Abdominal Wall Reconstruction in a Trauma Setting

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Abstract

According to the World Health Organization "Global burden of disease study", future demographics of trauma are expected to show an increase in morbidity and mortality. In the past few decades, the field of trauma surgery has evolved to provide global and comprehensive care of the injured. While the modern day trauma surgeon is well trained to deal with multitrauma patients with injuries involving several systems, the ever-increasing nature and variety of multitrauma has left lacuna in certain areas. One such area is the management of abdominal wall injuries, which has been the domain of both plastic and reconstructive and general surgeons. The trauma surgeon is adept at treating the contents of the abdomen but not always the container. If not managed properly complications associated with abdominal wall injuries can lead to increased morbidity and mortality. In considering reconstruction of the abdominal wall in multitrauma patients proper evaluation, scrupulous planning, appropriate, and meticulous technique improve the chances for success with minimal complications. In the present article, we provide a brief description of the most commonly used procedures, and more importantly we outline the principles and guidelines applied to abdominal wall reconstruction in order to inform the trauma surgeon of different available treatment options. In doing so, we hope that this review will assist trauma surgeons in their overall care of patients that present with abdominal injuries.

Key Words

Abdominal wall trauma · Reconstruction · Trauma surgeon

Eur J Trauma Emerg Surg 2007;33:3–13

DOI 10.1007/s00068-007-7023-7

Introduction

Traumatic abdominal wall defects can be grouped into penetrating and blunt injuries. Penetrating injuries are more common than blunt injuries and are due to firearms, motor vehicle accidents, burns and war missiles [1]. Blunt injuries occur as a result of motor vehicle accidents, assault, and handle bar injuries. The primary objectives of abdominal wall reconstruction are coverage for abdominal organs and function of the abdominal wall. Factors to be considered when choosing the ideal procedure are (a) degree of injury, (b) size and area involved, (c) presence or absence of infection, (d) timing and staging, (e) associated injuries, and (f) prior illness. Successful outcomes with minimal complications depend on careful planning and choice of the optimal procedure(s). The available options include primary closure, split thickness skin grafts, prosthetics, flaps (local, regional, and distal), tissue expanders, vacuum-assisted closure (VAC) therapy and more recently abdominal wall transplant or a combination of the above. Penetrating injuries to the abdomen with significant defects are not always suitable for immediate reconstruction as they are often associated with visceral edema, contamination, and an unstable patient. In this

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Received: May 25, 2005; revision accepted: June 23, 2005;
Published Online: March 1, 2007

situation, any effort to close the abdomen with tension invites infection, dehiscence, compartment syndrome and its associated problems. Such patients are best managed with an open abdomen technique and fascial closure after the edema resolves to temporize the wound. Various protocols have been described to treat the residual abdominal wall defect once the contents have been dealt with and the patient is stabilized [2–6]. In this article, we illustrate relevant practical anatomy, discuss indications, contraindications, and precautions of abdominal wall reconstruction specifically secondary to penetrating injuries. We also stress the importance of preoperative considerations, planning, and briefly discuss the most frequently used surgical techniques with their advantages and disadvantages. An algorithm for reconstruction of abdominal wall defects in traumatic injuries is also provided (Figure 5). We hope that by providing an insight into what plastic surgeons consider when reconstructing the ''container'' this review will help trauma surgeons improve care for the contents of their patient's abdomen and decrease unfavorable outcome in the long run.

Anatomy of the Abdominal Wall

The abdominal wall from outside inwards consists of skin, subcutaneous fat, fascia (superficial and deep), paired muscles (rectus abdominis, external and internal oblique, transversus abdominis, and pyramidalis) preperitoneal fat and peritoneum. The superficial fascia is divided into superficial (Camper's) and deep (Scarpa's) layers.

From medial to lateral – in the midline, linea alba is formed by the fused layers of aponeuroses from all the anterior abdominal muscles. Lateral to this is the rectus sheath, which encloses rectus muscle and is formed thus (Figure 2)– anteriorly, the aponeurosis of internal oblique at the lateral margin splits into two lamellae, the anterior lamella fuses with the aponeurosis of external oblique and forms the anterior rectus sheath. Posteriorly, it is formed by the fusion of posterior lamella with transversus aponeurosis. This arrangement is seen from the costal margin until midway between the umbilicus and the pubic symphysis. At this level, the posterior layers end as a curved line (*Arcuate line*) concave downward. Below this all the layers pass anteriorly and the posterior aspect of rectus muscle below is separated from the peritoneum only by tranversalis fascia. At the lateral border of the rectus muscle, the aponeuroses of all muscles form a shallow avascular groove, the *semilunar line.* The strength of the abdominal wall is derived from the musculo-fascial layers whose approximation

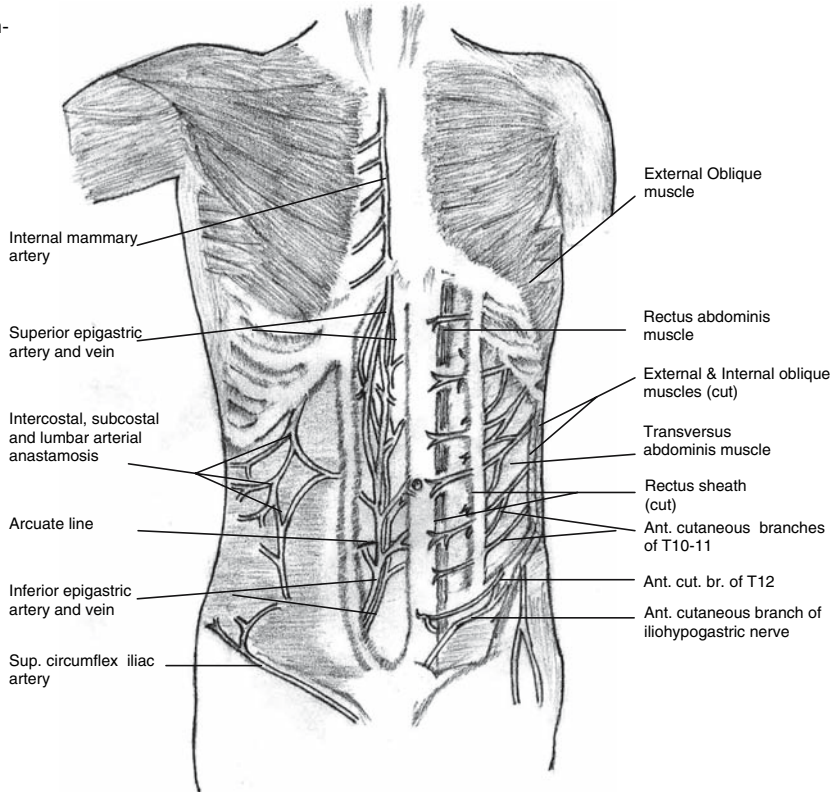

Figure 1. Vessels and nerves of the anterior abdominal wall.

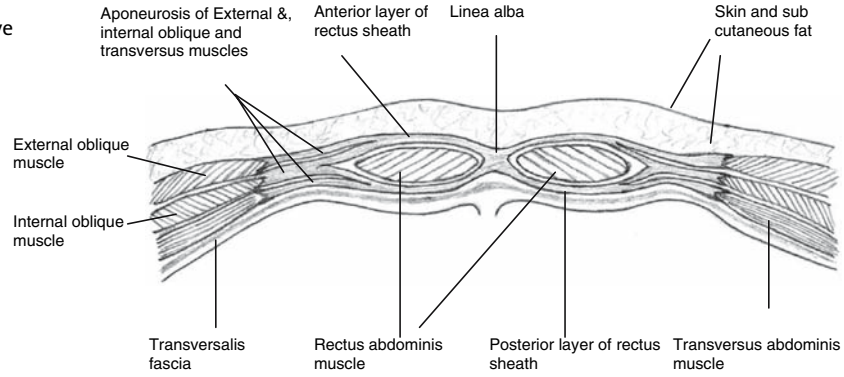

Figure 2. Cross section of the rectus sheath above the arcuate line.

during closure of abdominal wall is vital to its dynamic function.

The rectus abdominis muscle arises from the symphysis pubis and crests of pubis below and is attached to the cartilages of fifth, sixth, and seventh ribs above and some fibers also run into the xiphi-sternum. It has three transverse tendinous intersections at the level of xiphoid process, umbilicus, and midway between the two. External oblique muscle is situated on the lateral and anterior parts of the abdomen underneath which is the internal oblique followed by transversus muscle.

Nerve Supply

Derived from the roots of T7–L4 and together with the vessels lie in between the internal oblique and transversus muscles. The nerves traverse the posterior layer of internal oblique pass behind the rectus muscle and enter just near its midline. Lateral cutaneous branches supply the external oblique before they enter the rectus sheath.

Vascular Supply

El Mrakby et al. [7] recently described the vascular supply of abdominal wall as being predominantly by the musculo-cutaneous perforators of epigastric vessels. In the midline the superior and inferior deep epigastric vessels are the main sources (Figure 1) with contribution from superficial external pudendal and deep circumflex arteries for the lower abdomen. Intercostal, subcostal, and lumbar vessels supply the lateral abdominal wall and the umbilical region receives transperitoneal blood supply.

Function

With the pelvis and thorax fixed the abdominal muscles compress the abdominal cavity. If the pelvis is fixed then the muscles from both sides help in forward bending, when one side contracts then the trunk is bent toward that side with rotation on the opposite side. Climbing actions occur when the thorax is fixed during muscle action. Rectus muscle contributes significantly to all these actions and its loss leads to significant weakness of abdominal and extensor muscles of the back [8].

Indications, Contraindications, and Precautions of Abdominal Wall Reconstruction

All open wounds of the abdomen require immediate closure where possible to prevent further complications such as loss of domain, infection, fistula formation, and herniation all of which can prolong hospital stay. This should be achieved without tension. However, abdominal wounds due to gunshot and penetrating injuries are often associated with vascular and visceral injuries requiring immediate life saving measures to stem hemorrhage, treat shock, and coagulopathy. The abdomen meanwhile is packed and managed as an open abdomen till all parameters return to within the normal physiological range. This procedure in which a full definitive treatment is not carried out during the initial exploration has been termed ''damage control''. It is the current standard of care in all multitrauma patients around the world and has significantly reduced mortality in such patients [9]. Reconstruction should be delayed in this group of patients until they are stabilized. Secondly, trauma patients receive large volumes of fluid during resuscitation and surgery resulting in fluid overload, which can lead to cardiac failure. This is particularly so in those with preexisting cardiac and respiratory illness. When planning reconstruction for such cases it is necessary to choose procedures which they can endure as they are unable to withstand long duration of surgery. These patients also require critical monitoring with pulmonary ar-

Figure 3. Vacuum-assisted closure (VAC) dressing of the abdomen.

tery wedge pressure, mean arterial pressure, arterial blood gases, electrocardiogram, and urine output to optimize care and avoid complications.

Other factors which may prevent abdominal wall closure are visceral edema, peritoneal hematoma, and packs. A well-known entity occurring in this scenario is abdominal compartment syndrome (ACS) [10] characterized by cardiac and respiratory distress and compromised splanchnic and renal circulation. ACS develops as a result of raised intra-abdominal pressure leading to hypoperfusion, acidosis and coagulopathy with a high risk for multiple organ failure. This potentially life-threatening complication requires early recognition and immediate treatment. During the early stages a relatively noninvasive and easy technique to detect raised intra-abdominal pressure of compartment syndrome is by measuring continuous bladder pressures with an indwelling catheter. Although indirect this correlates well with intra-abdominal pressure and a measurement of > 25 mmHg is considered diagnostic of ACS. Other useful parameters defining ACS are increased

Figure 4. Tissue expanders in the abdominal wall of a patient with large ventral hernia.

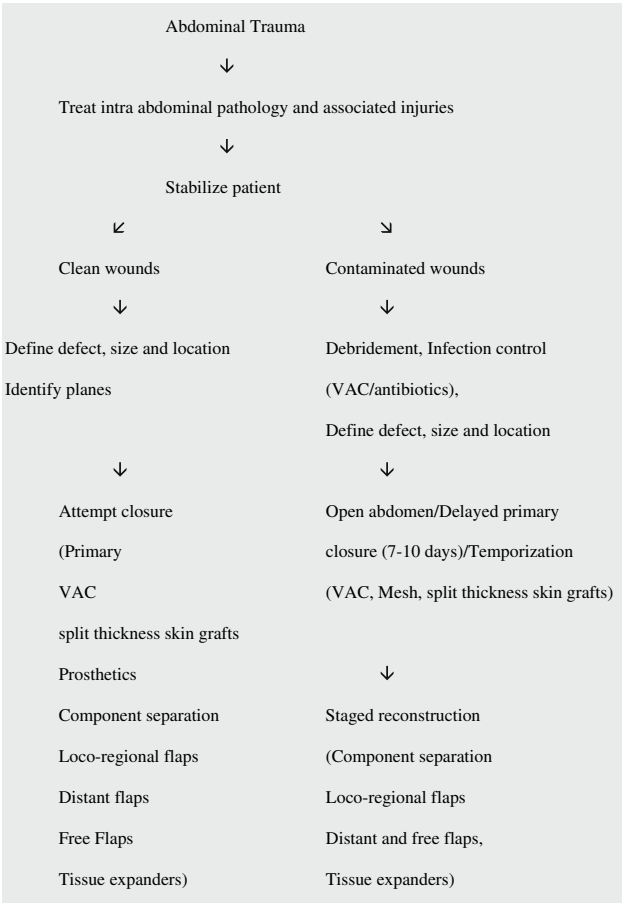

Figure 5. Algorithm for reconstruction of abdominal wall defects in traumatic injuries.

inspiratory airway pressure and urine output of < 30 ml/h. Treatment consists of immediate decompression and supportive measures in the form of ventilation, correction of acidosis, hypothermia, and coagulation disorders. Subsequent reconstruction is planned to achieve delayed primary closure or as a staged procedure depending on the status of the patient.

In the presence of infection, loss of tissue, an unstable patient due to multisystem injuries or when the choices are limited a staged reconstruction at a later date is the best course of action [11, 12]. Factors such as poor nutrition, immuno-deficiency, and prior radiotherapy are associated with increased infection rate. Previous surgery may be associated with scars and adhesions and necessitate adhesionlysis to fully mobilize fascia for direct closure.

Preoperative Work Up

A detailed history, clinical examination, and adequate laboratory investigations should be performed in all

trauma patients. Chest X-ray, arterial blood gases (ABG), and electrocardiogram (ECG) should be recorded in all patients. Chest X-ray and ABG can be helpful to diagnose patients with chronic obstructive pulmonary disease (COPD). It is important to avoid increasing intra-abdominal pressure and closing the abdominal fascia too tightly as it can make it difficult to wean patients from the ventilator postoperatively and is also associated with higher recurrence rates. In an unstable patient CT scan cannot be done but is otherwise helpful in getting the patient examined from head to toe. Liver function tests (LFT) should be performed to avoid abdominal hernia repair in patients with liver failure, cirrhosis, and ascitis as these patients are prone to high complication rates and recurrence. In general, patients are at higher risk for hernia recurrence if preexisting co-morbidities include smoking, COPD, obesity, diabetes, cancer, multiple hernia recurrences, and patient noncomplaince. Some patients with large hernia defects that are not at risk for bowel strangulation covered in intact skin can be managed successfully with an abdominal binder if their risk for complications outweighs the benefit of surgery [13]. All patients should receive preoperative intravenous antibiotic to cover for both aerobic and anaerobic organisms particularly in the presence of intestinal injury. A second/third generation cephalosporin or a combination of aminoglycoside with clindamycin has been widely used [14]. Deep venous thrombosis (DVT) prophylaxis should include graduated compression stockings, intermittent pneumatic compression, and low molecular weight heparin when it is considered safe [15]. Vena cava filters have been recommended for high-risk patients who cannot take anticoagulation due to increased risk of bleeding but their long-term requirement has not been proven [16]. Since catabolism of lean body mass is increased in multitrauma patients nutritional supplementation is needed for wound healing and may include total parenteral nutrition (TPN) if the patient has no bowel function. [17]. Catheter related sepsis is a complication to be considered but its benefits outweighs the risk in trauma patients.

Preoperative Planning

Since the original description of abdominal wall defects by Hurwitz and Hollins [18], it has been further modified into six working subunits [19]. It is first described as midline or lateral and then as upper, middle, or lower third. The type of defect can be classified as ''Partial'' when skin, subcutaneous tissue, and part of muscle/fascia are lost or ''Complete'' when all the layers are involved.

Based on the dimensions, tissue loss can be termed as small size (< 5 cm), intermediate size (5–15 cm), and large size (> 15 cm) defects [19]. Small-sized defects can be closed directly; intermediate defects require local advancement of tissues or split thickness skin grafts [20]. Whereas large defects may involve surrounding donor sites and often require importing tissues from distant areas or tissue expansion. One of the options which has significantly reduced the need for complex reconstructions is VAC therapy. In both intermediate and large size defects, VAC therapy has been shown to decrease the size of wound considerably to allow closure with advancement, local flaps or split thickness skin grafts.

All myofascial defects irrespective of their nature and size require careful consideration and planning to achieve closure ''without tension''. Depending on their location, midline partial thickness defects can be closed primarily, by component separation (see below), prosthetic mesh, autogenous grafts, local/distal flaps, tissue expansion or a combination of the above. Options for large defects include prosthetic mesh, nonvascularized fascial grafts, myocutaneous flaps [Tensor fascia lata (TFL), rectus femoris, gracilis, etc.], tissue expansion, free flaps, and acellular dermis (Alloderm®, Life Cell). A healthy noncontaminated wound with adequate skin and subcutaneous tissue calls for the use of a prosthetic mesh. When a large mesh is used it creates sufficient space to contain the abdominal viscera thereby accommodating for any changes in the intra-abdominal pressure and preventing the development of compartment syndrome. The use of nonabsorbable mesh also decreases the incidence of hernia at a later date. However, in the presence of contamination/unstable patient, management often consists of an open abdomen; temporization using omental onlay and split thickness skin grafts. When the infection is under control a staged reconstruction can be carried out. In patients with prior abdominal surgery, adhesions are often encountered which can complicate treatment. Release of adhesions should be done with care and enterotomy avoided to prevent contamination. This adhesionlysis should be complete to paracolic gutters to fully release the fascia allowing for midline approximation.

In considering the choice of procedure, midline defects are ideally suited for the component separation technique with maximum advancement when both sides are released. However, this may be difficult if the patient has a colostomy. Lateral defects are technically more challenging and difficult if they involve surrounding donor areas or when they are located near the

costal or pelvic margins. In the absence of these, they are best suited for local fascio-cutaneous and muscular flaps, e.g. thoraco epigastric, bipedicled iliolumbar, rectus abdominis, and external oblique or distal muscular flaps which include rectus femoris, TFL (see below), gracilis, vastus lateralis, and latissimus dorsi muscle. The component separation technique does not work well for lateral areas as they are one sided.

Access

Vertical midline incisions give good access to the intra-abdominal contents and are the first choice in emergencies. They are quick to make and cause less damage to the neurovascular bundles. Transverse incisions heal better with thinner scars as they are along the lines of least tension [21, 22] and therefore have lower incidence of postoperative hernias [23]. However, limited exposure of the abdomen remains their main drawback depending on their position. In patients with previous scars precautions should be taken to avoid producing an island flap, as these are prone to necrosis. Traumatic abdominal wall hernias due to low energy impact require exploration with an incision overlying the hernia in order to avoid missing an entrapped bowel.

Timing

Immediate reconstruction is limited to stable patients whose wounds are devoid of contamination and have minimal/no loss of tissue. In the vast majority of penetrating injuries, patients are often unstable due to visceral and systemic injuries and may require repeated explorations. Besides this significant tissue loss and bowel spillage also pose additional risks to the patient. During this period the abdominal contents are protected with alternate methods, such as packs, plastic bags [24] absorbable mesh grafts, and VAC dressings. In some patients when bowel edema and distension subsides a delayed primary closure can be achieved at between 7 and 10 days [25]. Inability to close the wound at this stage should proceed with split thickness skin graft application once the wound has granulated and allowed to heal. Subsequent reconstruction can be planned and performed after a period of at least 6–12 months to give the scars sufficient time to mature. During this waiting period tissue retraction is a draw back posing difficulties in approximation during definitive treatment. Due thought should be given to achieving closure in the most effective way without the need for complex procedures. A simple way of assessing the need to import tissue is by ''pinch test''. The abdominal wall is pinched gently between the thumb and index and middle fingers so as not to cause any pain and then moved in both vertical and horizontal directions. This gives a rough idea of the amount of tissue that can be advanced and also assesses the need to bring in tissues from other sources. The principle behind the pinch test lies in the fact that the subcutaneous fat of abdominal wall is tethered securely to the dermis but not so to the deeper layers and can therefore be easily moved.

Operative Procedure

Prosthetics

Commercially available grafts can be classified as absorbable or nonabsorbable and can be meshed or nonmeshed. Mesh grafts allow drainage of exudates and in growth of granulation tissue along the edges of the repair and are stronger. Newer prosthetic composites contain a mixture of absorbable and nonabsorbable substances; an interspersed barrier is present for tissue separation when it contains only nonabsorbable material. Mesh is best placed over the omentum when it is available to avoid adhesions to the underlying viscera. The different planes of placement are intra-peritoneal (associated with higher complications), beneath the rectus, or anterior to the rectus muscle. Complications of prosthetics include infection, seroma, extrusion, fistula, and hernia.

Synthetic nonabsorbable mesh usage is ideally suited for fascial defects in clean wounds with sufficient skin and subcutaneous tissue. Prolene and Marlex are knitted monofilaments with different pore sizes. They can be shaped, sealed, and are pliable [26, 27], and when used as the primary cover for the organs, sufficient tissue ingrowth occurs through the pores within 2–3 weeks to accept skin grafts. However, their complication rates are high with 55% infection and 44% extrusion [28]. Marlex mesh has been noted to have higher incidence of enteric fistulas as compared to prolene [29, 30].

ePTFE (Expanded Polytetrafluroethylene: Gore-Tex, W. L. Gore and Associates, Flagstaff, Arizona)

Expansion makes this graft inert in tissues therefore is less likely to exert inflammatory reaction which in turn makes it less prone to adhesions. They are compatible, provide stability and when patients are stable can be removed easily from the granulation tissue to allow definitive reconstruction. In a study by Danino et al. [31], the authors describe no significant ultrastructural changes on the visceral side of this graft as compared to unused controls and give this as proof of their stable nature. Disadvantages include infection, seroma, and

poor tissue ingrowth leading to the lack of a suitable graft bed. They are also weaker along the suture line and prone to recurrence.

Absorbable Grafts: Polyglactin (Vicryl and Dexon)

Ideal for staged reconstruction in the presence of contamination, infection, or compartment syndrome. Both products are woven mesh, inert and do not elicit antigenic reaction. But the tensile strength declines rapidly and by day 28 is only 5% [30]. They can however be used for temporization in the presence of infection and during re-explorations can also be divided and re-sutured. Subsequent granulation allows for the application of skin grafts. A disadvantage is the formation of incisional hernias.

New Prosthetics (Vypro, Proceed, and Sepramesh) [32, 33]

Advantages: good ingrowth of tissues, able to tolerate excess abdominal pressures and physiological compatibility. These have been in use for only a few years and still require long-term follow-up. Disadvantages: Not cost effective, prone for adhesions at wound edges and infection.

Bio Prosthetics (Human acellular tissue matrix (Alloderm), Porcine acellular matrix, and Porcine intestinal submucosa)

These are derivatives of human or animal tissues, which may retain some original properties and allow good integration and remodeling [34]. When using Alloderm it is critical to secure it tightly into the defect to minimize its tendency to bulge over time. The main advantage is that it heals by regeneration rather than by scarring. A recent study using ADM (acellular dermal matrix) in abdominal wounds in experimental rats showed accelerated epithelilization and wound contraction [35]. They can be used for immediate reconstruction, in infected wounds and has also been shown to decrease the incidence of foreign body reaction and adhesions. However, when used in the presence of open wounds and infection they are associated with a high incidence of recurrent hernias [36]. The other main disadvantages are its high cost as compared to the synthetic and composite mesh, small size of available sheets requiring several of them to be stitched together in large defects and lack of long-term results.

Autologous Flaps

Selection is based on the size and location of the defect and is classified into fascio-cutaneous, myo-cutaneous, adipofascial, and muscular flaps. Fascio-cutaneous flaps are suited for partial defects when strength is not the primary requirement. Defects in the upper third can be covered by thoroco-epigastric flaps, mid third with iliolumbar and lower third with a groin flap, inferior epigastric artery or a deep inferior epigastric artery perforator flap. The workhorse flap which can be used in all these areas is the myo-cutaneous rectus abdominis flap. In a recent case report, Guneren et al. [37] used an extended delayed groin flap along with prolene mesh to cover a large full thickness defect of the abdominal wall measuring 30×45 cm. The donor area was closed with split thickness skin grafts without any other complication.

Antero Lateral Thigh Flap

This flap was first described by Song et al. [38] in 1984 and since then has been widely used in the reconstruction of various defects. In abdominal wall defects it can be used as an adipofascial flap when adequate skin is available or with a skin paddle in complete defects. The *antero lateral thigh flap's* vascular supply comes from the lateral femoral circumflex artery descending branch with cutaneous perforators and it can be raised as either a pedicled or a free flap. The skin territory extends from the level of the greater trochanter to just above the patella and includes the iliotibial tract and may be nearly half the surface of the thigh. The main advantages are its dependable vascularity with a long pedicle, large skin paddle and its usefulness for upper abdominal defects. Large free flaps can be harvested in combination with tensor fascia lata, which not only increases the total area but also augments its chances of survival.

Kimata et al. [39] reported reconstruction in seven patients with post neoplastic complete defects of the abdominal wall with 100% flap survival. The largest flap dimension in this series was 15×20 and 15×23 cms as pedicled and free flaps, respectively.

Tensor Fascia Lata

This flap is based on the transverse branch of the lateral femoral circumflex artery. It has been extensively used in reconstruction of abdominal wall defects as fascial grafts, pedicled myocutaneous flaps and as free-tissue transfers. Fascial grafts are used when the defect has adequate vascularized skin coverage. Pedicled myocutaneous flaps are ideal for smaller lower abdominal wall defects with both fascial and soft tissue requirements and its cutaneous paddle is reliable to approximately 5–8 cm above the knee. An extended TFL flap skin paddle can be used for reaching defects

up to the umbilicus. If time allows for a delayed procedure this is a technique which can minimize distal flap necrosis. Up to 4 weeks of delay has been suggested for a greater chance of distal flap survival [40] or the alternative is to perform an anastomosis to the superior lateral genicular branch of the popliteal artery [41]. Free flaps are used in large defects and when wounds involve the epigastric region. Both sides can be harvested to cover large defects. In the series reported by Williams et al. [42], the complication rate in these reconstructions was as high as 44%; distal vascularity of flaps was unreliable in both pedicled and free flaps and a donor morbidity of 18% was reported. Disa et al. [43] have used devascularized fascial grafts in patients with contamination, infection, and fistulas and reported successfully closing all wounds. Their average wound size was 10×17 cm and the largest was 28×14 cms.

Latissimus Dorsi

Pedicled flaps have been used for lateral upper abdominal defects and with extension can reach midline defects; whereas larger defects and those involving other areas require free flaps. Innervated free flaps were successfully used to cover large defects in four patients by Ninkovic et al. [44], which not only restored continuity but also functional integrity to the abdomen. In these cases the thoracodorsal nerve was sutured to the intercostal nerves supplying the rectus abdominis muscle for re-innervation. In this series none of the cases developed hernia and the donor site was closed primarily. One patient died due to metastasis after 2 months but had no complications related to the procedure.

Other available muscular flaps include the gracilis and vastus lateralis flaps for lower abdominal wall defects but they are not as frequently used due to their small size and decreased arc of rotation, respectively. External oblique muscle and aponeurosis flap is mainly used for upper abdominal defects and has limited application in lower abdominal coverage. Rectus femoris flaps have been used in midline and lower abdominal wall defects and can also be combined with a fascia lata flap to cover large defects. After harvesting, the donor area requires approximation of vastus lateralis and medialis muscles to prevent any terminal functional deficit of knee extension.

Component Separation

This procedure is ideal for large midline defects and has low incidence of hernias. It was first introduced by Ramirez et al. [45] and involves (a) division of the aponeurosis of the external oblique from medial to lateral separating the external and internal oblique muscles, (b) additionally another dissection is performed to free the medial 2/3rd of posterior rectus fascia from the rectus muscle in the medial to lateral direction. This procedure advances tissues towards the midline for up to 10, 20 and 6 cm in the epigastric, umbilicus and suprapubic regions, respectively. One of the modifications of this technique by Shestak et al. [46] involves separation of the external and internal oblique muscles as before in a bloodless plane to the mid axillary line and if necessary can be extended to the posterior axillary line. The rectus muscle is then separated posteriorly from the medial side with care being taken to preserve the anterior sheath. All the tissues are then closed in layers without tension. With this method, reconstruction of large abdominal defects can be achieved by functional transfer of these components at the same time maintaining their innervation and vascularity. Rarely closure cannot be achieved in some large defects, under such circumstances it can be combined with the placement of mesh or fascia graft to accomplish this. In the series reported by Shestak et al. 21 out of 22 patients had successful primary repair of muscle and fascia and in those who had separately raised skin flaps 20 out of 22 were closed primarily. The remaining two required skin grafts. They reported only one case of hernia recurrence in a patient who was obese and diabetic. Wound infection was seen in two patients and one of which had a seroma [6].

Vacuum-assisted Closure (VAC)

The introduction of VAC therapy brought with it a revolution in the management of open abdominal wounds (Figure 3). Current usage includes unstable patients, infected, and contaminated cases when closure of abdomen is not advisable or prudent. The use of VAC device decreases edema, bacterial count, contracts the wound and also allows drainage of exudates. It has also been shown to increase granulation tissue production in excess of 60% [47]. In small partial defects, up to a third of wounds can be expected to contract and close spontaneously while the others can be closed by alternate methods without the need for complex procedures. Some of these patients can also be managed on an out patient basis. In large defects it can decrease the size of the wound to allow delayed primary closure. And when this is not possible it can be used in combination with mesh or split thickness skin grafts when the wound has sufficient granulation tissue. In the series reported by DeFranzo et al., 28 out of the 30 patients who had full thickness defects were treated successfully by the above methods

and nearly half of these were secondary to trauma. Complications seen were one patient having evisceration, two with infections one each of the abdominal wall and inside the abdomen and there were two deaths due to multiple organ failure [48]. VAC therapy has also been advocated in the presence of enteric fistula [49, 50]. In another study by Scott et al. [51], 37 patients were treated with a combination of vacuum pack, VAC, and human acellular dermal matrix with successful closure of all wounds.

Tissue Expansion

Tissue expansion permits recruitment of adjacent skin and soft tissue to cover the abdominal contents (Figure 4). It can be used in situations where there is wound retraction and loss of abdominal domain but without an open wound. It is important to ascertain that the wound is free from infection or inflammation before placement of expanders. Various sizes and shapes of tissue expanders are available depending on the size of tissue requirement. The commonly used ones are either semilunar or rectangular in shape and are introduced with a small incision in a clean area. Carlson et al. [52] reported introducing tissue expanders adjacent to the skin edge in four patients with ventral hernias and successfully closed them all. Other surgeons have reported placing them in different planes such as subcutaneous tissue, between external and internal oblique or between internal oblique and transversus muscles [53, 54]. Continuity of large defects can be restored with this technique. However, the disadvantages include several weekly expansions which delays closure and early removal when there is evidence of infection or exposure of expanders.

Abdominal Wall Transplant

A new concept was developed by Tzakis et al. [55] when they noticed that abdominal wall closure was difficult in approximately one out of five patients receiving multiorgan transplant. This led to the idea of transplanting abdominal wall as a separate organ in such cases. The abdominal wall flap is based on the deep inferior epigastric artery and taken along with femoral and iliac artery and includes skin, subcutaneous tissue, rectus muscle(s) and the fascia. Donor vessels are anastomosed to recipient's common iliac vessels. ABO compatibility is more significant for graft survival than HLA typing. In a series reported by Levi DM et al., two patients who had received abdominal wall transplants from different donors than that of the organs they received experienced acute rejection episodes [55]. These were treated and resolved with increased steroid dosages. Since the success of hand and facial tissue transplant with immunosuppression, abdominal wall as a composite tissue is similar and can therefore be transplanted as such. Although a relatively small number of patients have had this procedure it offers an option when large defects are encountered.

Conclusion

Reconstruction of abdominal wall in traumatic injuries is challenging and often a vexing problem to treat. The management of such patients should be approached in an effective, consistent, and logical sequence. One should remember that multiple procedures may be required to achieve satisfactory results particularly in patients who are moribund and have associated injuries. Finally, a thorough understanding of the anatomy, analysis of the problems, scrupulous planning, and meticulous technique will lead to successful outcomes with less complications and an improved quality of life for these patients.

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