Reconstruction of chest, abdominal walls and perineum

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ABSTRACT

The structural integrity of the chest and abdominal walls and perineum is frequently altered by cancer extirpation. Advances in reconstructive surgery and the availability of innovative techniques have helped the cancer surgeon to proceed with radical excisions with minimum morbidity. The ability to harvest flaps from distant sites and the availability of good prosthetic materials have now become part of the routine armamentarium of the plastic surgeon engaged in reconstructive surgery of these areas. Newer technologies incorporating tissue engineering may allow the reconstructive surgeon to achieve better functional and aesthetic rehabilitation of these patients.

KEY WORDS

Abdominal wall reconstruction, perineal reconstruction, thoracic wall reconstruction

Reconstruction of the thoracic and abdominal walls and perineal area after ablative cancer surgery is an infrequent but demanding task that is encountered by reconstructive surgeons. The advances made in the field of reconstructive surgery over the last two decades has made the job of the surgical oncologist a little easier, as resection with negative margins is not restricted by the fear of the defect caused by large excisions. The basic principle of cancer surgery will always remain a wide local excision. For tumors involving the chest and abdominal walls or perineum, either primarily or secondarily, an oncologic excision will often leave a large complex defect involving multiple layers and often associated with organ resection. The job of the reconstruction team is to address the anatomical, functional and cosmetic deformity caused by the excision and address each aspect to get optimal results.

An attempt will be made in this article to review the indications, anatomical and functional requirements of the defects to be reconstructed as well as the methods of reconstruction in these areas.

CHEST WALL RECONSTRUCTION IN ONCOLOGY

Surgery is usually the best option for malignant tumors of the chest wall. The common indications for resection of chest wall in oncologic practice include primary tumors of the chest wall (the most common being chondrosarcoma), tumors of the breast invading the chest wall (especially in postmastectomy recurrences) and less commonly, tumors of the lung and mediastinum invading the chest wall. Another common indication in the past but less common nowadays due to better quality radiotherapy is osteoradionecrosis of the chest wall.

Why reconstruct chest wall defects?
The thorax has to move as one single segment. If more than three ribs are resected, there is a possibility of a flail segment causing paradoxical movement. The flail segment results in hypoventilation and increased respiratory work leading to ventilatory disturbances. Also, any closure of defects in the chest wall must be impermeable to air, free of tension and must protect vital structures inside the
tissue. The thorax also supports the pectoral girdle via the clavicle and scapula; hence, the mobility of the upper limbs can be affected if this is disturbed.

Not all defects however need reconstruction. The size and site of the neoplasm would decide the need for reconstruction. Anterior and lateral defects are more likely to cause paradoxical respiration while partial sternal and posterior defects require less stabilization. Posterior defects covered by the scapula without any risk of inward rotation usually may not require any skeletal reconstruction. Defects < 5 cm in diameter usually do not require any skeletal stabilization. The ultimate goal of reconstruction is to obliterate dead space especially in cases requiring pneumonectomy, maintain adequate chest wall stability, provide coverage and preserve form and function.

Methods of reconstruction
Traditionally, reconstruction of the skeletal framework has been performed using bone, diced cartilage, strips and plates of metal, stainless steel, tantalum, fiberglass, autogenous rib grafts, fascia lata, Teflon, Ivalon sponges and other substances. The disadvantage of most metal plates is that they are too rigid for the chest wall and the continuous movement causes erosion and destruction of adjacent structures.[1] Garcia et al. have used cryopreserved iliac bone allografts fixed with steel wires and covered with a pedicled, myocutaneous flap with excellent results for chest wall reconstruction.[2]

The allograft’s role in repair is to provide a scaffold for the receptor cells to invade and repopulate it, thus, bridging the gap. If treated properly, the graft can also play a part in osteoinduction. The only factor against an allograft is the potential risk of transmission of disease.

With the advent of prosthetic materials, reconstruction options have increased. Prosthetic materials are preferred as they have become widely available and are inherently flexible with the ability to conform to any size or shape of the defect(s). The inert materials used to accomplish skeletal reconstruction include Gore-tex™ (polytetrafluoroethylene, PTFE), Prolene™, Vicryl™ or Marlex™ methylmethacrylate and combinations of these. PTFE patches have the advantage of being impervious to the flow of air and fluids.[3] According to some authors,[4] marlex, vicryl and prolene mesh are as effective as PTFE although they permit a transient flow of serum and blood. Vicryl mesh is preferred if there is wound contamination or infection. If rigidity is crucial, methylmethacrylate can be used alone or incorporated into the vicryl mesh in a sandwich fashion, leaving a rim of mesh to act as a sewing surface.[5-7] This is often required following sternal resection when stability and protective coverage are essential over the heart and the great vessels.

Soft tissue reconstruction
All the chest wall muscles and omentum are available for reconstructing soft tissue defects. Myocutaneous flaps are safe and reliable[8-10] and the latissimus dorsi (LD),[11] pectoralis major, rectus abdominis and external oblique[12] are the principal muscles employed either as myocutaneous or muscle alone flaps. Their utility, however, will depend on the nature and location of the malignancy, especially the pectoralis major myocutaneous (PMMC) flap, the use of which may be limited as it comes in the close proximity of the malignancy. The rectus abdominis is much more in use both as a pedicled flap and as a free flap. Free flaps are preferred for very large defects or unusually located defects, our preference being the rectus abdominis and lateral thigh flaps [Figures 1, 2]. The recipient vessels are usually selected from the internal mammary, branches of the axillary vessels or superior epigastric vessels. The omentum is another alternative to muscle flaps,[11] being particularly useful in the setting of osteoradionecrosis and in the presence of infection because of its excellent blood supply. The greater omentum is dissected, pedicled on the right gastroepiploic artery and then inserted through a tunnel in the chest pocket. Its disadvantage is the lack of solidity and alternative source of skin cover if needed. The addition of a laparotomy is another disadvantage for this flap, but recently Ferron et al. have published their experience with laparoscopically harvested omental flaps with meshed skin grafts for complex chest wall defects. They also combined vacuum-assisted closure (VAC) with laparoscopically harvested omental flaps,[13] which has been shown to be an effective way to accelerate healing of wounds by exposing the wound bed to a subatmospheric pressure.[14] VAC treatment has been shown to significantly increase the success rate of skin grafts.[15,16] VAC theoretically provides the perfect conditions for graft take: a suitable wound bed, firm fixation, prevention of shearing forces, adaptation to various concave/convex surfaces, evacuation of hematoma and seroma under the graft and reduction of infection.[17,18] Feron et al.[13] observed fast and complete healing in ten patients with a mean of 3.3 dressing changes (range = 2–5). VAC is more expensive than conventional treatment.
but the shorter duration of treatment and fewer additional interventions help to even out the cost.

Based on large series, many authors have proposed reconstructive algorithms for chest wall reconstruction,[19-21] The main issues to decide are whether pleural cavity has to be addressed, whether bony chest wall has to be reconstructed and whether skin and soft tissue cover is needed. The pleural cavity needs to be addressed only in certain occasions, e.g., to obliterate postpneumonectomy empyema spaces or for closure of broncho-pleural or tracheoesophageal fistulas. The Latissimus dorsi (LD), Serratus anterior and Pectoralis major muscles as well as the omentum have all been used for this purpose.[22,23]

**Skeletal reconstruction**

Skeletal reconstruction is influenced by numerous factors. In general, resection of more than three ribs at most sites usually requires reconstruction. According to Arnold,[24] most patients can tolerate sternectomy or resection of 4–6 ribs at the cartilage level without experiencing flail chest or respiratory insufficiency. The decision on the type of reconstruction is widely influenced by the surgeon’s preference. Prosthetic materials like Prolene™ and Marlex™ mesh are commonly used because of their wide availability and flexibility.

**ABDOMINAL WALL RECONSTRUCTION**

The correction of complex defects is a challenge to both plastic and reconstructive and general surgeons. In 1934, Wangenstein[25] first performed a pedicled tensor fasciae lata (TFL) reconstruction of the lower abdominal wall. Numerous flaps with various combinations of muscle and skin from the adjacent abdominal wall or from distant sites have been described. It is established that abdominal hernia, abdominal wall laxity, persistent chronic back pain and scoliosis are problems commonly associated with the loss or absence of abdominal wall muscle structures.

**Timing of reconstruction**

The best time for reconstruction is at the time of the primary surgery as it is most cost-effective and less time-consuming. The repair has to be deferred if the patient is unstable or if there is significant abdominal distention or inflammation.[26] In such cases, frequent dressings, mesh[27] placement, splitskin grafting[28,29] may be done. VAC[30] may also be used to get speedy granulation and a temporary cover to give increased vascularization to the wound, decreased bacterial colonization, increased formation of granulation tissue and increased flap survival.[31]

If abdominal reconstruction is delayed, surgery should be avoided for six months or until the previous abdominal scar has fully matured.[32] This will decrease the number of adhesions and the density of the scar tissue.

Standard precautions have to be considered during treatment of a previously irradiated patient. The reconstructive surgeon should consider the transfer of nonirradiated tissue by mobilizing distant flaps. Hyperbaric oxygen therapy has been shown to be useful for these patients.[33]

**Types of reconstruction**

Reconstruction could be static or dynamic. It is preferable to have a dynamic reconstruction when there is a complete defect.

**Static reconstruction**

Static reconstruction of the abdominal wall defect uses autologous tissues or alloplastic materials. Dynamic movements of the abdominal wall are often preserved even in static repair procedures if the major bulk of the abdominal wall musculature including the rectus abdominis, internal and external oblique and iliopsoas muscles, are left undisturbed.

**Functional reconstruction**

An intact abdominal wall is essential in controlling respiratory effort and in increasing intraabdominal pressure to aid bowel movements, coughing and micturition. An ideal method of abdominal wall reconstruction should restore muscle activities without any cicatricial adhesions of the viscera.

It is important to separate all the muscle components and coopt them. If this is not possible, at least the external oblique muscle should be coopted for dynamic reconstruction. If identification of muscle layers is difficult and primary cooptation of muscle layers is not possible, the defect can be covered with pedicled muscle flaps like the Rectus femoris, Latissimus dorsi (LD) or Tensor fascia lata muscle flaps. The problem with the use of the rectus femoris is the position of the vascular pedicles, which enter the muscle much lower than the nerve.
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Figure 1A: Extensive, locally advanced breast cancer involving the chest wall

Figure 1B: Defect of the chest wall including the ribs and pleura.

Figure 1C: Chest wall defect (1B) covered by prolene mesh and free transverse rectus abdominis musculocutaneous flap

Figure 2A: Defect of the chest wall following excision of chondrosarcoma of the ribs

Figure 2B: Fascia lata raised along with anterolateral thigh (ALT) flap used to cover the chest wall defect

Figure 2C: Well-settled flap after six months
The intact motor nerve of the rectus femoris muscle is transferred without transection by tracing it up in the thigh, but the pedicle vessels may need to be transected and anastomosed to the nearby vessels.\cite{34}

**Prevention of cicatricial adhesion**

Dacron sheets, gore-tex, silicone sheets and autogenous facial sheets are inert and prevent adhesions.

**SURGICAL TECHNIQUES**

The selection of an appropriate technique is governed by size of the defect, location, tissues and materials available for reconstruction and the condition of the patient.

**1. Primary and layered closure techniques**

They are useful in closing defects < 7 cm in size. When defects are closed under tension, tissue necrosis, respiratory compromise, abdominal compartment syndrome can occur.

**Component separation technique**

In 1990, Ramirez et al.\cite{35} closed large midline defects by separating the structural components and mobilising the musculofascial tissues. The anterior rectus sheath was separated from the external oblique aponeurosis by making a longitudinal relaxing incision along the linea semilunaris. Posteriorly, the rectus muscle was separated from the posterior sheath, but the lateral border was left undisturbed. The muscle belly along with the anterior rectus sheath, was mobilized to cover the structural defect. Using bilateral-relaxing incisions and release, a total of 10, 18 and 6–10 cm width of advancement of the layer consisting of the muscle with the anterior sheath can be obtained in the upper, middle and lower thirds of the abdomen, respectively.\cite{35} Using the endoscopic technique\cite{36} for this separation preserves the midline-perforating vessels to the skin and decreases overall morbidity. Girotto et al.\cite{37} suggested an algorithm for this component separation. If there is tightness in closing anterior abdominal wall defects, the external oblique muscle is separated from the anterior rectus sheath and the internal oblique at the linea semilunaris on one side. The procedure is repeated on the other side if the closure is still tight. The posterior rectus sheath is then released if the tightness persists.

**Layered closure after tissue expansion**

When a defect is primarily closed only with a split skin graft, the adjacent tissues are expanded and used to cover the defect. The expander is placed just above the muscle fascia layer. The most effective area is over the ribs and the lumbar fascia. A mesh may be used to reinforce the soft tissue. The expander may also be placed between the internal oblique and the transversus abdominis through an incision made in the rectus sheath.\cite{38,39} It may also be placed between the external and internal oblique muscles laparoscopically.\cite{40}

**2. Skin grafts, fascial grafts, prosthetic and bioprothetic materials**

Their use is limited to partial thickness defects.

**Skin grafts**

This is usually reserved for defects where the bed has good vascularity and is often the treatment of choice for defects with adequate musculofascial support. In cases where it is not possible to give a primary flap cover, skin grafts are applied directly over the viscera on a temporary basis. Later, they are deepithelialised and a permanent cover is given.

**Free fascial grafts**

Commonly used free fascial grafts are the fascia lata or the anterior rectal sheath. There must be adequate skin coverage when using them and they can reportedly be used in contaminated wounds\cite{41} also. The fascia lata, the preferred fascial graft material having a low foreign body reaction, seldom adheres to intraabdominal viscera.\cite{42}

**Prosthetic materials**

There are a wide variety of prosthetic materials available to bridge the musculofascial defect. A meshed material\cite{43} is preferred due to better tissue strength, the most commonly used one is a polypropylene mesh. It has to be fixed with slight tension without any folds to prevent erosions and enterocutaneous fistulas. An expanded PTFE patch has been reported to cause less adhesion to the visceral surface.\cite{44} An absorbable mesh made of polyglycolic acid or polyglactin 910 lasting for a period of 3-4 months has been recommended for use in case of heavy wound contamination also but with a higher rate of hernia formation.

Prosthetic materials are placed either as inlay, onlay or underlay grafts. In the inlay technique, which is associated with a higher chance of hernia formation, the material is placed in the defect and anchored to its edge. Onlay grafting is the commonly followed technique with a lower chance of adhesion wherein there is an overlap of the mesh over the
normal tissues around the edge of the defect. The underlay grafting technique places the prosthetic material between the peritoneum and the posterior rectus sheath.

**Bioprosthetic mesh**

Bioprosthetic meshes derived from animal or human tissue, get incorporated initially into host tissues and function as mechanical bridges and later get remodeled by the same host tissues. Acellular human and porcine dermis are some of the different bioprosthetic materials available. They have fewer visceral adhesions, have no donor site morbidity and may be used in contaminated wounds. Their disadvantages are high cost, availability of smaller sizes and seroma formation without any data available for long-term use.

3. **Flaps**

Cutaneous and Fasciocutaneous flaps are useful to repair partial defects of the skin and subcutaneous tissue or are occasionally used along with a prosthetic mesh to repair a full-thickness defect. The flaps commonly used include the groin flap and the iliolumbar flap.

Musculocutaneous flaps are used to reconstruct a full-thickness defect of the abdomen. The most commonly used flap is the rectus abdominis musculocutaneous flap based on either the inferior or superior epigastric vessels. The skin paddle may be vertically or transversely (transverse rectus abdominis musculocutaneous flap, TRAM flap) oriented. The other flaps described include the extended deep inferior epigastric flap, which is used to reconstruct a defect in the upper and lower abdomen. It bases its blood supply on the paraumbilical perforators of the inferior epigastric vessels oriented towards the angle of scapula and relies on the communication between the perforators of the inferior epigastric vessels and intercostals vessels. to

**Distant composite flaps:** The majority of full-thickness defects require a transfer of tissue from a distance due to the lack of adequate suitable tissue locally. Commonly used flaps include the anterolateral thigh fasciocutaneous flap transferred as a pedicled flap or a free flap [Figures 3A, B] and the tensor fascia lata (TFL) flap based on the transverse branch of the lateral circumflex femoral artery. The TFL flap can be harvested as a muscle, fascial or a fasciocutaneous flap and will reach a few centimeters above the umbilicus superiorly and the midline of the abdomen medially. A free TFL musculocutaneous flap is not only useful for surface coverage but is also effective in restoring musculofascial continuity with the areolar tissues on the undersurface of the tensor fascia lata, which are included in the flap as they reduce cicatricial adhesion. These two flaps can be combined with the pedicle, which can either be the lateral circumflex femoral artery or the descending branch of the same vessel to give wider area of coverage. The superior gluteal nerve innervating the tensor fascia located in the posteroinferior aspect of the muscle can be harvested along with and coopted with an appropriate intercostal nerve at the site of flap transfer to make it a functional transfer.

Figure 3A: Extensive recurrent lower abdominal wall tumor

Figure 3B: Defect covered with a free ALT flap along with prolene mesh
may be used as a free flap to cover any area of the abdomen as well as an innervated flap. The gracilis musculocutaneous flap may be used to repair a defect in the lower third region of the abdomen.

Algorithmic approach to abdominal wall reconstruction
The goals of abdominal reconstruction are threefold: restoration of the function and the integrity of the musculofascial abdominal wall, prevention of visceral eventration and the provision of a dynamic muscle support.[52,53] An algorithmic approach has been suggested to make decisions in abdominal wall reconstruction.[52,53]

Defect < 7 cm
Skin defect: The wound can often be closed primarily. If skin grafting is not an option, random and local fasciocutaneous flaps can also be used. VAC or tissue expansion may also be considered options.

Musculofascial loss: Prostheses may be used if there is no contamination. Component separation and local flaps are used depending on the area.

Complete defects - area-wise and techniques used:
- **Upper abdomen**: The component separation technique, latissimus dorsi (LD) musculocutaneous flap or free flaps
- **Mid abdomen**: The component separation technique, local flaps (vertical rectus abdominis musculocutaneous, external oblique), distant flaps (TFL, Rectus femoris or iliolumbar skin flap), prosthesis plus flap or free flaps
- **Lower abdomen**: The component musculoaponeurotic flap, local flaps (vertical rectus abdominis musculocutaneous flap and internal oblique), distant flaps (tensor fascia lata musculocutaneous flap, the anterior thigh flap, vastus lateralis, gracilis and the rectus femoris musculocutaneous flaps).

Defect > 7 cm
Soft tissue loss without musculofascial loss: Regardless of the size of the defect, the initial approach should be autologous skin grafting for wound control. Later, tissue expansion may be done and the skin graft removed. A skin flap harvested from an adjacent area may be considered if the extent of soft tissue loss is extensive. VAC is another useful technique.

Only musculofascial loss: Distant flaps like extended TFL, rectus femoris and Latissimus dorsi (LD) may be tried but should be done without any delay. Free flaps or expansion of the muscles are other options.

Complete defects: Pedicled flaps have limited use. Free composite tissue transfer is the safer option. Useful pedicled flaps include the vertical rectus abdominis and LD flaps in the upper abdomen and TFL, rectus femoris or vastus lateralis in the lower abdomen. Generally, these would require a free transfer of the tensor fascia lata musculocutaneous flap with or without concomitant inclusion of the anterior thigh flap.

PERINEAL RECONSTRUCTION
The main problems of perineal reconstructions are fecal and urinary contamination due to the proximity of the anal canal and the urethra. Filling the surgical defect with healthy, well-vascularized tissue has been shown to decrease the incidence of fistulas, bowel obstructions, infections and hemorrhage in irradiated patients. Vaginal reconstruction after pelvic exenteration not only affords significant psychological benefit but also decreases the accompanying morbidity and mortality. There are many adjacent flaps that may be used in the perineum, which could be muscular, musculocutaneous or fasciocutaneous in nature.

Muscle and musculocutaneous flaps
The gracilis is a very useful muscle in the reconstruction of the anterior perineum as well as of perirectal defects. It can also be used to reconstruct the vagina,[54] anal canal, anal sphincter, scrotum and penis. It may be used as a muscular or a musculocutaneous flap.

Tensor fascia lata is used to reconstruct the posterior as well as the anterior perineum. It may be used as a musculocutaneous or musculofascial flap. With its wide arc of rotation and bulk, the rectus femoris flap can cover the entire perineum although the functional deficit of its harvest makes it a reserve flap. The inferiorly based rectus abdominis myocutaneous flap[55,56] can be tunneled and used to reconstruct the anterior perineum. It may also be taken trans-pelvic to cover anal wall defects. Perineal closure with a rectus abdominis flap significantly decreases the incidence of perineal wound complications[57,58] in patients undergoing external beam pelvic radiation and in those who undergo abdominoperineal resection for
anorectal neoplasia. Another useful flap is the gluteus maximus flap, which can be used to cover the perineum and to reconstruct the anal sphincter.

Regional fasciocutaneous and perforator flaps[59,60]

These flaps may be appropriate for perineal reconstruction when the defect is superficial with not much of dead space. However, they have to be used with caution in irradiated field(s) or if postoperative radiation is planned.

Lotus petal flaps[61] are perforator-based, fasciocutaneous flaps around the urogenital and the anal orifices.[62] They have been used for vaginal reconstruction after cancer surgery. Other local flaps like gluteal fold flaps[63] are also utilized for perineal reconstruction.

The gluteal thigh flap[64] utilizing the descending branch of the inferior gluteal artery, is used to cover very large defects without much donor site morbidity. The anterolateral thigh (ALT) perforator flap[64] may be used both as a pedicled or a free flap for reconstructing large perineal defects. Deep inferior epigastric perforator flaps (DIEP) may also be used both as a pedicled or a free flap for perineal reconstruction. The DIEP flap has much less abdominal wall morbidity than a pedicled rectus myocutaneous flap[59] but is more difficult to harvest and execute. The gluteal perforator-based flap has also been reported to be useful in cases of posterior pelvic exenteration.

REFERENCES


