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Volume IV

Reconstruction of Trunk, Genitalia, Lower limb, and Maxillofacial Trauma

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Abdominal Wall Reconstruction

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Introduction

The anterior abdominal wall may be conceptualized as a semirigid shield that protects the abdominal viscera from external injury while acting as a functional aid to locomotion and respiration. The anterior abdominal wall may require reconstruction when there exists a deficiency or loss in its myofascial integrity with or without loss of cutaneous cover. Various genetic or external factors may be responsible for such a defect or deficiency. In terms of incidence, the most common etiologies for anterior abdominal wall defects are hernias (spontaneous and incisional), abdominal wall trauma (including mechanical, electrical, radiation injuries), necrotizing soft tissue infection and resection of abdominal wall tumors. Traditionally, the goal of managing such defects was primarily to ensure protection of the abdominal viscera and secondarily to restore abdominal wall function and its cosmetic appearance. Currently, both the goals are given equal importance because of the realization that simply achieving structural continuity does not prevent recurrence of the abdominal wall deficiency or laxity. Functional restitution of the abdominal wall is of utmost importance to prevent recurrence of a hernia, bulge, or laxity.

Anatomy of the Anterior Abdominal Wall

The gap in the skeletal system between the bony chest wall and the bony pelvis ("lacuna sceleti sternopubica") is enclosed anteriorly and posteriorly by the abdominal walls which join each other at the flanks.[1] The abdominal wall is composed of multiple tissue layers which encompass the abdominal viscera. The posterior abdominal wall is basically the retroperitoneum and will not be discussed in this chapter. The anterior abdominal wall is bounded superiorly by the osteocartilaginous framework of the thorax and inferiorly by the inguinal ligament. On both sides it extends up to the anterior axillary lines. The layers of tissue that form the anterior abdominal wall, however, are anatomically in continuity with the layers of tissue that form the anterior chest wall, flanks, and groin.

The anterior abdominal wall is composed of distinct layers of tissues, from the surface down the skin and superficial subcutaneous fat, Scarpa's fascia, deep subcutaneous fat, aponeurotic fascia of paired abdominal muscles, the paired abdominal muscles, extraperitoneal fascia, and the parietal layer of the peritoneum (**Box 2.1**).

The subcutaneous fat over the anterior abdominal wall has a rich vascular network supplied by perforators passing through the abdominal muscles, the subcostal and lumbar vessels, and from the superficial inferior epigastric vessels. Below the level of the umbilicus, there is a distinct fibrous membrane, termed Scarpa's fascia, situated deep to the subcutaneous fatty layer (which is termed Camper's fascia at this level). Scarpa's fascia merges with the superficial fascia of the chest superiorly, laterally with external oblique fascia, and inferiorly it is continuous with the fascia lata of the thigh. In the midline, it is contiguous with the linea alba. In males, at the inferior midline, Scarpa's fascia merges with the fundiform ligament, a fascial thickening at the pubic bone surrounding the base of the penis. There exists another layer of fat underneath Scarpa's fascia. Beneath this layer is the musculoaponeurotic layer that provides the structural framework of the anterior abdominal wall. The extraperitoneal fascia is situated deep to the musculoaponeurotic layer and has received different names based on its proximity to certain muscles, namely, transversalis fascia or the psoas fascia. The parietal layer of the peritoneum which forms the deepest layer of the anterior abdominal wall provides a smooth surface on which the mobile abdominal viscera may glide.

There are a total of five paired abdominal wall muscles which have a unique arrangement that not only allows the abdomen to expand and contract as required but also helps stabilize the trunk and aid in locomotion. The three flat muscles from superficial to deep are the external and internal oblique and the transversus abdominis. These muscles act in concert not only to allow distension of hollow abdominal viscera but also to increase abdominal pressure during expulsion of feces or fetus. These muscles while acting in concert also play an important role in respiratory mechanics.[2] The two cylindrical vertical muscles are the rectus abdominis and pyramidalis. These serve as a tensor of the anterior abdominal wall and also as flexors of the vertebral column.

The rectus abdominis originates at the pubic symphysis and pubic crest and inserts at the xiphoid process and fifth to seventh costal cartilages. It receives blood supply from both ends, by the superior and inferior epigastric vessels. Both muscles are enclosed in a fascial tunnel, which is formed by the intertwining aponeuroses of the three flat muscles of the abdomen. The external oblique muscle originates from the outer surface of the lower eight ribs, passes anteriorly and inferiorly to insert as an aponeurosis at the linea alba, pubic tubercle, and iliac crest. Inferiorly, the free edge of the external oblique aponeurosis folds on itself to form the inguinal ligament. The internal oblique muscle originates at the thoracolumbar fascia, iliac crest, and lateral half of the inguinal ligament and passes in a direction orthogonal to the external oblique fibers and inserts as an aponeurosis at the inferior border of 10th to 12th ribs, linea alba, and pubis.

Box 2.1 Layers of the anterior abdominal wall

- Skin
- Superficial subcutaneous fat
- Scarpa's fascia
- Deep subcutaneous fat
- Paired abdominal muscles and aponeurosis
- Extraperitoneal fascia
- Parietal layer of the peritoneum

The transversus abdominis muscle originates from the internal surface of the lower six costal cartilages, thoracolumbar fascia, iliac crest, and lateral half of the inguinal ligament and inserts as an aponeurosis at the linea alba, pubic crest, and pecten pubis.

The intersection of these three aponeuroses is particularly pronounced at the two semilunar lines, situated lateral to the rectus muscles and at the linea alba, situated in between the recti. Fibers of the aponeurosis intertwine in a particular fashion in front and posterior to the recti and are termed anterior and posterior rectus sheath, respectively. The anterior sheath extends from the xiphoid to the pubic symphysis. The posterior sheath, however, is absent from a point midway between the umbilicus and the pubis, and its inferior free edge is termed the arcuate line. The gap in the aponeurosis maybe presumed to be present to allow the deep inferior epigastric vessels, which arise from within the pelvis, to provide vascular supply to the recti. The recti are adherent to the anterior rectus sheath by three to four tendinous intersections. Lateral to the semilunar line, the external oblique and internal oblique aponeuroses and muscles are completely separate from each other, providing an avascular plane for surgical dissection right up to the midaxillary line.

Sensory and motor nerves supplying the anterior abdominal wall originate from the spinal nerves. The ventral rami of thoracic 5th to 11th and subcostal (thoracic 12th) nerves provide motor innervations to the anterior abdominal wall and these nerves run between the internal oblique and transversus abdominis muscles. This plane should not be violated while reconstructing the anterior abdominal wall, since dividing the motor nerves will lead to a poor abdominal tone. It is important to note that since the motor supply to the recti run from the lateral to the medial side, a lateral defect in the anterior abdominal wall will also result in loss of motor supply to the recti and cause further loss in abdominal wall tone, despite a structural restitution. The ilioinguinal nerve passes between the internal oblique and transversus abdominis muscles to supply the hypogastric region and iliac crest. The iliohypogastric nerve innervates the skin of the scrotum, labia, mons pubis, and the medial thigh.

Vascular Supply of the Anterior Abdominal Wall

The cutaneous blood supply of the abdominal wall was described by Huger,[3] which has been supported by the anatomical studies of Taylor et al.[4] According to Huger, the abdomen can be divided into three zones "*for descriptive purposes*" (**Fig. 2.1**). Zone I covers the area for xiphoid to suprapubic area and extends up to the semilunar lines laterally. It is supplied by the perforators of the deep epigastric system which consists of the deep inferior epigastric artery (DIEA) and the superior epigastric artery. The umbilical skin is supplied primarily by perforators from bilateral deep epigastric vessels.[5] Zone II covers the lower abdomen "*below a line arbitrarily drawn at the level of the anterior iliac spine*." It is supplied by the external iliac system, which comprises the superficial inferior epigastric artery and superficial and deep circumflex iliac arteries. Zone III bilaterally covers an "*area around the flank*" lateral to the semilunar lines. It is supplied by the intercostal, subcostal, and lumbar arteries which arise from the aorta. These vessels traverse the plane between the internal oblique and transversus muscles and perforate the oblique muscles to supply the skin over zone III. These three zones are connected to each other via numerous anastomoses and choke vessels. It is important to note that Huger's zone IIII perforators need to be preserved while raising a standard abdominoplasty flap, as the vascular supply to the flap from zones I and II are necessarily divided during this surgery.

The DIEA is a branch of the external iliac artery. After its emergence from the medial wall of the external iliac artery, it pierces the transversalis fascia and runs on the undersurface of the rectus abdominis muscle till the arcuate line. Here, it gives off two branches: medial and lateral. Rarely, it gives a third branch which supplies the umbilicus. The medial and lateral branches give off perforators which supply the fasciocutaneous tissue overlying the midabdomen. Each of them gives rise to four to seven perforating vessels mainly clustered at the periumbilical region. At this region, there are anastomotic connections to the superior epigastric artery which is a continuation of the internal mammary artery.

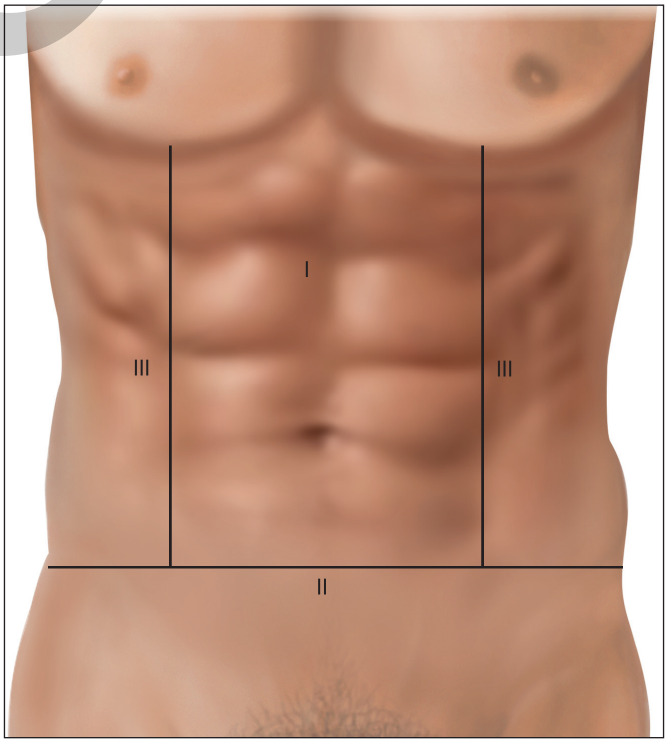


Fig. 2.1 Huger's zones of abdominal wall vascular supply.

The deep circumflex iliac artery (DCIA) is also a branch of the external iliac artery. It travels along the iliacus muscle and gives off a large ascending branch 1 cm medial to the anterior superior iliac spine (ASIS). At the flank, it anastomoses with the lumbar and the iliolumbar arteries. The perforators supply a small area of skin over the iliac crest.

The superficial inferior epigastric artery (SIEA) is a branch of the femoral artery arising 3 cm below the inguinal ligament. The vessel travels from its origin and pierces Scarpa's fascia approximately 0.5 to 5 cm above the inguinal ligament midway between the ASIS and pubic tubercle. It travels above the fascia as it branches medially and laterally to supply the lower abdominal skin.

The superficial circumflex iliac artery (SCIA) is also a branch of the femoral artery. It supplies the skin and subcutaneous tissue of the inferior part of the anterolateral abdominal wall bilaterally.

Clinical Presentations Requiring Abdominal Wall Reconstruction

Presentation of a Patient with a Ventral Hernia

Patients requiring abdominal wall reconstruction have varied presentations to the reconstructive surgeon, the most common being an incisional hernia that is an iatrogenic sequel to a laparotomy. In these situations, the skin overlying a deficiency in the myofascial layer of the abdomen is generally intact. Rarely, there may be ulceration of the overlying skin due to pressure necrosis. Incisional or ventral hernias are generally large openings in the abdominal wall and are at very low risk for intestinal strangulation. The patients often complain of pain and difficulty in evacuation of bowels. It is important to assess the patient in detail with particular emphasis on the medical comorbidities that may have caused the poor healing of the abdominal wall. Malnutrition, protein deficiency, and obesity have been known to cause poor wound healing after abdominal surgery.

Persistence of a gastrointestinal source of sepsis needs to be controlled first before embarking on a plan for abdominal wall closure. Presence of intestinal fistulae, stoma, and radiation-related changes over the anterior abdominal wall needs to be evaluated meticulously and may change the operative plan.

History of multiple surgeries in the past may have damaged or altered the blood supply to the skin over the anterior abdominal wall. This will alter the placement of access incisions during reconstructive surgery.

In addition to addressing the anatomical parameters, physiological status of the patient needs to be optimized as well before embarking on a complicated surgery. Smoking cessation for a minimum of 4 weeks,[6] optimization of diabetic state,[7] reduction of excessive body weight,[8] and nutritional optimization will contribute toward a positive outcome in patients presenting with large and complex abdominal wall hernias.

Presentation of a Patient with Open Abdomen

The next most common presentation is that of an open abdomen, which is impossible to close primarily by the general surgeon often following an emergency laparotomy for trauma or sepsis. In the emergency situation, it is always prudent to use a temporizing technique like simple skin closure, use of a plastic bag, or a negative-pressure wound sponge to close the abdomen.[9] Once the damage is controlled and the source of sepsis controlled, the patient is then optimized for a more definitive plan of reconstruction.

Presentation of a Patient with an Abdominal Wall Tumor

The other presentations include a large tumor involving a large part of the anterior abdominal wall musculature and the skin. The surgery is thoroughly planned preoperatively with the excisional surgeon such that the defect, components of the abdominal wall being excised, the components to be reconstructed, and the donor sites for flap are evaluated comprehensively. If no local or regional tissue is available for reconstruction, microvascular tissue transfer may be considered. The preoperative imaging of the tumor and vascular imaging of the planned flap donor site are very important in these patients.

Preoperative Imaging

In addition to physical assessment of abdominal wall strength and defect characteristics, various imaging modalities are routinely used as an adjunct to physical assessment and to visualize vascular supply to the anterior abdominal wall. Abdominal computed tomography (CT) and CT angiography (CTA) are the imaging modalities of choice in these patients. CTA also aids in identifying recipient vessels for microvascular tissue transfer.

Classification of Abdominal Wall Defects

It is difficult to understand the various techniques used to reconstruct the abdominal wall without deconstructing the various methods used across the world. Mathes et al were the first to classify abdominal wall defects based on the availability of stable skin cover.[10] I have classified all defects of the anterior abdominal wall into three types based on the management required for these defects (**Box 2.2**).

Box 2.2 A classification of defects of the anterior abdominal wall

Type I.	Deficiency or dehiscenc of the myofascial layer alone Ia. Midline or Ib. Lateral location
Type II.	Deficiency or defect in the myofascial layer with loss of overlying skin IIa. Midline or IIb. Lateral location
Type III.	Skin defects with preservation of the myofascial layer

Principles of Abdominal Wall Reconstruction

The anterior abdominal wall construct may have a dehiscence of its myofascial layers or an actual loss of tissue with a resultant defect. Although both result in defects of the wall, the former is usually a result of failed primary closure of a laparotomy wound and the latter occurs usually following extirpation of a tumor or traumatic loss. Detachment of myofascial units from the ribcage superiorly, the pubis inferiorly, or the linea alba in the midline is generally not accompanied by an actual loss of tissue elements and results in bulging of the abdominal viscera under the intact skin. These hernias may present as an asymptomatic bulge or a painful bulge with features of early or established intestinal obstruction. Sometimes, large hernias can lead to loss of domain of the abdominal viscera and present with severely restricted daily activities and back pain due to the musculoskeletal imbalance of the trunk. These problems may get automatically corrected with restoration of the structural integrity of the abdominal wall. Acute traumatic loss (surgical or otherwise), however, will need restitution of both myofascial units and skin simultaneously. The reconstructive efforts, however, have to be tempered to individual needs and requirements with due consideration given to age, comorbidities, lifestyle, disease stage, donor site issues, morbidity, and available resources.[11] These defects may be closed using various techniques that have been elaborated in **Box 2.3**.

Box 2.3 A classification of definitive closure techniques for anterior abdominal wall defects

A. Wall displacement techniques
- Components separation (with[12] or without[13] prosthesis)
- Flaps based on abdominal tissues with prosthesis[14]

B. Wall replacement techniques
- Prosthetic closure alone
- Flaps based on nonabdominal tissues with prosthesis[15]
- Autologous functioning muscle transfer (with or without prosthesis)[16]
- Vascularized abdominal wall allograft[17]

Reconstruction of Type I Defects

Type I defect is a pure deficiency or dehiscence of the myofascial layer with an intact overlying skin. These defects are ventral hernias located either centrally or in the lateral part of the anterior abdominal wall. For type Ia dehiscence medial to the semilunar line, the components separation technique is generally the preferred method of definitive reconstruction.[18] For type Ib deficiencies lateral to the semilunar line, especially in patients with hernia formation after transverse or subcostal incisions, components separation is not a viable option for reconstruction, and a prosthetic closure is most commonly preferred. Butler and Kapur have defined the lateral abdominal wall as an area that extends between the costal margin superiorly, the iliac crest inferiorly, the semilunar line medially, and the paraspinous muscle complex laterally.[19]

A neonatal omphalocele presenting with a dehiscence of the recti with a central herniation of visceral contents is a type Ia defect.[20] These defects maybe closed using a prosthetic mesh or using the components separation technique. Anterior abdominal wall deficiencies in a patient with bladder or cloacal exstrophy also require reconstruction.

An acute postoperative failure of primarily closed midline laparotomy wound is termed a "burst abdomen." A more chronic variant with an intact overlying skin is termed a ventral hernia. Both are type I defects. In acute conditions, following damage control laparotomy for trauma or sepsis when the abdomen cannot be primarily closed, to prevent development of abdominal compartment syndrome or for the purpose of a relook laparotomy, various techniques have been employed for temporary abdominal closure. These include simple packing of the wound, clips for closure of the skin alone, Bogota bag (sterile plastic bag or silo), zipper devices, and the negative-pressure wound therapy devices placed over a porous polyethylene sheet.[21] If fascial closure is deemed impossible, it is generally advised to wait for granulation to appear over the exposed surface of viscera and then apply a meshed skin graft. This converts an open wound into a closed one. Once the wound has healed completely, the skin graft needs to be removed and patient prepared for a definitive abdominal wall closure. This may be achieved in one of two ways. One method is to dermabrade the epidermal layer of the skin graft and then close the abdominal wall. The second method is to wait for approximately 6 months, when a thin layer of loose areolar tissue develops between the skin graft and the viscera, which makes it safe for a straightforward excision of the skin graft. Once this is achieved, the patient may be prepared for a definitive closure using a components separation technique or any other method deemed suitable.

In type Ib deficiencies and hernias following transverse or subcostal incisions, a prosthetic closure of the defect is the most favored approach among reconstructive surgeons.[22] This is because the lateral abdominal wall has a higher proportion of muscular tissue to aponeurosis which prevents an accurate and balanced aponeurotic closure. Moreover, the forces along the borders of the hernia defect are also asymmetric owing to the pull of the muscles, unlike the uniform and symmetric arrangement of aponeurotic tissues in the median part to the abdomen.[23] A vascularized fascial flap from the thigh has also been described for reconstructing the fascial continuity of the lateral abdominal wall.[24]

Various prosthetic devices, commonly termed "mesh" or "bioprostheses" depending on their synthetic or biological manufacturing process have been described since the middle of the 20th century.[25] It has been comprehensively proven that using a mesh is superior to primary fascial closure for preventing recurrence of a midline ventral hernia.[26] One of the first prostheses to be used for restoring the structural integrity of the abdominal wall was a synthetic polypropylene mesh.[27] Because of the large pore size of a polypropylene mesh (> 75 µm), these were associated with high rates of enteric adhesion, fistulization, and subsequent infection requiring resurgery and mesh removal.[28] The use of bioabsorbable polyglactin meshes were associated with lesser incidence of fistulization but higher incidence of hernia recurrence once the mesh resorbed completely over a period of 120 days.

Usage of expanded polytetrafluoroethylene (ePTFE) mesh resulted in lesser degrees of bowel adhesion, due to a small pore size (< 10 µm) but no integration of the mesh to the abdominal wall and a higher rate of infection.[29] The reason for a higher infection rate was due to the minute size of the pores in ePTFE mesh (< 10 µm) that allow bacteria (~ 1 µm in size) to enter its interstices but not macrophages and neutrophils (> 10 µm in size).[30]

In the 1990s, biological prostheses like acellular human dermal matrix and acellular porcine matrix were introduced to the surgeons as an alternative to the synthetic prosthesis especially for contaminated fields.[31] These biological matrices are processed allogenic or xenogeneic collagen molecules which intend to provide a lattice framework, allowing native tissue and vascular ingrowth, and are eventually replaced by native collagen molecules. Unfortunately, in vitro experience with these biologicals has not translated into actual in vivo advantages. The data suggests that the ongoing remodeling is neither complete nor organized and as a result the resultant abdominal wall laxity or recurrent hernia has not been completely eliminated using these techniques.[32] What remains critically important is not the composition of the prostheses but their accurate placement not only in the desired plane but also under the desired tension.

Laparoscopic and robotic repair[33] of ventral hernias using prosthesis has been described in the literature and are routinely performed by general and laparoscopic surgeons. The prosthesis used in these patients is commonly ePTFE mesh placed intraperitoneally.[34] In patients who desire an abdominoplasty along with ventral hernia repair, the laparoscopic approach results in lesser incidence of wound complications and improved aesthetics.[35] Although, abdominoplasty in conjunction with open ventral hernia repair has been described, these studies have reported a high incidence of wound complications and hernia recurrence.[36] Concurrent panniculectomy with open ventral hernia repair has also been shown to increase risk of wound complications, venous thromboembolism, and unplanned reoperation.[37] It is therefore recommended that before embarking on an abdominoplasty/panniculectomy with a ventral hernia repair in a patient with comorbidities, an honest discussion with the patient regarding the pros and cons of a simultaneous versus a staged procedure should be undertaken by the operating surgeon.

Reconstruction of Type II Defects

Type II defects present with a loss in the myofascial layer and the overlying skin. These defects are generally created following tumor excision (like dermatofibrosarcoma, desmoid tumor, and other soft tissue sarcomas) or following massive abdominal trauma or failed bladder exstrophy repair. These defects require two components for reconstruction, namely, restoration of the structural integrity of the abdominal wall and provision of a durable skin cover. Hence, abdominal wall replacement techniques are preferred for reconstructing such defects. If a musculocutaneous flap is used, the muscle component of the musculocutaneous flap may be neurotized using donor fascicles from the intercostal, subcostal, or the first lumbar nerves.[38] The neurotized muscle maintains its tone and does not atrophy with time so as to prevent the occurrence of a hernia/bulge. Type II defects that are closed using a fasciocutaneous flap alone will result in a postoperative bulge and hernia formation and hence a prostheses must be used in conjunction with these flaps for additional structural support.[39] Even when a neurotized free muscle flap is used for single-stage reconstruction, it is prudent to use a mesh underneath the muscle, since the coapted nerve may or may not function adequately.[40] Pedicle flaps used for skin cover are generally rectus abdominis musculocutaneous flap (for central supraumbilical defects), latissimus dorsi musculocutaneous flap (for lateral supraumbilical defects), and tensor fascia lata or the anterolateral thigh perforator flap (for infraumbilical defects).[41-43] The reach of a thigh flap may be increased by tunneling the thigh flap under the rectus femoris muscle.[44] **Fig. 2.2** shows a type IIa defect following failed repair of a bladder exstrophy, closed using a pedicled anterolateral thigh perforator flap and a prosthesis. **Fig. 2.3** shows a type IIb defect following excision of an abdominal wall tumor, closed using a pedicled anterolateral thigh flap and a prosthesis. Some type II defects maybe converted into a type I defect by prudent planning of incisions and wise usage of locally available abdominal skin flaps. **Fig. 2.4** shows a type IIa defect over the epigastrium following excision of a metastatic tumor, being reconstructed using a rectus abdominis muscle transposition flap

Fig. 2.2 **(a)** Type IIa defect following repair of exstrophy bladder. **(b)** Defect covered using a polypropylene mesh and an anterolateral thigh perforator flap is planned. **(c)** Flap transposed over defect with pedicle superficial to the rectus femoris muscle. **(d)** Flap transposed over defect with pedicle deep to the rectus femoris muscle. **(e)** Final inset of flap with primary closure of donor site. (These images are provided courtesy of Dr Santanu Suba, Kolkata, West Bengal, India.)

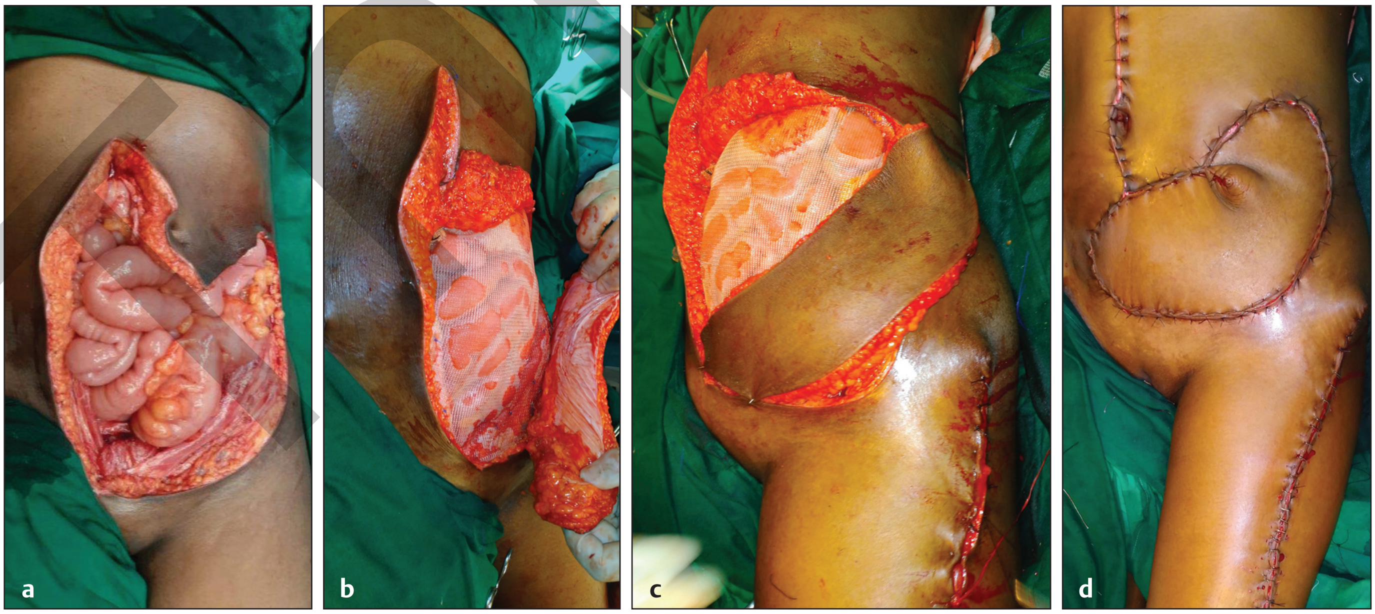
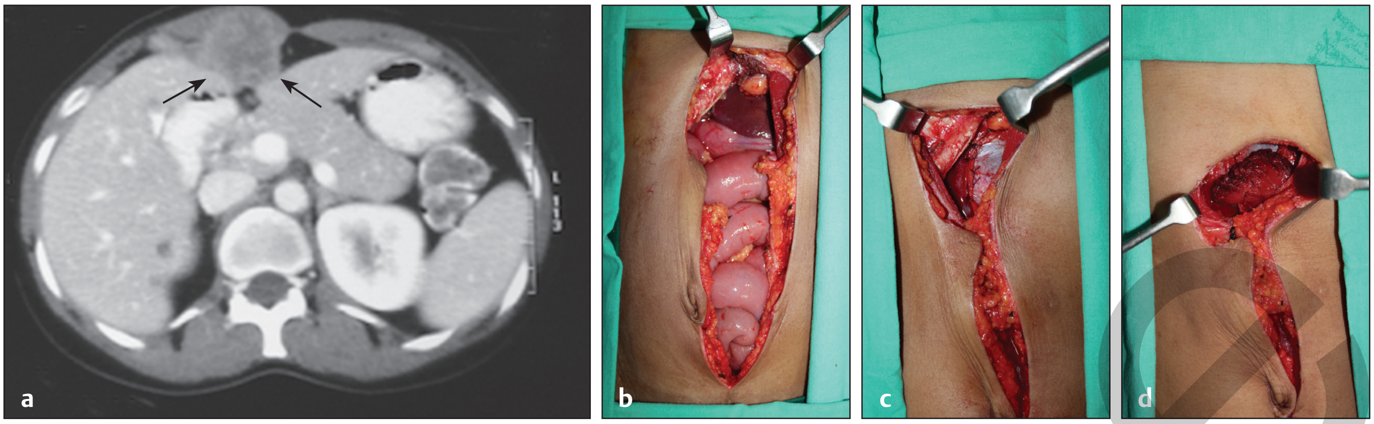


Fig. 2.3 **(a)** Type IIb defect following tumor excision. **(b)** Anterolateral thigh flap tunneled under a skin bridge to reach the defect. **(c)** Flap inset over polypropylene mesh. **(d)** Final flap inset with primary closure of donor site. (These images are provided courtesy of Dr Vinay Shankhdhar, Mumbai, Maharashtra, India.)



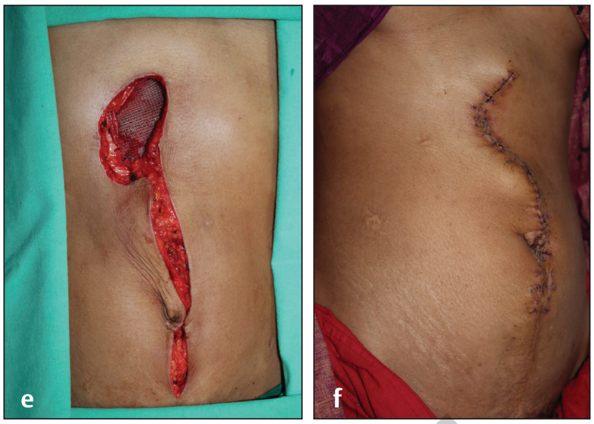


Fig. 2.4 **(a)** CT scan with *arrows* showing a metastatic tumor involving the anterior abdominal wall. **(b)** Type IIa defect following removal of abdominal wall tumor. **(c)** Primary fascial repair achieved for lower incision with upper abdominal defect with loss of upper half of the right rectus muscle and sheath. **(d)** Left rectus muscle transposed as a inferiorly based muscle flap to cover the defect. **(e)** Polypropylene mesh used to buttress the defect. **(f)** Local abdominal skin flaps advanced to close the defect.

buttressed with a polypropylene mesh. The locally available skin was used as an advancement flap for skin closure.

On rare instances, a type IIa defect is seen to result from a ventral hernia which has suffered multiple failed attempts at repair and the skin over the rectus muscles have undergone necrosis with healing by second intention. In these situations, although the fascial layers may be repaired using the components separation technique, the local skin is insufficient to provide cover. In these rare scenarios, a tissue expander is used preoperatively to expand the skin over the lateral abdomen, which is advanced to cover the resultant defect.[45]

Reconstruction of Type III Defects

Type III defects present with a skin defect over the abdominal wall with a preserved myofascial layer. Skin defects maybe closed using any technique chosen to be feasible, for example, advancement of abdominal skin flaps, local perforator flaps, tissue expansion or free flaps. It is aesthetically pleasing to place the final scar, if possible, in such situations in the inguinal crease as seen following standard abdominoplasty operations. **Fig. 2.5** shows an upper abdominal wall tumor involving the skin alone being closed using a rotation design abdominal perforator flap.

Description of Specific Methods of Abdominal Wall Closure

Components Separation of the Abdominal Fascia

Although release incisions of the external oblique aponeurosis for closing ventral hernias had been described earlier by Albanese in 1966, it was Ramirez who systematically tested the medial mobility of the rectus muscle with its overlying sheath and the skin in cadavers.[18] He found the external oblique muscle to be the most inelastic among the three flat muscles of the anterior abdominal wall. To achieve medial movement of the “sliding rectus abdominis muscle flap” without compromising on lateral abdominal wall integrity, he suggested the mobilization of the rectus muscle in the retro-rectus plane in addition to longitudinal division of all the fibers of the external oblique aponeurosis lateral to the semilunar line. A medial pull on the edge of the linea alba would then allow substantial medial movement of the rectus muscle and allow stretching of the internal oblique and transverses abdominis muscles (**Figs. 2.6 and 2.7**). This advancement was found to be maximal at the waistline (~ 10 cm unilaterally) and much less at the epigastrium (5 cm) and suprapubic region (3 cm). In effect, a 20-cm-wide

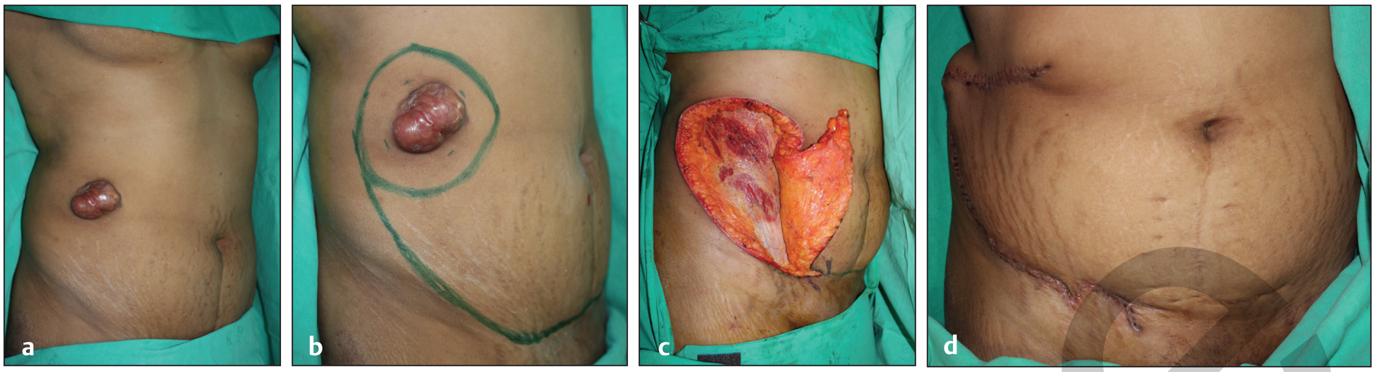


Fig. 2.5 **(a)** Desmoid tumor over the abdomen. **(b)** Defect following excision planned to be covered using a rotation design flap from the abdomen. **(c)** Defect with elevation of rotational design flap based on the deep inferior epigastric artery perforators. **(d)** Closure of defect using the rotation design perforator flap.

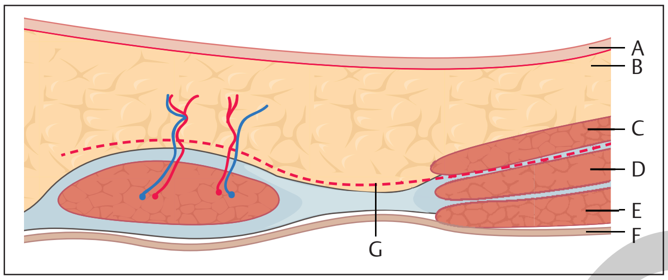


Fig. 2.6 Components separation technique as described by Ramirez. The dotted line represents the incision through the subcutaneous tissue and then through the external oblique aponeurosis just lateral to the semilunar line. (A) Skin. (B) Subcutaneous tissue. (C) External oblique muscle. (D) Internal oblique muscle. (E) Transversus abdominis muscle. (F) Peritoneum. (G) Incision line.

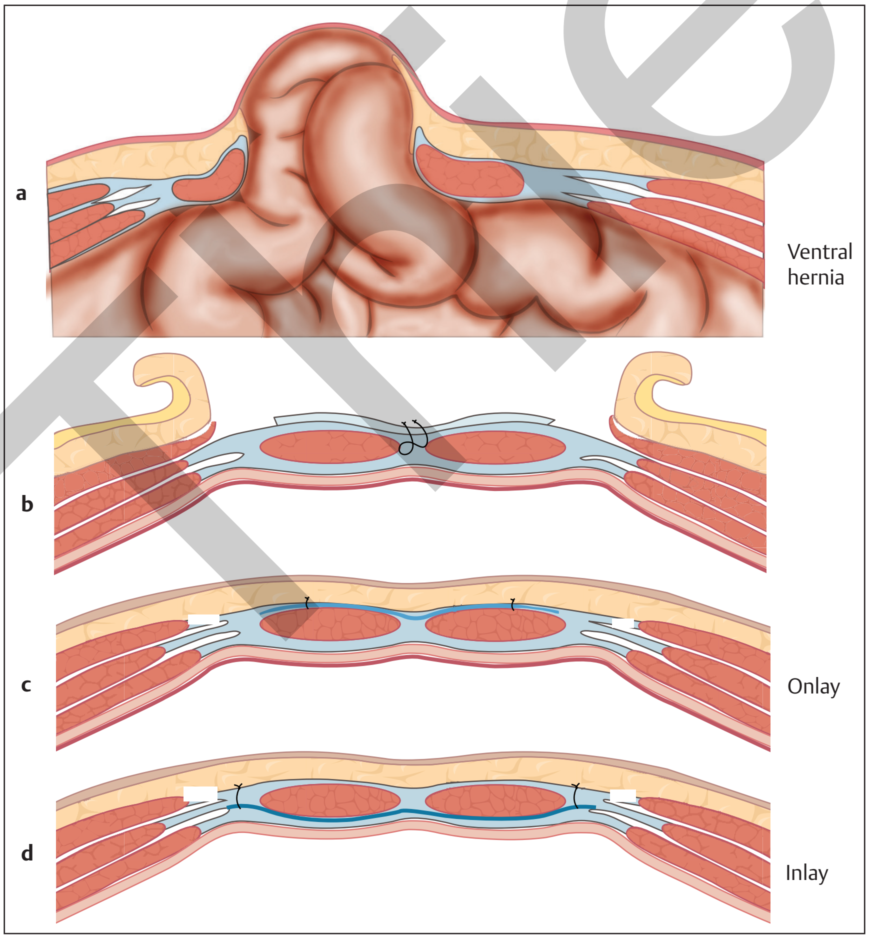


Fig. 2.7 Components separation. **(a)** A patient presenting with a ventral hernia with complete dehiscence of the linea alba. **(b)** Components separation technique of Ramirez is used to incise the external oblique aponeurosis and pull both the rectii towards the midline. **(c)** An onlay prosthesis is placed over the approximated rectii under the subcutaneous fat. **(d)** An inlay prosthesis is placed on the peritoneum and under the rectii. Note the sutures placed in black to hold the prosthesis in position.

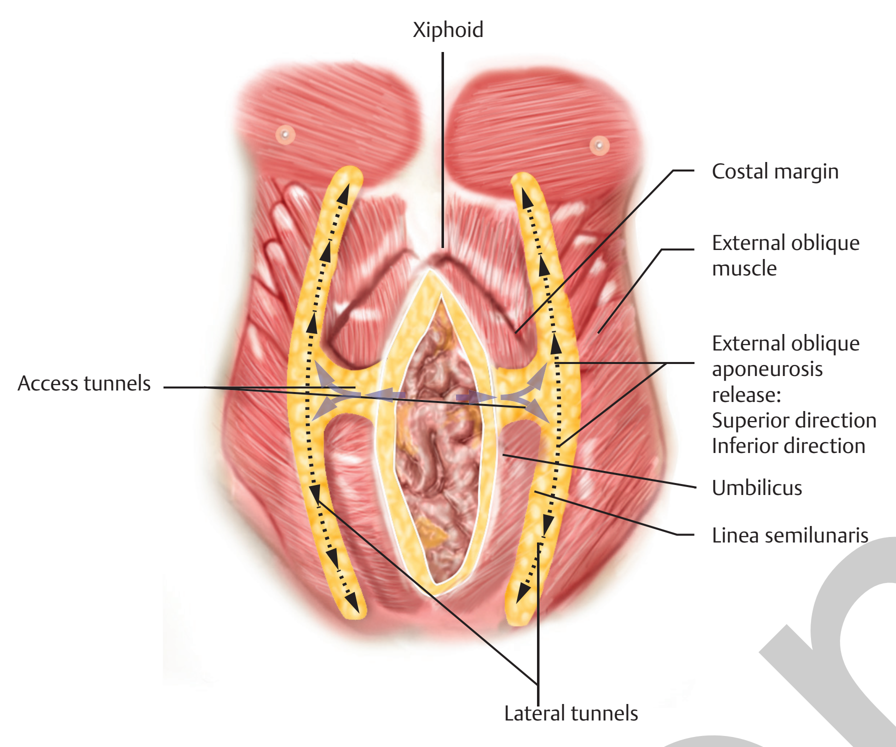


Fig. 2.8 Diagram showing the release incisions made over the skin and subcutaneous tissue in preparation for perforator preserving components separation.

defect in the area of the waistline could hence be closed applying this technique bilaterally. The advantage of this sliding flap is that it has an intact innervation thereby preventing the development of any abdominal wall laxity in the future.

Numerous modifications of the anterior components separation of Ramirez have been described till date. Originally, the skin and subcutaneous tissue used to be widely undermined over the external oblique before the aponeurosis was incised (**Fig. 2.6**). However, issues with vascularity of the overlying skin and subsequent wound healing led to minimal access transverse incisions in the lateral abdominal skin through which the aponeurosis could be divided (**Fig. 2.8**). A perforator-sparing approach of elevating the lateral skin off the rectus sheath to reach lateral to the semilunar line has also been described.[46] Endoscopic approaches for anterior components separation using a balloon inserted in the subcutaneous[47] or subfascial plane (under the external oblique aponeurosis)[48] and using a trocar system[49] are also described in the literature.

The use of botulinum toxin for paralyzing the flat muscles of the abdomen has been described for aiding closure of large ventral hernias.[50] Botulinum is injected directly into the individual flat muscles namely the external oblique, internal oblique, and the transversus abdominis under electromyographic or ultrasound guidance. This technique has been used to aid secondary closure of open abdomens as well.[51]

Transversus abdominis muscle release as an alternative myofascial advancement without releasing the external

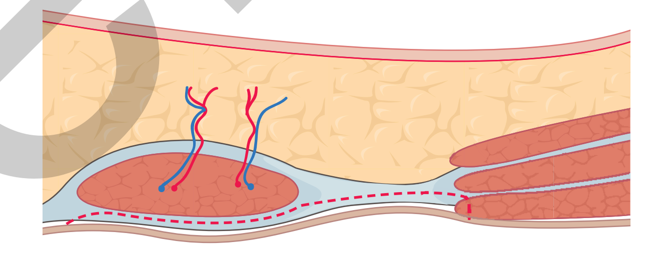


Fig. 2.9 Posterior components separation. The dotted line represents the incision through the posterior rectus sheath twice. First, at the medial border of the rectus muscle and second just medial to the semilunar line. The last incision is made through the transversus abdominis muscle, just lateral to the semilunar line.

oblique and thereby avoiding raising of abdominal skin flaps has also been described in the literature. In this technique, the posterior lamella of the internal oblique is first released (just medial to the semilunar line) followed by division of the transversus abdominis muscle (just lateral to the semilunar line), thereby preserving the neuromuscular bundles at all times (**Fig. 2.9**).[52] The preperitoneal space is then accessed and wide dissection is performed to enable insertion of a broad mesh which extends bilaterally deep to the internal oblique and rectus abdominis muscles but superficial to the peritoneum and bilateral posterior rectus sheaths. The prosthesis is thereby protected from the underlying bowel and also gets incorporated into the muscles of the anterior abdominal wall to provide optimal structural restitution of the abdominal wall. This submuscular placement of the mesh also has the advantage of virtually eliminating the incidence of seromas that is seen commonly with onlay placement of the mesh under the adipose tissue (**Fig. 2.7**). It is important to note that at no point should the mesh be in direct contact with the bowel to prevent adhesions and subsequent fistulization.[53]

Regional and Free Flap Cover

Soft tissue coverage for reconstructing the anterior abdominal wall may be required following tumor resection, blunt or penetrating trauma with loss of tissues, radiation-induced skin necrosis, necrotizing soft tissue infections, and electrical injury. Need for a regional or free flap cover is felt when the locally available tissue may not be adequate to resurface the abdominal wall defect. In addition to soft tissue cover, careful attention must be paid to restoring the structural and functional integrity of the abdomen and cosmesis. The timing of reconstruction needs to be adjusted such that local wound bed is optimal for receiving the flap cover. Negative-pressure wound therapy has been extensively used for the purpose of providing temporary wound cover while allowing the physiological parameters of the patient to be optimized.

Skin grafting the exposed surface of the viscera and a delayed definitive abdominal wall closure is generally recommended in these patients who require additional visceral surgery. On rare occasions, an emergency free flap is required for coverage of the exceptional injuries sustained in a blast injury or high-voltage electrical injury (**Fig. 2.10**).

The back, groin, and the thigh are the most commonly used donor site for regional and free flaps. The upper and lateral abdominal defects are most commonly covered using the latissimus dorsi muscle or musculocutaneous flap with or without the serratus muscle. The infraumbilical abdomen can be covered using the anterolateral thigh perforator flap or the tensor fascia lata perforator flap.[54] The pedicle is generally dissected as superiorly as possible and the flap may need to be transposed medially by dividing the rectus femoris muscle in order to improve the reach of the flap. All flaps are planned in reverse.[55]

If the regional flaps do not reach the defect, the pedicle will need to be divided and the flap transferred as a free flap. Choosing the recipient vessels in these cases is critically important. Generally, the internal mammary vessels are used for flaps required for upper central abdominal defects. The deep inferior epigastric vessels are selected for flaps being inset lower in the abdomen (**Fig. 2.11**). In the absence of suitable vessels, vein grafts or loops are required to increase the length of the pedicle. The greater saphenous vein may be dissected till the lower thigh and the cut end anastomosed to the femoral artery to form an arteriovenous loop, which is then transposed to reach the abdomen and divided to function as a recipient artery and vein.[56] This in effect requires only three anastomoses rather than four, when two separate vein grafts are used. Rarely, the omental and gastroepiploic vessels are used as recipient. However, the latter has numerous disadvantages, namely, the possibility of tension on the anastomosis while insetting the flap, the morbidity of a laparotomy if a pedicle thrombus occurs, and finally, the need to make a hole in the mesh or lower chest wall to bring the pedicle out, which may lead to a kink and also a chance of occurrence of an hernia.[57] When the abdominal wall defect is large, two free flaps harvested from both thighs have been described for reconstructing the abdominal wall with anastomosis performed in a flow-through fashion.[58]

Abdominal Wall Transplantation

Transplantation of an abdominal wall as a vascularized composite allograft (VCA) was first described in 2003 for

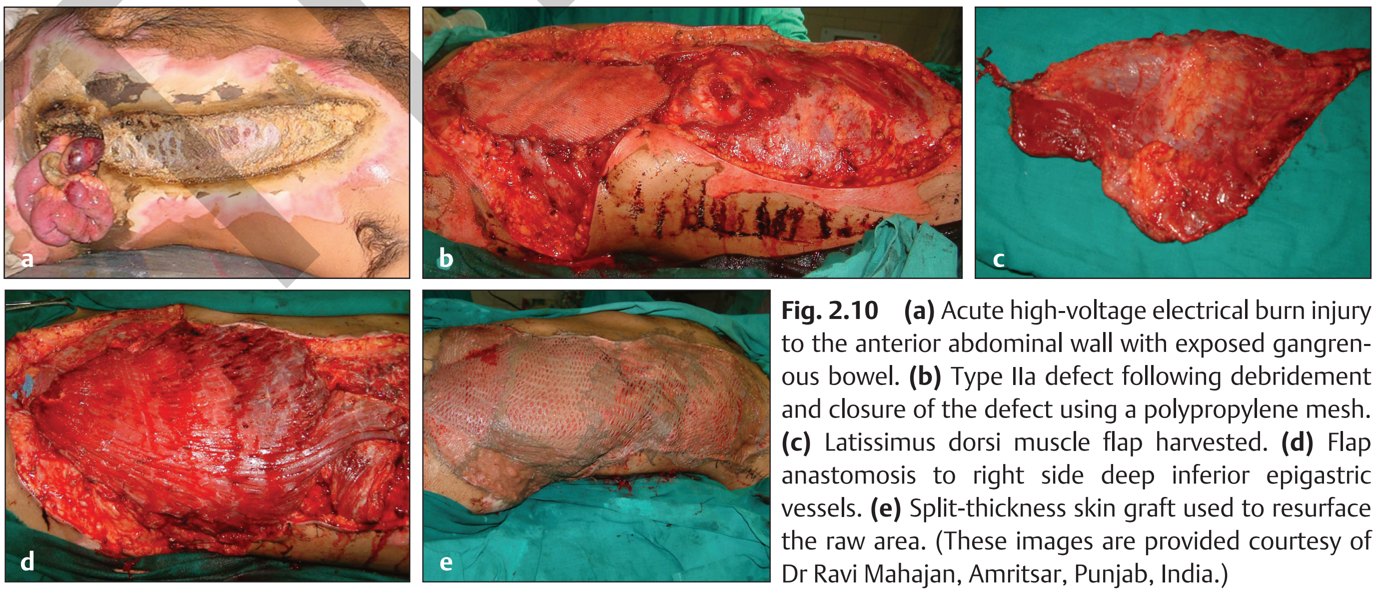


Fig. 2.10 **(a)** Acute high-voltage electrical burn injury to the anterior abdominal wall with exposed gangrenous bowel. **(b)** Type IIa defect following debridement and closure of the defect using a polypropylene mesh. **(c)** Latissimus dorsi muscle flap harvested. **(d)** Flap anastomosis to right side deep inferior epigastric vessels. **(e)** Split-thickness skin graft used to resurface the raw area. (These images are provided courtesy of Dr Ravi Mahajan, Amritsar, Punjab, India.)

Fig. 2.11 **(a)** Large desmoid tumor over the anterior abdominal wall. **(b)** Postexcisional type IIb defect over abdomen. **(c)** Free latissimus dorsi musculocutaneous flap with anastomoses to left deep inferior epigastric vessels. (These images are provided courtesy of Dr Richie Gupta, New Delhi, India.)

patients receiving a small bowel (or multivisceral) graft where the access laparotomy wound could not be closed using local tissues.[59] This VCA consists of a full thickness of anterior abdominal wall including all the layers from the peritoneum to the skin and both the recti along with the encasing sheaths bordered laterally by the linea semilunaris with a variable amount of flat muscle aponeurosis. This VCA is nourished by the deep inferior epigastric vessels with or without a segment of the iliac vessels (**Fig. 2.12**).[60] No neurotization of the VCA for motor function has been attempted in any of the AWTs till date; however, there is no report of significant hernia formation in the recipients.[61] All the cases of AWT have been performed in conjunction with small bowel or multivisceral transplants and never in isolation.[62] The advantages of such a simultaneous transplant is threefold. First, there is no donor site morbidity in the recipient. Second, immunosuppressive regimen for the recipient remains comparable to that for isolated small bowel transplantation. However, the most important final advantage is that preliminary data are suggestive of the fact that abdominal wall skin rejection may be considered as a sentinel marker of early intestinal graft rejection. Further research is needed for optimizing immunosuppressive regimens such that isolated AWT or even isolated skin flap transfers may be possible in the future. This will completely eliminate donor site morbidity in all patients requiring complex and large reconstructions especially for the abdominal wall.

Complications and Outcomes

Managing complex abdominal wall defects is a challenge for the plastic surgeons. These patients need to be carefully assessed preoperatively and meticulously planned for a successful outcome. Timing of surgery, selection of flap donor

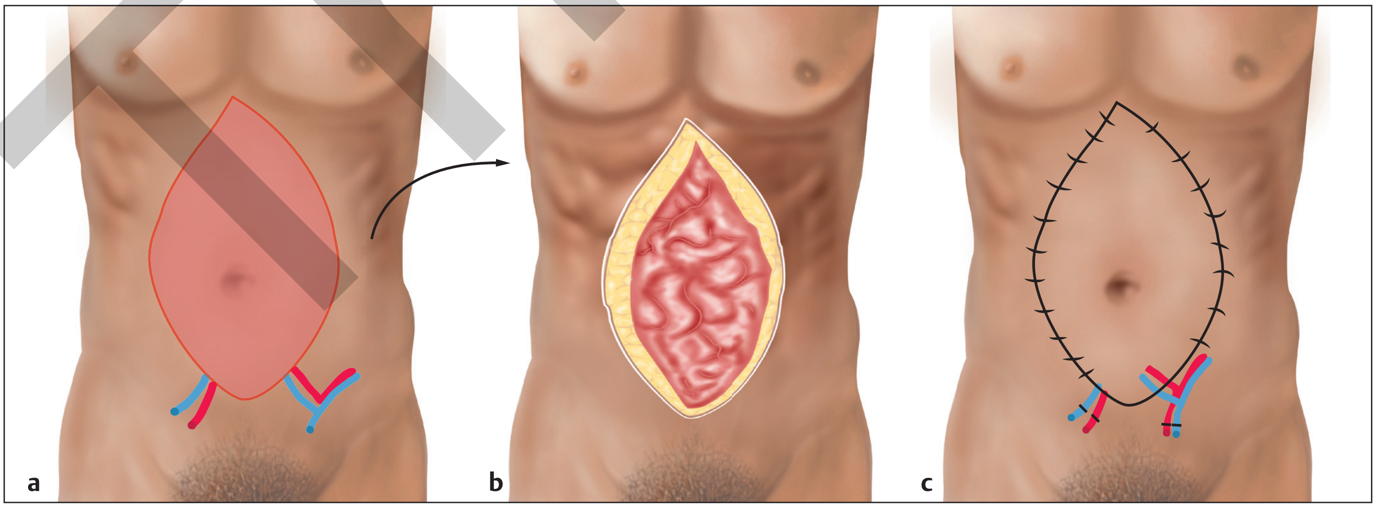


Fig. 2.12 Abdominal wall transplantation. **(a)** Abdominal wall flap harvested with deep inferior epigastric vessels (with or without a cuff of external oblique vessels) as the pedicle. **(b)** Defect in the multi-transplant recipient. **(c)** Post-transplant with vascular anastomoses of the pedicle performed to external iliac vessels on both sides.

site, selection of prosthesis or bioprosthesis, and meticulous postoperative care are of critical importance. Flap failure rates should be as low as in any other part of the body. Institution of a systematic postoperative rehabilitation program has been shown to reduce the incidence of recurrence of ventral hernias in these patients.[63]

Seroma

Postoperatively, the operated area in patients undergoing a prosthetic repair may need to be adequately drained and the drains may have to be left in place for a period of 4 weeks to prevent formation of seromas. In case of a seroma(s), serial percutaneous aspirations with external garment compression may be prescribed. Usage of sclerosing agents like doxycycline or fibrin glue have also been described.[64] Operative exploration and pseudocapsule excision with quilting suture placement may be required as a last resort in certain refractory cases.[65]

Respiratory Complications

The patients need to be provided with judicious postoperative respiratory care and monitoring of the intra-abdominal pressure.[66] This will prevent any tension on the wound closure and also prevent compression of the flap pedicle.[67] Abdominal binders should be avoided in the postoperative period.

Surgical Site Infection and Exposure of Prosthesis

Surgical site infection is a serious complication and may be seen even following usage of bioprosthetics.[68] Attention to surgical technique, a close monitoring of patients for any clinical signs of inflammation in the postoperative period, and early intervention may lead to a successful outcome. Explantation of a mesh maybe required for eradication of the infection and the associated biofilm. In certain cases, limited debridement and thorough local wound measures may be adequate in controlling a localized wound infection with salvage of the mesh. This is possible only in those prostheses where the pore size is more than 75 µm as they allow the free entry of macrophages in the interstices of the mesh, thereby helping in eradication of the bacteria. Coverage of an exposed prosthesis following partial flap necrosis may require a second flap.

Conclusion

Reconstructing abdominal wall defects require a multidisciplinary team approach. Pulmonary, metabolic, dietary, and general medical management form the basis of preoperative optimization of the patient for a long and complicated surgery. Ensuring meticulous preoperative planning, exceptional intraoperative technique, and mitigation of postoperative complications are key to a successful outcome in these patients.

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References

1. Grevious MA, Cohen M, Shah SR, Rodriguez P. Structural and functional anatomy of the abdominal wall. Clin Plast Surg 2006;33(2):169–179, v
2. Jensen KK, Backer V, Jorgensen LN. Abdominal wall reconstruction for large incisional hernia restores expiratory lung function. Surgery 2017;161(2):517–524
3. Huger WE Jr. The anatomic rationale for abdominal lipectomy. Am Surg 1979;45(9):612–617
4. Taylor GI, Corlett R, Boyd JB. The extended deep inferior epigastric flap: a clinical technique. Plast Reconstr Surg 1983; 72(6):751–765
5. Stokes RB, Whetzel TP, Sommerhaug E, Saunders CJ. Arterial vascular anatomy of the umbilicus. Plast Reconstr Surg 1998; 102(3):761–764
6. 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(6):1069–1079
7. Petro CC, Posielski NM, Raigani S, Criss CN, Orenstein SB, Novitsky YW. Risk factors for wound morbidity after open retromuscular (sublay) hernia repair. Surgery 2015;158(6):1658–1668
8. Rosen MJ, Aydogdu K, Grafmiller K, Petro CC, Faiman GH, Prabhu A. A multidisciplinary approach to medical weight loss prior to complex abdominal wall reconstruction: is it feasible? J Gastrointest Surg 2015;19(8):1399–1406
9. Rutherford EJ, Skeete DA, Brasel KJ. Management of the patient with an open abdomen: techniques in temporary and definitive closure. Curr Probl Surg 2004;41(10):815–876
10. Mathes SJ, Steinwald PM, Foster RD, Hoffman WY, Anthony JP. Complex abdominal wall reconstruction: a comparison of flap and mesh closure. Ann Surg 2000;232(4):586–596
11. Gottlieb LJ, Pelletier AT. Abdominal and chest wall reconstruction. In: Boyd JB, Jones NF, eds. Operative Microsurgery. New York, NY: McGraw Hill Education; 2015
12. Dumanian GA. Periumbilical perforator sparing component separation. In: Rosen MJ,ed. Atlas of Abdominal Wall Reconstruction. Philadelphia, PA:Elsevier; 2017
13. 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(2):731-738
14. Gopinathan R, Granick M. Anterior abdominal wall reconstruction. Clin Plast Surg 2006;33(2):259-267
15. Lin SJ, Butler CE. Subtotal thigh flap and bioprosthetic mesh reconstruction for large, composite abdominal wall defects. Plast Reconstr Surg 2010;125(4):1146-1156
16. Sasaki K, Nozaki M, Nakazawa H, et al. Reconstruction of a large abdominal wall defect using combined free tensor fasciae

latae musculocutaneous flap and anterolateral thigh flap. Plast Reconstr Surg 1998;102(6):2244-2252
17. Levi DM, Tzakis AG, Kato T, et al. Transplantation of the abdominal wall. Lancet 2003;361(9376):2173-2176
18. 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(3):519–526
19. Kapur SK, Butler CE. Lateral abdominal wall reconstruction. Semin Plast Surg 2018;32(3):141–146
20. van Eijck FC, de Blaauw I, Bleichrodt RP, et al. Closure of giant omphaloceles by the abdominal wall component separation technique in infants. J Pediatr Surg 2008;43(1):246–250
21. DeFranzo AJ, Argenta L. Vacuum-assisted closure for the treatment of abdominal wounds. Clin Plast Surg 2006;33(2): 213–224, vi
22. Pezeshk RA, Pulikkottil BJ, Bailey SH, et al. An evidence-based model for the successful treatment of flank and lateral abdominal wall hernias. Plast Reconstr Surg 2015;136(2): 377–385
23 Baumann DP, Butler CE. Lateral abdominal wall reconstruction. Semin Plast Surg 2012;26(1):40–48
24. Wangensteen OH. Repair of recurrent and difficult hernias and other large defects of the abdominal wall employing the iliotibial tract of fascia lata as a pedicled flap. J Surg Gynec Obst 1934;59:766–780
25. Krpata DM, Rosen MJ. Abdominal wall reconstruction. In: Cameron JL, ed. Current Surgical Therapy. 12th ed. Philadelphia, PA: Elsevier; 2017:651–656
26. 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(6):392–398
27. Usher FC, Ochsner J, Tuttle LL Jr. Use of marlex mesh in the repair of incisional hernias. Am Surg 1958;24(12):969–974
28. Jones JW, Jurkovich GJ. Polypropylene mesh closure of infected abdominal wounds. Am Surg 1989;55(1):73–76
29. Grevious MA, Cohen M, Jean-Pierre F, Herrmann GE. The use of prosthetics in abdominal wall reconstruction. Clin Plast Surg 2006;33(2):181–197, v
30. Amid PK. Classification of biomaterials and their related complications in abdominal wall hernia surgery. Hernia 1997; 1(1):15–21
31. Butler CE. The role of bioprosthetics in abdominal wall reconstruction. Clin Plast Surg 2006;33(2):199–211, v–vi
32. Gaertner WB, Bonsack ME, Delaney JP. Experimental evaluation of four biologic prostheses for ventral hernia repair. J Gastrointest Surg 2007;11(10):1275–1285
33. Ballantyne GH, Hourmont K, Wasielewski A. Telerobotic laparoscopic repair of incisional ventral hernias using intraperitoneal prosthetic mesh. JSLS 2003;7(1):7–14
34. Jin J, Rosen MJ. Laparoscopic versus open ventral hernia repair. Surg Clin North Am 2008;88(5):1083–1100, viii
35. Le Gall H, Reibel N, De Runz A, Epstein J, Brix M. Abdominoplasty and simultaneous laparoscopic ventral hernia repair. Clinical study about 45 patients. Ann Chir Plast Esthet 2017;62(2): 115–121
36. Robertson JD, de la Torre JI, Gardner PM, Grant JH III, Fix RJ, Vásconez LO. Abdominoplasty repair for abdominal wall hernias. Ann Plast Surg 2003;51(1):10–16
37. Fischer JP, Tuggle CT, Wes AM, Kovach SJ. Concurrent panniculectomy with open ventral hernia repair has added risk versus ventral hernia repair: an analysis of the ACS-NSQIP database. J Plast Reconstr Aesthet Surg 2014;67(5):693–701
38. Koshima I, Nanba Y, Tutsui T, Takahashi Y, Itoh S, Kobayashi R. Dynamic reconstruction of large abdominal defects using a free rectus femoris musculocutaneous flap with normal motor function. Ann Plast Surg 2003;50(4):420–424
39. Song Z, Yang D, Yang J, et al. Abdominal wall reconstruction following resection of large abdominal aggressive neoplasms using tensor fascia lata flap with or without mesh reinforcement. Hernia 2018;22(2):333–341
40. Ninković M, Kronberger P, Harpf C, Rumer A, Anderl H. Free innervated latissimus dorsi muscle flap for reconstruction of full-thickness abdominal wall defects. Plast Reconstr Surg 1998;101(4):971–978
41. Sharma RK, Singh G, Naidu PM. Abdominal wall defects: anatomic classification and a scheme for management. Ann Plast Surg 1998;41(2):180–184
42. LoGiudice JA, Haberman K, Sanger JR. The anterolateral thigh flap for groin and lower abdominal defects: a better alternative to the rectus abdominis flap. Plast Reconstr Surg 2014;133(1):162–168
43. Srinivas JS, Panagatla P, Damalacheru MR. Reconstruction of Type II abdominal wall defects: Anterolateral thigh or tensor fascia lata myocutaneous flaps? Indian J Plast Surg 2018; 51(1):33–39
44. Fernandez-Alvarez JA, Barrera-Pulido F, Lagares-Borrego A, Narros-Gimenez R, Gacto-Sanchez P, Gomez-Cia T. Coverage of supraumbilical abdominal wall defects: the tunnelled-pedicled ALT technique. Microsurgery 2017;37(2):119–127
45. Cohen M. Management of abdominal wall defects resulting from complications of surgical procedures. Clin Plast Surg 2006;33(2):281–294
46. 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(7):2275–2280, discussion 2281–2282
47. 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(2):720–729, quiz 730
48. Rosen MJ, Jin J, McGee MF, Williams C, Marks J, Ponsky JL. Laparoscopic component separation in the single-stage treatment of infected abdominal wall prosthetic removal. Hernia 2007;11(5):435–440
49. Dauser B, Ghaffari S, Ng C, Schmid T, Köhler G, Herbst F. Endoscopic anterior component separation: a novel technical approach. Hernia 2017;21(6):951–955
50. Ibarra-Hurtado TR, Nuño-Guzmán CM, Echeagaray-Herrera JE, Robles-Vélez E, de Jesús González-Jaime J. Use of botulinum toxin type a before abdominal wall hernia reconstruction. World J Surg 2009;33(12):2553–2556
51. Zielinski MD, Goussous N, Schiller HJ, Jenkins D. Chemical components separation with botulinum toxin A: a novel technique to improve primary fascial closure rates of the open abdomen. Hernia 2013;17(1):101–107
52. Krpata DM, Blatnik JA, Novitsky YW, Rosen MJ. Posterior and open anterior components separations: a comparative analysis. Am J Surg 2012;203(3):318–322, discussion 322
53. Rosen MJ. Posterior component separation with transverses abdomens muscle release. In: Rosen MJ, ed. Atlas of Abdominal Wall Reconstruction. Philadelphia, PA: Elsevier;2017
54. Srinivas JS, Panagatla P, Damalacheru MR. Reconstruction of Type II abdominal wall defects: Anterolateral thigh or tensor fascia lata myocutaneous flaps? Indian J Plast Surg 2018; 51(1):33–39
55. Basu A. Classification of flaps and application of the concept of vascular territories. In: Agrawal K, ed. Textbook of Plastic,

Reconstructive and Aesthetic Surgery. New Delhi: Thieme Medical Publisher; 2016:93–120
56. Senghaas A, Kremer T, Schmidt VJ, et al. Sliding free transverse rectus abdominis myocutaneous flap for closure of a massive abdominal wall defect: a case report. Microsurgery 2019;39(2): 174–177
57. Baumann DP, Butler CE. Soft tissue coverage in abdominal wall reconstruction. Surg Clin North Am 2013;93(5):1199–1209
58. Kim DY, Lee J, Kim JT, Chang HK, Moon SH. Reconstruction of a large full-thickness abdominal wall defect with flow-through-based alt flaps: a case report. Microsurgery 2019;39(1):85–90
59. Levi DM, Tzakis AG, Kato T, et al. Transplantation of the abdominal wall. Lancet 2003;361(9376):2173–2176
60. Cipriani R, Contedini F, Santoli M, et al. Abdominal wall transplantation with microsurgical technique. Am J Transplant 2007;7(5):1304–1307
61. Selvaggi G, Levi DM, Cipriani R, Sgarzani R, Pinna AD, Tzakis AG. Abdominal wall transplantation: surgical and immunologic aspects. Transplant Proc 2009;41(2):521–522
62. Giele H, Vaidya A, Reddy S, Vrakas G, Friend P. Current state of abdominal wall transplantation. Curr Opin Organ Transplant 2016;21(2):159–164
63. Pezeshk RA, Pulikkottil BJ, Mapula S, et al. Complex abdominal wall reconstruction: a novel approach to postoperative care using physical medicine and rehabilitation. Plast Reconstr Surg 2015;136(3):362e–369e
64. Butler CE. Treatment of refractory donor-site seromas with percutaneous instillation of fibrin sealant. Plast Reconstr Surg 2006;117(3):976–985
65. Baumann DP, Butler CE. Abdominal wall reconstruction. In: Wei FC, Mardini S, eds. Flaps and Reconstructive Surgery. 2nd ed. Philadelphia, PA: Elsevier; 2017:219
66. Basu A. A low-cost technique for measuring the intraabdominal pressure in non-industrialised countries. Ann R Coll Surg Engl 2007;89(4):434–435
67. Muresan M, Muresan S, Bara T, et al. The intraabdominal pressure: a real indicator of the tension free principle during anterior wall repair procedure after incisional hernias. Ann Ital Chir 2015;86:421–426
68. 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(3):498–505