Flap Reconstruction of the Abdominal Wall

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Abstract

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Due to the abundant and lax tissue of the abdominal wall, most ventral trunk defects are amenable to local soft tissue closure. However, when abdominal defects are accompanied by a lack of soft tissue, the surgeon faces a more complex subset of reconstructions. Three important principles guide the reconstruction of these wounds: timing of closure, careful assessment of the true extent of the wound, and the components of the defect. This article focuses on these three guiding principles and suggests the authors' preferred technique for these difficult defects.

Due to the abundant soft tissue and laxity of the abdominal wall, most abdominal wounds are amenable to local soft tissue closure. However, when abdominal wall defects are accompanied by lack of soft tissue, the surgeon faces a more complex subset of reconstructions. Indications for flap coverage vary by etiology of defect, defect characteristics, and timeline for closure. Multiple clinical scenarios can lead to a loss of abdominal wall soft tissue requiring flap reconstruction including massive ventral hernia with loss of domain, traumatic injury, soft tissue infection, oncologic resection, and septic evisceration.

Three important principles guide the reconstruction of these complex wounds. First, the timing of soft tissue flap coverage in abdominal wall reconstruction depends on the type of wound. Some defects benefit from early flap coverage, such as with oncologic resection. Other wounds are more appropriate for delayed flap coverage, such as those from traumatic or septic causes. Second, the true extent of the wound must be realized. The surface area of tissue loss and the amount of remaining local skin available for advancement must be factored into the reconstructive

plan. The surgeon must recruit what is available while acknowledging the limitations of scarred or unhealthy tissue. Lastly, the components of the wound should be assessed. Abdominal wall defects requiring soft tissue flap coverage can be classified as partial or full thickness defects. Partial defects involve the skin and subcutaneous tissue only, while full-thickness defects involve a composite loss of fascia, muscle, and skin and subcutaneous tissue. Partial defects imply the lack of coverage, while full-thickness defects also imply the lack of abdominal functional domain. An abdominal defect without adequate soft tissue available for coverage implies a catastrophic wound complication or resection. Adhering to the principles of abdominal wall reconstruction helps guide the surgeon to manage any defect encountered in their practice.

Timing

Historically, abdominal wounds were treated with wound care and allowed to heal over time by secondary intention or skin grafting. This resulted in a prolonged course of care and

significant morbidity. With time, the concept of delayed-primary closure gained popularity allowing certain patients with favorable wound characteristics to undergo closure after a short period of wound care, instead of being committed to weeks or months of an open abdomen wound environment. This enabled patients to achieve definitive wound closure without a skin-grafted surgical site and associated donor site morbidity.¹

Over the past 20 years, the role of negative pressure wound therapy (NPWT) has revolutionized the approach to wound care particularly in the management of abdominal wall defects. NPWT allows preservation of the wound environment by managing fluid and protein losses, decreasing bacterial contamination, and accelerating granulation tissue formation. In abdominal wall reconstruction, this translates into preserving the option for delayed primary closure or delayed flap reconstruction when immediate reconstruction is not possible.²

However, for patients with massive abdominal wounds, delayed primary closure or secondary healing is often not possible. While a “hot” abdomen should always be given time for swelling or infection to dissipate, patients with massive defects will never obtain reasonable coverage by prolonged waiting. In fact, most patients will only lose further domain. Soft tissue flap reconstruction therefore offers significant advantages. Flap reconstruction offers immediate and definitive wound closure, effectively ending the local tissue injury and inflammatory response seen in chronic open wounds. The respiratory and nutritional morbidity of an open abdomen can immediately be improved. In wounds requiring prosthetic mesh reinforcement, immediate closure reduces infection risk. Similarly, in defects requiring bioprosthetic mesh reinforcement, a closed environment diminishes the proinflammatory state of an open wound and limits the degree of enzymatic degradation of the bioprosthetic mesh during the incorporation phase.³

Wound Extent

When assessing a massive abdominal wall defect, the surgeon must use a trained eye to establish what remains and what is lost. In immediate reconstructions, tissue must be assessed for laxity and potential advancement. Additionally, friable or edematous tissue should be viewed with suspicion and removed if necessary. In the cases of oncologic resection, pathologic margins should be definitive. In areas of previous radiation, surgery, or burn, the tissue will certainly be hypovascular and hostile. In chronic wounds, the surgeon should plan for the wound to dramatically increase in dimension as scar bands and retractions are released. Curled wound edges, large areas of undermining, or sites of recurrent ulceration all point to unstable and unreliable tissue. Lastly, in the presence of stomas or conduits, the wound borders should be considered at the lateral extent of the stoma placement, as reinforcement will likely be necessary to prevent future parastomal hernia formation.

Wound Components

For partial thickness defects, early myofascial closure is paramount. The risk of developing a hernia increases sevenfold when bridging fascial repairs are performed instead of reinforced mesh repairs.⁴ When early fascial closure is not an option owing to ongoing debridement of the musculofascia or the need to perform a second-look laparotomy, a temporizing abdominal wall closure can be utilized such as the NPWT system. Once the musculofascial domain of the abdomen is achieved, several local or free flaps can be used for soft tissue coverage. While a skin graft is always a reasonable option in the very sick, it will never have the durability or cosmesis of a flap reconstruction.

In massive abdominal wall defects requiring flap reconstruction, composite full-thickness loss of the abdominal wall is most common. Reestablishment of musculofascial continuity is paramount to setting the stage for a durable abdominal wall reconstruction. Reconstituting the deficient myofascia converts the open abdomen to a more manageable abdominal wound by reestablishing domain.

When both the soft tissue and musculofascia require reconstruction, it is the authors' preference to reconstruct these two components with different techniques. Historically, before the introduction of mesh material for use in contaminated cases, myocutaneous flaps such as the tensor fascia lata flap were used to reconstruct full-thickness abdominal wall defects especially in the setting of wound contamination.⁵ Selecting a single myocutaneous flap to restore the musculofascial integrity and resurface the skin defect can compromise durability of the hernia repair, as well as lead to a perfusion-related complication (wound dehiscence, flap necrosis) at the skin level due to contradicting tension of the fascial inset.

Thus, for composite midline defects, the authors recommend myofascial reconstruction with either synthetic or bioprosthetic mesh materials. Surgeon preference and the variables of any given clinical scenario will determine whether bioprosthetic mesh or synthetic mesh is implanted. Regardless of the mesh type, the expectations are that the mesh will maintain the abdominal wall contour, without development of a hernia or bulge. In addition, the mesh should be able to interface with the intra-abdominal viscera without forming extensive adhesions or erosion that can lead to fistulization. Bioprosthetic and synthetic meshes can meet these expectations, and the decision to use either is based on patient comorbidities, wound contamination, prior radiation, availability of greater omentum, and the quality of the overlying soft tissue.

For massive abdominal wall defects, the reconstructive algorithm for cutaneous coverage of full-thickness defects usually incorporates advancement of the remaining local tissue flaps combined with regional pedicled or free flap reconstructions, as tissue is scarce. In select patients who have a long-standing deficiency, tissue expansion can be performed in the trunk to increase the surface area and availability of local fasciocutaneous flaps as an alternative to a pedicled or free flap donor site.

Overview of Soft Tissue Reconstruction by Region

The anterior abdominal wall can be divided into three anatomic regions: the epigastrium, the periumbilical region, and the hypogastrium (►Tables 1–3). The relationship of defects to these anatomic regions guide decision-making when regional pedicled flaps are planned for reconstruction.

Local Flap Options

Local flaps involve recruiting tissue adjacent to the wound defect. Well-planned incisions are critical to preserve blood supply to the local flap and avoid wound-healing complications at the donor site. There are various flap transposition designs available including advancement, rotation/advancement, interpolation, V-Y advancement, and bipediced flaps. These flaps can be oriented in any dimension; vertically, obliquely, or horizontally. Given that these flaps are perfused

through random or axial blood supply, the understanding of regional vascular angiosomes and perforator location is critical to designing robust flaps.

Previous incisions that cross an angiosome should be considered a disruption of the blood supply distal to it. When encountering a mature scar the surgeon can use his or her judgment regarding the vascularity of the tissue distal to the scar. However, the distal tissue should never be treated as surgically naïve and great care should be taken to avoid stressing it.

Another key factor in performing a local flap reconstruction is limiting tension across the wound closure both at the defect site and the donor site. It is counterproductive to reconstruct one part of the abdomen at the expense of creating a secondary wound. One strategy that can be employed to mitigate excessive tension across the flap is to transpose the flap to cover the defect and then skin graft the donor site. This concept is the mainstay of the bipediced flap in trunk reconstruction. For

Table 1 Abdominal wall flap reconstruction algorithm epigastric defects

	Local	Pedicled	Free
Epigastric	Transposition IM, IC, SE	Rectus	Thigh-based (ALT, AMT, VL, TFL, RF, STF)
	Keystone	Omentum	Back-based (LD, TAP, Scap/Para)
	Bipediced Fasciocutaneous		

Abbreviations: ALT, anterolateral thigh flap; AMT, anteromedial thigh flap; IC, intercostal epigastric artery perforator flap; IM, internal mammary artery perforator flap; LD, latissimus dorsi flap; RF, rectus femoris flap; Scap/Para, scapular/parascapular flap; SE, superior epigastric artery perforator flap; STF, subtotal thigh flap; TAP, thoracodorsal artery perforator flap; TFL, tensor fascial lata flap; VL, vastus lateralis flap.

Table 2 Abdominal wall flap reconstruction algorithm periumbilical defects

	Local	Pedicled	Free
Periumbilical	Transposition DIEP, SIEP, TLP	Rectus	Thigh-based ALT, AMT, VL, TFL, RF, STF
	Keystone	Omentum	Back-based LD, TAP, Scap/Para
	Bipediced Fasciocutaneous	Thigh-based	

Abbreviations: ALT, anterolateral thigh flap; AMT, anteromedial thigh flap; DIEP, deep inferior artery perforator flap; LD, latissimus dorsi flap; RF, rectus femoris flap; Scap/Para, scapular/parascapular flap; SIEP, superficial inferior epigastric artery perforator flap; STF, subtotal thigh flap; TAP, thoracodorsal artery perforator flap; TFL, tensor fascial lata flap; TLP, thoracolumbar perforator flap; VL, vastus lateralis flap.

Table 3 Abdominal wall flap reconstruction algorithm hypogastric defects

	Local	Pedicled	Free
Hypogastric	Transposition DIEP, SIEP, TLP	Rectus	Thigh-based ALT, AMT, VL, TFL, RF, STF
	Keystone	Omentum	Back-based LD, TAP, Scap/Para
	Bipediced Fasciocutaneous	Thigh-based	

Abbreviations: ALT, anterolateral thigh flap; AMT, anteromedial thigh flap; DIEP, deep inferior artery perforator flap; LD, latissimus dorsi flap; RF, rectus femoris flap; Scap/Para, scapular/parascapular flap; SIEP, superficial inferior epigastric artery perforator flap; STF, subtotal thigh flap; TAP, thoracodorsal artery perforator flap; TFL, tensor fascial lata flap; TLP, thoracolumbar perforator flap; VL, vastus lateralis flap.

midline defects, a bipediced fasciocutaneous flap from the thoracoepigastrium or intercostal perforators can be used unilaterally or bilaterally. The flap is oriented vertically with a minimum of a 3:1 length/width ration and maintains a blood supply from both the superior and inferior aspects of the flap. The flap is then directly transposed to resurface the defect and, by design, the donor site cannot be closed without an undue degree of tension. To offload the donor site tension, a skin graft is placed.

Perforator flaps are flaps based on a dominant named vessel that perfuses the entire flap through an organized vascular network. Perforator flaps present multiple options for flap design and rotation throughout the entire abdominal wall. Flaps based on internal mammary, superior epigastric, deep inferior epigastric, superficial inferior epigastric, and superficial circumflex iliac perforators provide local flap options in all zones of the abdominal wall. The keystone flap is one strategy to reconstruct large trunk defects with perforator flaps.⁶ Keystone flaps enable one stage resurfacing of both the defect and donor site. The flap is designed as a large 3:1 ellipse parallel to the long axis of the defect. The blood supply to the flap is based on cutaneous perforators that shift toward the defect when the flap is advanced. Once the leading edge of the keystone flap is inset, the donor site is closed on itself from the poles of the long axis of the flap to the side of the flap remote from the defect. The success of this flap is due to the transposition tension from the advancement and closure being distributed over the lengthy circumference of the flap skin island.

In summary, local flaps such as a bipediced flap or keystone flap may resurface a wound if it is favorably sized and the adjacent tissue is sufficient. In massive abdominal wall defects, local flaps can be combined with regional or free flaps to minimize additional tissue needed.

Regional Flap Options

In cases where the defect size exceeds the availability of local soft tissue for coverage, the next line of option is to consider a regional pedicled flap. Regional pedicled flaps are harvested from adjacent anatomic areas such as the chest, groin, thigh, or back. Pedicled flaps can be designed as fasciocutaneous flaps, myocutaneous flaps, or muscle flaps resurfaced with a skin graft. Options for pedicled flaps in the upper abdomen and epigastrium include the latissimus dorsi flap and omental flaps. Thigh-based flaps such as anterolateral thigh, vastus lateralis, and tensor fascia lata flaps are generally able to reach the hypogastrium and flank as pedicled flaps (→ Fig. 1). The periumbilical region is more challenging with large loss of domain. A contralateral component release, using the technique first described by Ramirez et al in 1990, can allow sliding of the innervated contralateral rectus abdominis, anterior and posterior rectus fascia, toward the midline.⁷ This technique is best used for moderate size defects in the periumbilical region and requires intact lateral musculature.

When selecting a pedicled flap, it is important to factor the donor morbidity incurred. As an example, a contralateral vertical rectus abdominis myocutaneous flap can be used to reconstruct a lower lateral abdominal wall defect; however,

the donor site closure may be difficult due to the tension and may predispose the patient to new hernias in the donor region.

Additionally, when selecting a flap, the pedicled flap's ability to "reach" the defect must be considered, as well as how the transferred flap will tolerate the rotational, flexion/extension forces placed on it by truncal movements. As an example, a vastus lateralis thigh flap can be used to resurface a hypogastric defect; however, the flap's pedicled vessels traverse the groin and their flow may be compromised by compression or rotation when sitting or flexing.

When the volume of tissue loss, resultant donor site morbidity, or the arc of the rotation needed precludes a pedicled flap transfer, a free flap is required for soft tissue coverage. Free flaps should be considered judiciously; however, for the massive abdominal wall defect, they are often the gold standard of reconstruction.

Free Flap Options

Microsurgical free tissue transfer enables the reconstructive surgeon to provide soft tissue coverage for abdominal wall defects that are not amenable to either local or regional flap coverage. Flaps of essentially any size, volume, dimension, and composition can be transferred from donor sites remote from the abdominal wall. While much more technically demanding, the evolution of microsurgical techniques enables successful free flap transfer in excess of 98% of cases.⁸

There are a multitude of free flap donor site options available for abdominal wall reconstruction. The torso and thigh are the main areas of flap harvest for defects extending from the upper abdominal wall and epigastrium to the suprapubic region. The posterior chest wall donor site yields the latissimus dorsi myocutaneous flap, scapular/parascapular fasciocutaneous flaps, and thoracodorsal artery perforator flaps. In addition, these flaps can be harvested together as a chimeric flap to increase the tissue volume for flap transfer. For example, in cases where a large skin paddle is required for the abdominal wall defect, a free scapular or parascapular flap can be designed on the circumflex scapular branch of the subscapular arterial system along with latissimus dorsi components on the thoracodorsal branch of the subscapular system.

When selecting a free flap, as with pedicled flaps, donor site morbidity must be considered. If a latissimus or serratus flap is harvested, the functional donor site impact must be considered as it relates to the weakened abdominal wall. Patients who have decreased core muscle strength will rely on the upper extremity strength and range of motion to complete activities of daily living. The impact of impaired shoulder and upper extremity movement should be considered in these patients.

In addition, in terms of logistical planning of a free flap procedure, the patient must undergo an intraoperative position change to facilitate flap dissection in the posterior chest wall. This adds complexity and additional time to the procedure and extends flap ischemia time. Therefore, thigh-based flaps are often preferred choices.

The thigh represents the mainstay for flap donor sites for the abdominal wall. The descending branch of the lateral

Fig. 1 Pedicled anterolateral thigh flap reconstruction of abdominal wall. (A) Preoperative view of open abdomen treated with negative pressure wound therapy. (B) Inlay biologic mesh reconstruction of the abdominal wall. (C) Pedicled left anterolateral thigh (ALT) myocutaneous flap delivered into lower abdominal defect. (D) ALT flap prior to inset. (E) Postoperative follow-up at 6 weeks.

circumflex femoral system provides blood supply to the vastus lateralis, rectus femoris muscles, and anterolateral thigh skin. The anteromedial thigh flap can be designed on medial perforators from the descending branch of the lateral circumflex femoral system. The transverse branch of the lateral circumflex

femoral system provides blood supply to the tensor fascia lata muscle.

These flaps can be harvested as muscle-only flaps, myocutaneous flaps, or fasciocutaneous flaps. For example, the rectus femoris muscle is more commonly designed as a

muscle flap; however, a skin island can be included over the central muscle when appropriate-sized cutaneous perforators are present. Additionally, the anterolateral thigh flap can be harvested with vastus lateralis or as a fasciocutaneous flap alone if a septal perforator is present or the perforator is amenable to muscle-sparing dissection.

Similar to the torso flaps off the subscapular system, these thigh-based flaps can be designed in any combination as chimeric flaps, that is, anterolateral thigh (ALT) with anteromedial thigh flaps, ALT with tensor fascial lata (TFL), and vastus lateralis with TFL. For massive abdominal wall defects, the vastus lateralis, tensor fascia lata, and the rectus femoris can be harvested with all overlying skin territory as a subtotal thigh flap for increased volume and skin coverage.⁹

Free Flap Recipient Vessels

The success of any free tissue transfer relies on the availability of suitable recipient vessels providing arterial inflow and venous outflow to the free flap. There are several recipient vessels available for abdominal wall reconstruction with free flaps. The main vascular axis in the central abdominal wall is the internal mammary superior epigastric–DIEP system. The internal mammary and deep inferior epigastric vessels provide large caliber 2 to 3 mm diameter recipient vessels for microanastomosis.

In cases where the internal mammary epigastric vascular axis is unavailable, the thoracodorsal pedicle or groin recipients can be reached by way of vein grafts. There are several options in the groin based on the superficial femoral system. The superficial inferior epigastric artery, the superficial circumflex iliac artery, and the deep circumflex iliac artery provide reasonable caliber vessels for free flap transfer to the lower central and lateral abdominal wall.

In addition, in abdominal wall reconstructions with concurrent laparotomy intra-abdominal vessels can be used as recipients. The omental and gastroepiploic vessels can be easily mobilized to reach the undersurface of the abdominal wall. Care must be taken in inseting and supporting the flap pedicle so that there is no tension on the anastomoses when the visceral contents shift when the patient transitions from supine to sitting/standing. Furthermore, the morbidity of reentering the abdominal cavity must be considered if there is a vascular thrombosis requiring flap reexploration. Lastly, when mesh is used for the musculofascial reconstruction the pedicle must traverse an aperture in the mesh. This may potentially increase the risk of pedicle kink and/or a hernia defect. For these reasons, local recipient options should be explored before intra-abdominal vessels are selected.

Vein grafts and arterialized vein loops can be designed to provide adequate recipient vessels in the central abdominal wall. Vein grafts can be harvested from either the upper or lower extremity as a cephalic vein graft or saphenous vein graft. For central and lower abdominal defects, an arterialized saphenous vein loop can be designed. The saphenous vein is dissected and transected distally and then anastomosed to the superficial femoral artery or a side branch. This loop is brought to the abdomen and divided near the flap pedicle, providing an arterialized afferent limb and a venous drainage efferent limb.

One advantage of this technique is that it only requires three vascular anastomoses instead of four as in the case with direct individual arterial and venous vein grafts.

Abdominal Wall Transplantation

Abdominal wall transplantation represents the zenith of abdominal wall flap reconstruction. It is used in very select patients only and it is generally reserved for patients undergoing single or multiorgan visceral transplants in which abdominal wall closure by autologous flaps is not technically feasible or presents significant donor morbidity. Abdominal wall closure after visceral organ transplantation is challenging in the setting of donor/recipient organ size mismatch, prior recipient abdominal surgery, and/or intestinal edema. While the risks of lifelong immunosuppression potentially outweigh the potential benefits of abdominal wall transplantation in healthy nontransplant patients, transplant patients are already bound to an immunosuppressive regimen and can benefit from the addition of allograft abdominal wall musculofascial tissue to reduce abdominal wall wound complication at the time of transplantation.

Extensive study of the vascular supply of the abdominal wall has allowed design of musculofasciocutaneous flaps based on the deep inferior epigastric system. These flaps can be transferred based on either the deep inferior epigastric vessels through microsurgical technique or the external iliac for a macrovascular anastomosis. Cipriani and colleagues describe a series of 15 abdominal wall transplants with three episodes of rejection salvage with modulating immunosuppression and two flap losses due to vascular thrombosis.¹⁰

Case Example

Patient RC is a 62-year-old male who presented with an extremely large and fungating abdominal wall sarcoma. Despite induction chemotherapy, the tumor size decreased minimally. He was taken to surgery for resection and a resultant 20 × 20 cm full-thickness defect was left that included resection of the bilateral rectus abdominis muscles and fascia and near total resection of the bilateral external oblique, internal oblique, and transverses abdominis muscles above the arcuate line. Additionally, the patient's fifth through seventh ribs, bowel, and liver were exposed. Local and pedicle flap options were inadequate both by size and reach. Immediate coverage was necessary to restore abdominal wall continuity (► Fig. 2).

Once pathologic margins were completed, the patient was reconstructed with a bridged bioprosthetic mesh and free anterolateral thigh myocutaneous flap. Mobilization of the remaining local tissue decreased the needed soft tissue to approximately 14 × 17 cm. The bioprosthetic mesh was sewn to the remaining ribs and lateral and inferior abdominal wall with permanent suture to restore the abdominal wall domain. A myocutaneous ALT flap was designed on the right thigh with the dimensions noted above. The vastus lateralis was included to provide optimal vascularized soft tissue interface with the bioprosthetic mesh and to increase

Fig. 2 Free anterolateral thigh flap reconstruction of the abdominal wall. (A) Abdomen after sarcoma resection with exposed intra-abdominal contents and ribs. (B) Bioprosthetic mesh to restore the intra-abdominal domain and free anterolateral thigh flap anastomosed to the deep inferior epigastric vessels. (C) Patient with healed wound and donor site 2 weeks postoperatively.

the vascularity of the skin paddle given the patient's significant smoking history. The flap was anastomosed to the right deep inferior epigastric artery and veins with interrupted 9-0 nylon and 3.0 and 3.5 mm couplers. His donor site was skin grafted for closure.

Postoperatively, the patient did very well. The patient was extubated in the operating room. By postoperative day 1, the patient was ambulating and started oral diet. His flap healed without issue and closed with wound without tension. Before surgery, the patient had chronic and foul-smelling drainage from his tumor. At the end of surgery, he had a closed wound that was left open to air and donor site that required ointment only.

Conclusion

In conclusion, abdominal wall defects requiring local, pedicled, or free flap coverage represent the most complex abdominal wall reconstructions. However, adhering to the principles of reconstruction, including accurate initial assessment of the defect, will guide the surgeon and provide a framework on which to build a solution. The body was built with redundancy and on this the skilled surgeon can capitalize.

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Conflict of Interest

None.

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