such undermining may result in skin flap devascularization, leading to higher rates of wound healing complications. Skin undermining more than 2 cm has been shown to increase the risk of surgical-site occurrences 2.3-fold [6]. Maximal perforator preservation has been shown to reduce the rate of wound healing complications [7].



**Fig. 1** A large periumbilical perforator, which should be preserved whenever possible

When compared to the onlay position, mesh placement in the retrorectus and intraperitoneal positions has been shown to result in fewer complications [8], partially because less undermining is required for mesh inset. Those two mesh positions afford the ability to use advanced techniques to inset the mesh with practically no skin undermining using percutaneous transfascial sutures [9]. This is performed by placing 1 cm or less U-stitches in the mesh, located 1 cm from the mesh margin, and placed at 1 cm intervals from each other (in the case of an intraperitoneal position) or at cardinal positions (in the case of retromuscular mesh). Alternatively, self-adhering mesh can be used. For percutaneous transfascial suture fixation, 3-mm skin incisions are made with an #11 scalpel, and a Carter-Thomason® laparoscopic suture passer (Cooper Surgical, Inc, Trumbull, CT) is inserted, grasping the suture tails and withdrawing them through separate transfascial punctures (Online Resource 1). We have previously demonstrated low rates of surgical-site occurrences using this technique, which is derived from the low surgical-site infection and wound healing complication rates of laparoscopic hernia repair where no skin undermining is performed [9].

Components separation is another portion of the procedure that may require skin undermining. Traditional, open components separation with wide subcutaneous undermining to the semilunar line has been shown to result in high rates of wound healing complications [10]. However, modern, perforator-sparing techniques have been developed with reduced complication rates. In 2000, Lowe et al. described an endoscopic technique whereby the semilunar line is accessed through an incision 5 cm medial to the anterior superior iliac spine with improved complications over the standard open approach [11]. In 2002, Saulis and Dumanian described their periumbilical perforator-sparing technique, with a decrease in wound healing complications rates versus traditional techniques, 20 vs 2% ( $p < 0.05$ ) [12]. In 2011, even more perforator preservation was achieved by Butler et al., who accessed the semilunar line through a single 3-m

wide tunnel located 2 cm below the costal margin [13]. We have previously described our modification of this approach (Online Resource 2), using techniques borrowed from the laparoscopic literature and applying them to Butler's minimally invasive approach [9]. Finally, also in 2011, Novitsky et al. described the transversus abdominis release, which has a prime advantage of avoiding skin flaps [14]. All of these share the common concept of vascular preservation without compromising the integrity of the repair [9, 11, 13].

### Management of undermined, marginal and redundant skin

In patients with large hernias, the hernia sac often acts as a tissue expander, causing the overlying skin to be undermined and attenuated [15]. This can be easily seen on CT scan and confirmed intraoperatively. This marginal skin may have poor blood supply, and may pose a wound healing risk. It should, therefore, be excised back to healthy tissue. Marginal skin usually undergoes necrosis in the first few days postoperatively, and results in an open wound that may lead to mesh exposure. Similarly, poorly vascularized fat usually results in fat necrosis and oil cysts that also lead to wound breakdown.

Similarly, in obese patients, especially those who have undergone massive weight loss, excessive, redundant skin creates lateralized distracting forces on the incision, increasing the risk of dehiscence, necrosis, and infection [16]. Excision of redundant skin has been shown to help decrease complication rates, improve patient satisfaction and function, and to make ostomy placement easier, when needed [9, 17, 18]. In patients with mostly horizontal skin excess (excess skin that can be gathered by pinching in a horizontal direction), the vertical panniculectomy usually allows for excision of the entirety of the undermined and marginal skin. Since most patients have more skin inferiorly than superiorly, we recommend a teardrop-shaped excision pattern, rather than elliptical [9]. A reliable technique to avoid over-resection is the use of "tailor tacking", which involves imbrication of the skin using forceps and temporary staples to design the skin resection pattern using haptic feedback of the simulated incisional tension (Online Resource 3).

In patients with vertical skin excess (excess skin that can be gathered by pinching in a vertical direction), a classic horizontal panniculectomy incision can be performed. In those cases, the panniculectomy incisions should be designed first, and access to the hernia can be obtained through that incision. In patients who have both vertical and horizontal skin excess, a fleur-de-lis panniculectomy can be performed. This results in two upper triangular skin flaps and the generation of a T-point where these skin flaps are reapproximated to the low transverse component of the incision. This T-point is prone to wound healing complications. Improvement in

wound outcomes would be expected by shortening the length and acuity of the upper triangular flaps, by minimizing flap undermining, by designing the flaps with an axial (rather than random) blood supply, and by placing the T-junction more superiorly, keeping the most complication-prone portion of the incision in a more hygienic location. The resulting “Mercedes” incision pattern [18] results in improved vascularity to the tips of the upper triangular flaps, an axial blood supply to the inferior flap (superficial inferior epigastric arteries) and decreased tension on the closure (Online Resource 4).

In patients who have lost weight, panniculectomy has been shown to reduce wound healing complications when added to hernia repair [19, 20]. In contrast, patients who are morbidly obese at the time of hernia repair do not seem to benefit from simultaneous panniculectomy [21]. This highlights the importance of weight loss before elective surgical intervention: BMI greater than 35 has been shown to increase the risk of surgical complications by 89%, while BMI greater than 40 increased the risk of surgical complications by 166% [19].

It is essential that the hernia surgeon be able to assess the vascularity of the skin and subcutaneous tissue before skin closure. Methods for assessment of skin vascularity are detailed in the “[Skin closure](#)” section below. Every effort should be made to preserve skin vascularity during dissection. Skin with marginal blood supply must be excised before closure.

### Management of deficient skin

Patients with hernias may have composite soft tissue defects, which may be due to a wound, fistula, resection of a previous skin graft on viscera, or defect created after oncologic resection. Management of these defects is an integral part of abdominal wall reconstruction. For small wounds with no exposure of vital structures or prosthetic material, healing by secondary intention with dressing changes or negative pressure wound therapy may be an adequate option, especially when no further surgical intervention is desired [22]. These wounds, however, may require a long period of time to heal. In patients who have a well-perfused and clean granulated wound bed, a meshed split-thickness skin graft may be applied, although this has the disadvantages of color mismatch and contour deformity.

The next rung on the reconstructive ladder is the use of local flaps, which recruit adjacent abdominal skin. These usually take the form of advancement flaps, in which judicious undermining of the skin and subcutaneous tissue is performed, backcuts created as needed, and the skin advanced to close the incision in tension-free fashion. For low-transverse defects, the upper abdominal skin is advanced, similar to an abdominoplasty. Flexing the bed at

the waist will greatly help offload tension off the closure. Axial flaps may also be designed based on one of more perforators from the deep epigastric system [23]. When local tissue is insufficient, regional flaps are required. For the mid and lower abdomen, the thigh is an excellent donor site. Multiple different flaps can be raised from the thigh, usually based on the branches of the lateral circumflex femoral artery and vein. These flaps can be muscular (rectus femoris, tensor fascia lata) [24], or fasciocutaneous/musculocutaneous (anterolateral thigh flap) [25, 26]. Subsartorial transposition can be used to gain pedicle length and therefore flap excursion, if needed [25].

Regional flaps from the thigh may not be able to reach the epigastric region. In those situations, there are two options. Free tissue transfer allows the harvest of tissue from one part of the body with microsurgical anastomosis of the flap vessels to recipient vessels adjacent to the defect (Fig. 2). Potential recipient vessels for free flaps to the abdominal wall include the superficial femoral vessels (usually requires a vein graft), internal mammary vessels (with vein graft), or the deep epigastric vessels. The other option in these difficult cases is tissue expansion [27]. A tissue expander is essentially a “surgical water balloon”, which is inserted adjacent to the defect and gradually filled with saline over several weeks, causing the overlying tissue to expand via mitosis and collagen synthesis [28]. Once sufficient expansion has been achieved, the expander is removed, and the expanded tissue is transposed to obtain coverage (Fig. 3). An algorithm for soft tissue reconstruction of the abdominal wall is shown in Fig. 4.

### Management of dead space

Fluid must be prevented from accumulating postoperatively within a surgical plane, as it may become infected or may prevent revascularization or incorporation of mesh. During the dissection, the surgeon should only undermine as needed to perform the hernia repair, as wider undermining creates more dead space. Onlay meshes tend to require wider undermining than intraperitoneal and retromuscular meshes.

When dead space is present, it must be obliterated to prevent fluid accumulation [29]. Strategies that have been shown to be successful in obliterating dead space include the placement of closed-suction drains [30, 31], frequent drain stripping [32], and volume-dependent discontinuation of drains when their daily output is below 30 cc for two consecutive days with the patient ambulatory [29, 33]. Additionally, the placement of progressive tension sutures between Scarpa’s fascia of the skin flap and the anterior abdominal fascia reduces dead space and shear forces that can lead to subcutaneous seroma formation [29, 34]. Similarly, central suspension sutures can be used to obliterate dead space between intraperitoneal mesh and the overlying





**Fig. 2** Microsurgical free tissue transfer for soft tissue coverage of a large composite abdominal wall defect. **a** A composite defect involving all layers of the abdominal wall, encompassing the entire *right lower* quadrant, and a portion of the *right upper* quadrant, after tumor excision. **b** A right anterolateral thigh flap is designed. The central axis of the flap is a line from the anterior superior iliac spine to the superolateral patella. The 3 cm-radius circle marks the expected location of the main “B” perforator from the descending branch of the lateral circumflex femoral artery to the skin. **c** The descending branch

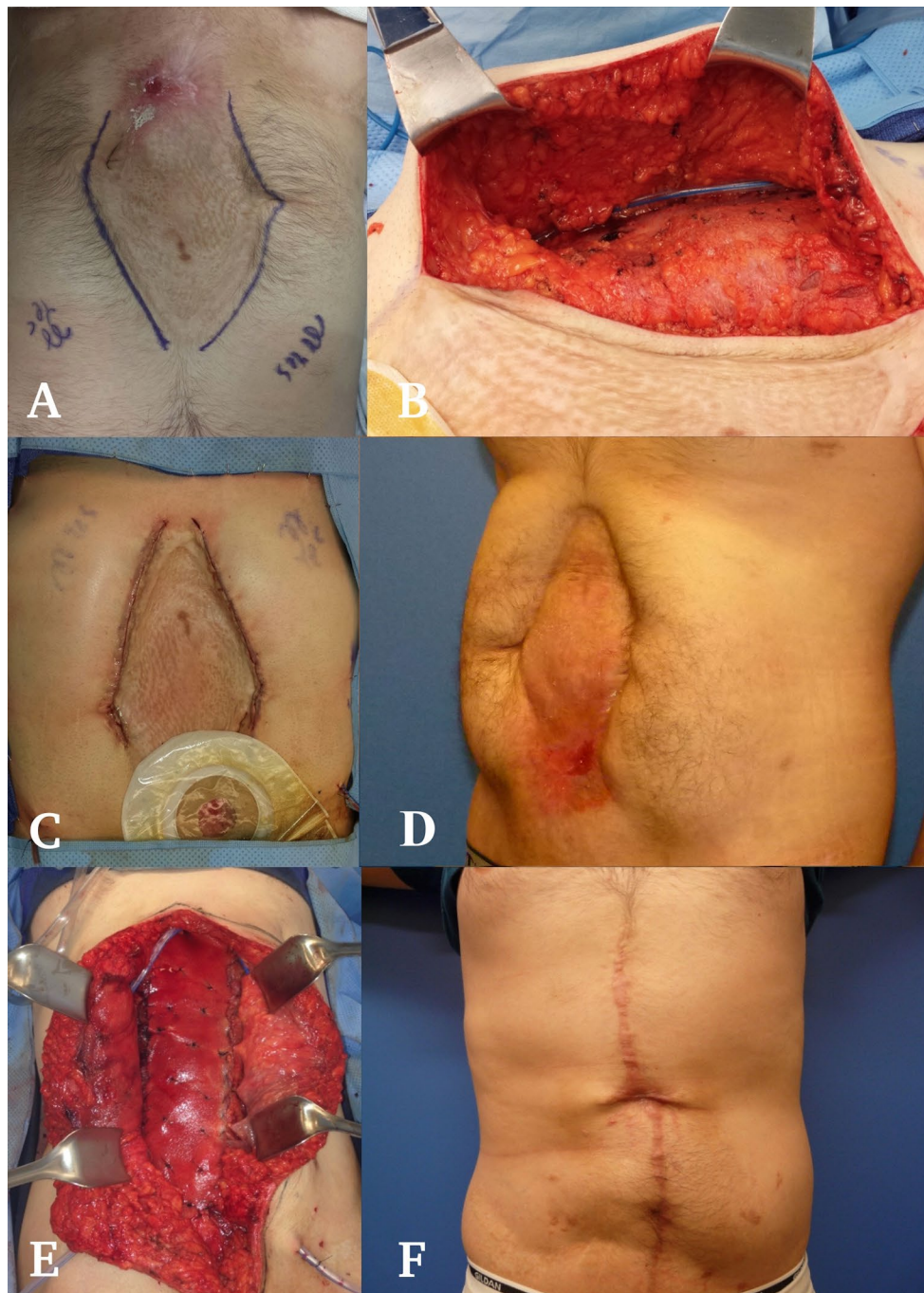
of the lateral circumflex femoral artery, which constitutes the blood supply to the flap, is fully dissected. **d** After full flap dissection and vascular pedicle identification, the flap is unable to reach the superior aspect of the defect. **e** The flap is transferred microscopically by ligating the descending branch of the lateral circumflex femoral artery and vein, and anastomosing them to the deep inferior epigastric artery and vein. **f** The donor site is partially closed primarily, and the remaining area is covered with a split-thickness skin graft

fascia, allowing greater apposition between the mesh and vascularized tissue which is important irrespective of the type of mesh used (Online Resource 5) [9].

### Skin closure

To optimize primary closure of the incision, several factors must be taken into account

- 1) Adequate vascularity: Excessive skin undermining decreases blood supply to the skin. Vascularity of the



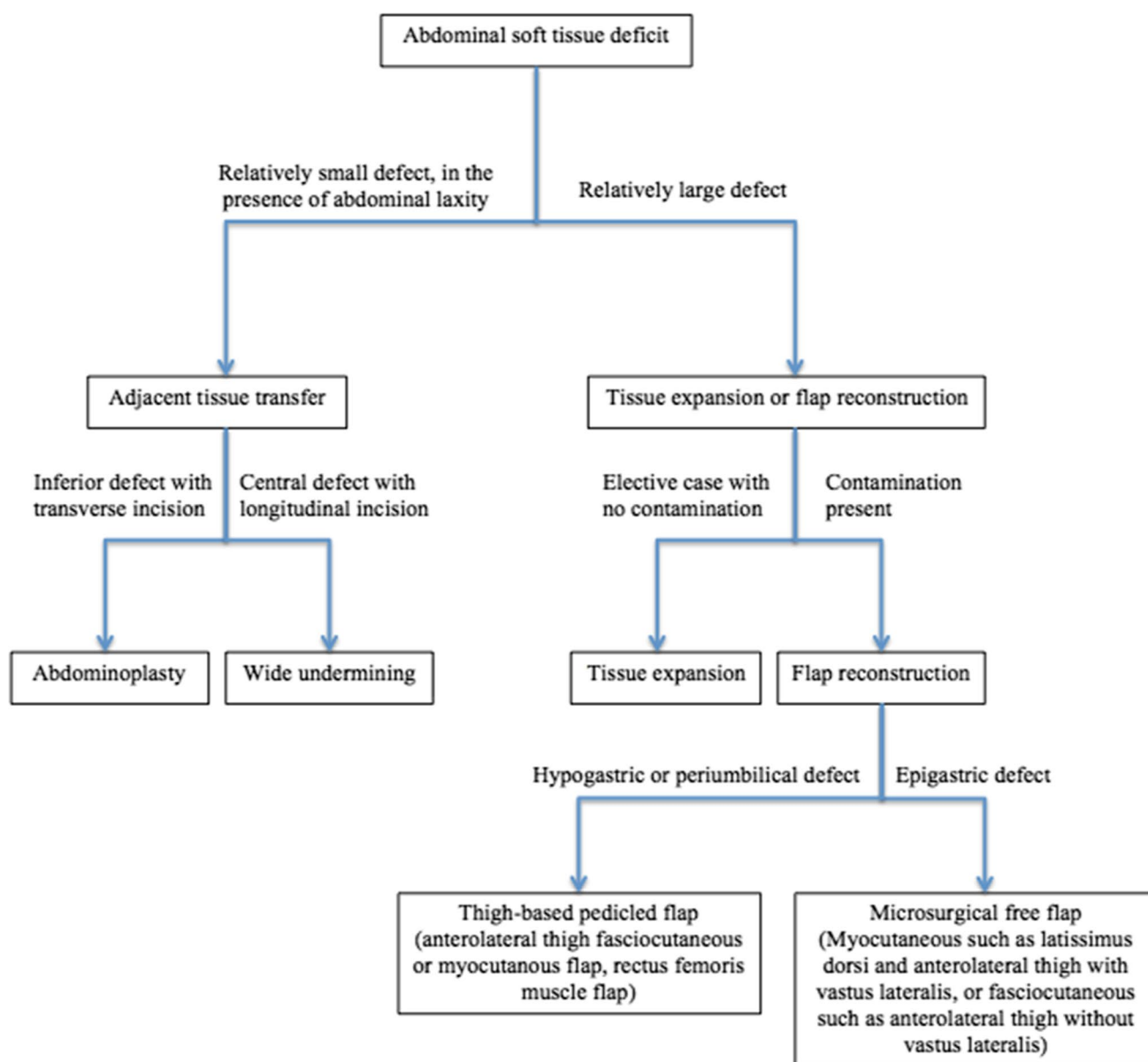
**Fig. 3** The use of tissue expansion in a patient with soft tissue deficit. **a** A young, thin patient with a hernia, as well as an enterocutaneous fistula and skin graft on viscera. **b** A subcutaneous pocket is dissected on each side for the insertion of tissue expanders. **c** Skin closure at the conclusion of the tissue expander insertion. **d** View of the abdominal wall at the completion of the tissue expansion process.

**e** At the second stage, the tissue expanders are removed, and definitive hernia repair is performed using bilateral minimally invasive components separation, and combined intraperitoneal and onlay biologic mesh placement. The expanded skin is advanced and closed primarily. **f** Postoperative view of the healed incision

skin can be easily assessed clinically by observing the color and bleeding pattern of the skin edges. Well-vascularized dermis is pink, and exhibits bright red punctate bleeding when cut or rubbed with a sponge.

Dermis with poor arterial inflow is pale and slow to bleed. Dermis with poor venous outflow appears purple with dark bleeding. Skin with poor arterial inflow or venous outflow will not heal, and is likely to necrose





**Fig. 4** Algorithm for soft tissue reconstruction of the abdominal wall

and cause exposure of underlying structures. It, therefore, must be debrided back to healthy skin. In addition to clinical examination for capillary refill and dermal bleeding, skin perfusion and viability can be assessed in the operating room using indocyanine green fluorescent angiography [35].

- 2) Minimize tension: This can be facilitated by several maneuvers: obtaining primary musculofascial reapproximation takes tension off the skin, and is, therefore, preferred over using mesh as a bridge. The placement of progressive tension sutures advances the skin flap and helps offload tension [9]. Additionally, layered incisional closure, in which absorbable sutures are placed

in Scarpa's fascia, followed by deep dermal absorbable sutures, helps offload tension as well [9]. Deep dermal sutures should evert the skin edges, which has been shown to accelerate healing and improve scar quality [36–38]. The surgeon must carefully balance the amount of undermining needed to minimize tension without devascularizing the skin.

Many patients undergoing complex abdominal wall reconstruction are at high risk for dehiscence and infection after primary incisional closure. This includes patients with diabetes mellitus [39, 40], smokers [41], and morbidly obese patients [42]. The application of incisional negative pressure

wound therapy (NPWT) as a surgical dressing for 5–7 days over these high-risk primary closures has been shown to significantly reduce the risk of wound healing complications (63.6–22%), and dehiscence (39–9%), compared to standard dressings [43], largely out of improved peri-incisional blood flow, decreases in interstitial edema, and “splinting” of the incision to offload tension. It has also been shown to decrease the risk of surgical-site infections and seromas [44–48].

Skin closure in multiple layers helps offload tension and minimize dead space. Dissolvable sutures should be placed in Scarpa’s fascia and the deep dermis. For the next layer, there has not been evidence to show that subcuticular sutures are superior to staples in clean cases [49]. In contaminated cases, the use of staples facilitates partial opening of the wound in case of infection.

In cases where the wound cannot be closed primarily, or where contamination precludes such primary closure, NPWT is a useful adjunct. It has been shown to be superior to traditional dressings, as it enhances blood flow, granulation tissue formation and bacterial clearance from the wound [50]. NPWT is also very useful in cases of dehiscence after primary closure. It can be used over exposed biologic mesh, and even, according to more recent evidence, over macroporous, monofilament light and mid-weight polypropylene mesh [51].

A novel approach that optimizes outcomes in high-risk surgical incisions by taking advantages of both traditional and incisional NPWT is the “String-of-Pearls, French Fry Technique” [22]: The incision is closed intermittently for 5 cm (2-0 polyglactin or polylactic-co-glycolic acid) sutures in Scarpa’s fascia, 3-0 monofilament poliglecaprone in the deep dermis, and staples in the skin, interspersed with 5 cm open areas. A non-adherent dressing, such as Xeroform (Covidien, Mansfield, MA) or Adaptic (Johnson & Johnson, New Brunswick, NJ), is applied over the closed portions. Vertical struts of polyurethane foam, which have the appearance of French fries, are inserted into the open areas, and connected over the closed portions with a horizontal crossbar of foam. This is followed by the application of transparent adhesive dressing and negative pressure at 125 mmHg of continuous suction (Online Resource 6). This technique facilitates the management of high-risk incisions: the closed portions benefit from incisional NPWT, while the open portions benefit from traditional NPWT. This technique is superior to simply keeping the wound open and applying traditional NPWT to it, since it transforms a large wound into multiple small wounds, which can heal much faster with lower levels of exudative protein loss. Furthermore, the NPWT allows for efficient removal of fluid, and the cosmetic result is superior to healing completely by secondary intention. However, when synthetic mesh is used, this technique is only appropriate if the mesh is in an intraperitoneal

or retromuscular position, and fully covered with healthy anterior rectus sheath.

## Discussion

While most of the techniques mentioned have been previously described, few have been previously applied to open abdominal wall reconstruction, especially in combination. For example, careful attention to skin perfusion is an integral part of breast reconstruction with tissue expanders after skin-sparing mastectomy [52]. In those cases, skin necrosis can have extremely deleterious consequences, and can lead to the loss of the entire reconstruction. Similarly, skin necrosis in abdominal wall reconstruction can lead to mesh exposure and loss of the repair. Progressive tension sutures have been proven, in a randomized-controlled trial, to reduce seroma formation after abdominoplasty [31], but little has been written about their use in abdominal wall reconstruction. Similarly, most studies on incisional negative pressure wound therapy have been performed in orthopedic surgery [46], but this technique can be a valuable adjunct in hernia repair. Application of these techniques for abdominal wall reconstruction can improve patient outcomes, and decrease surgical-site occurrences.

## Conclusion

Soft tissue management techniques can be utilized 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.

### Compliance with ethical standards

**Conflict of interest** IK declares no conflict of interest. JJ is a consultant for LifeCell, Bard, Daiichi Sankyo, and Pacira. He has received a prior honorarium from KCI. He receives royalties from Thieme Publishing.

**Financial disclosure statement** Dr. Janis is a consultant for LifeCell, Bard, Daiichi Sankyo, and Pacira. He has received a prior honorarium from KCI. He receives royalties from Thieme Publishing. Dr. Khansa has no financial disclosures.

**Ethical approval** All experiments in this article comply with the current laws of the country in which they were performed.

**Research involving human participants and/or animals** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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