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Chest Wall Reconstruction: A Comprehensive Analysis

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Abstract
Purpose of Review Chest wall reconstruction often includes complex defects requiring coordination with consulting services and attention to both skeletal and soft tissue defects. Through a review of the historical context of chest wall reconstruction, this article will address current considerations for both components of reconstruction. Special considerations related to reconstruction of the chest wall will be reviewed.
Recent Findings Exciting advancements have been made in the past decade in solving the ongoing challenge to find optimal materials for use in skeletal reconstruction and stabilization. Biologic meshes and titanium osteosynthesis devices may provide future promise in chest wall reconstruction and continue to be evaluated. Additionally, 3D printing presents an opportunity to custom design implants for skeletal defects. Though principles of soft tissue reconstruction remain pillars to successful chest wall reconstruction, advances in the management of tumors, as well as care of complex cardiac and pulmonary surgical patients, have allowed an opportunity to address more complex intrathoracic and extrathoracic defects.
Summary Reconstruction of chest wall defects presents unique challenges to the reconstructive surgeon. Consideration of patient factors, as well as reconstructive components, should be discussed preoperatively. Although complication rates remain high in this population, involvement of the plastic reconstructive surgeon and use of flap reconstruction have been shown to reduce morbidity and mortality in chest wall reconstruction.

Keywords Chest wall reconstruction · Sternal reconstruction · Intrathoracic reconstruction · Chest reconstruction algorithm · History of chest wall reconstruction · Chest reconstruction evolution

Introduction

The art of chest wall reconstruction has evolved over the past few centuries. The first large case series of chest wall tumor resection and reconstruction was published by Frederick Parham in 1899. In this paper, he collected 78 cases of chest wall resection performed across the world beginning in 1778 [1]. The next important contribution to chest wall reconstruction and to the field of plastic and reconstructive surgery was in 1906, when Iginio Tansini described a large myocutaneous flap elevated from the axillary region for reconstruction of an anterior chest wall defect after a radical mastectomy [2]. This was the first published report of a myocutaneous flap for chest wall reconstruction, but unfortunately his work went largely unnoticed; it would be another 50 years until myocutaneous flaps were rediscovered [3]. Pioneers of the modern era of chest wall reconstruction were Arnold and Pairolero [4–11]. In 1995, they published an account of 500 consecutive patients who underwent chest wall reconstruction and subsequently have introduced the modern era of reconstructive options. The most commonly used flaps for soft tissue reconstruction were pectoralis major, followed by latissimus dorsi and then omentum [10].

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The need for skeletal stability posed a further challenge to the reconstructive surgeon. In 1933, Goodman employed periosteal flaps from adjacent ribs and sutured them together to cover a thoracic wall defect [12]. While autologous tissue provided good stability for smaller defects, prosthetic material was required for larger defects. The use of metal prostheses was first advocated in 1909 by Gangolphe [13]. In the 1950s, tantalum plates became a popular product for chest wall reconstruction [14]. Half a century later and a myriad of materials exist including plastic, synthetic meshes, osteosynthesis systems, bone substitutes, and dedicated metal prostheses [15].

The development of improved anesthesia, surgical technique, antibiotics, and critical care has allowed surgeons to perform larger chest wall resections [16, 17]. These defects can lead to altered ventilation, skeletal instability, and significant cosmetic defects. These all pose an arduous challenge for the reconstructive surgeon [18]. These cases can be broadly divided into five categories: tumors, radiation necrosis, infection, congenital, and trauma. Tumors account for the largest category and can be further subdivided into primary tumors of the chest wall, adjacent tumors (lung, breast, pleural, mediastinal), and metastatic lesions [19]. The extent of resection will depend on the etiology of the defect. Radiation necrosis and infection will require debridement to healthy tissue. Tumor resection will depend on the pathology as different tumors will require different margins. The most up to date information on tumor margins and management can be accessed on the National Comprehensive Cancer Network [20]. Benign lesions require resection to microscopically clear margins, while malignant lesions require wide local excision. In most instances, the tumor will have been biopsied prior to surgery [21]. Free surgical margins are the main prognostic criteria [22•]. Knowledge of the possible extent of defect is required for adequate preoperative planning by the reconstructive surgeon.

The chest wall has many important functions, including protection of vital organs, assisting with respiration and skeletal stabilization of the shoulder and arm [21]. The principles of chest wall reconstruction depend on defect location, size, prior procedures, and extent of skeletal defect [23]. The two major goals of chest reconstruction are re-establishment of chest wall stability and coverage with well-vascularized soft tissue [24]. Thomas and Brouchet described five additional objectives: avoiding lung herniation and paradoxical chest wall motion, preventing scapula impaction into the defect in cases of posterior chest wall resection, counteracting the contraction of the operated side of the thorax, protecting the underlying mediastinal organs from external impact, and maintaining an aesthetically acceptable chest shape [15]. There is currently no gold standard for chest wall reconstruction, as evidenced by the variety of reported treatment algorithms and operative techniques in the literature [25–27]. In the following sections, we will review the different options for skeletal and soft tissue reconstruction.

Skeletal Reconstruction

Initially, the success of chest wall reconstruction was limited by a lack of suitable materials for skeletal reconstruction. Autologous tissues, such as ribs grafts, fascia lata, and other cutaneous grafts, were commonly employed. The introduction of synthetic materials revolutionized the field [24, 28]. The impact of reconstruction on functional outcomes is poorly studied, with evidence being mainly limited to small retrospective studies [22•]. Therefore, the choice of material is dependent on patient factors, institutional availability, and surgeon preference. The features of an ideal prosthetic material for chest wall reconstruction were outlined by le Roux and Shama and are shown in Table 1 [29]. Currently, no material fulfills all of these criteria, and each material has its own advantages and disadvantages (Table 2). In this section, we will review the different options available for skeletal reconstruction of the chest wall.

Traditionally, skeletal reconstruction is recommended for defects equal or greater than 5 cm and for resection of four or more ribs. This is especially true for anterolateral resections and sternal resections. This is due to the theoretical risk of larger resections leading to flail chest and subsequently respiratory compromise. Although there is a paucity of evidence in the literature to support definitive recommendations, defects located adjacent to the spine, under the scapula, and under pectoralis major typically do not require prosthetic reconstruction [16, 18, 23, 30]. Some argue for reconstruction of defects of even 4 cm in patients with preoperative decreased pulmonary function [19]. A traumatic flail chest is defined as the fracture of four or more consecutive ribs leading to paradoxical motion of the chest wall segment. Stabilization through open reduction and internal fixation for these fractures has become

Table 1 Features of ideal prosthetic material for chest wall reconstruction, as outlined by le Roux and Shama [29]

1. Malleability for contouring
2. Rigidity to abolish paradoxical chest wall motion
3. Radiolucent
4. Inert
5. Allow for tissue incorporation
6. Sterile and resistant to infection
7. Inexpensive

Table 2 Skeletal reconstruction materials

Material	Advantages	Disadvantages
Synthetic meshes and patches		
Methyl methacrylate	Rigidity, contourability	Impermeable, no tissue ingrowth, not radiolucent
Polypropylene (Marlex, Prolene)	Tissue ingrowth, macroporous	Dense adhesion formation
Polytetrafluoroethylene (Dualmesh, GoreTex)	Ease of use, watertight	Negligible tissue ingrowth, need to remove with infection
Titanium (MDF Medica)	Inert, biocompatible	Fracture
Bioprosthetic meshes		
Cadaveric human dermis (AlloDerm)	Tissue ingrowth, can be used in infected field	High cost, possibly long-term laxity/stretching
Porcine (Permacol, XenMatrix, Strattice, Surgisis)		
Bovine (Tutopatch, Veritas, SurgiMend)		
Osteosynthesis system		
Titanium (Stratos, Stracos, MatrixRIB Fixation)	Inert, biocompatible	Displacement, rupture

increasingly popular with evidence of shorter intensive care unit stays, faster ventilator wean, decreased cost, and improved pulmonary function [31].

Autograft and Allografts

The late 1940s saw the introduction of autogenous materials for reconstruction of chest wall defects. Bisgard and Swenson described the use of costal autograft [32]. Meanwhile, Watson and James proposed the use of fascia lata grafts [33]. The disadvantage of autogenous materials is the limited amount of available tissue and the donor site morbidity [34•]. The introduction of prosthetic materials led to autografts falling out of favor. The first use of an allograft in chest wall reconstruction was in 1993, when cryopreserved iliac crest bone was used for sternal reconstruction [35]. Allografts eliminate the donor site morbidity and limitations on the amount of material available. They provide both osteoconductive and osteoinductive properties, making them more resistant to infection [23]. In a recent multicenter study evaluating sternal reconstruction with cadaveric sternal allograft, no accounts of infection or rejection of the allograft and no respiratory compromise were noted. The allograft was tailored intraoperatively to fit the chest wall defect and then fixed in place with titanium plates and screws [34•].

Synthetic Meshes and Patches

There are numerous synthetic products available to the reconstructive surgeon. These include flexible options and rigid constructs [18]. Prosthetic flexible meshes were first reported in the 1950s. In 1960, Graham et al. published a case series of 13 patients who underwent chest wall reconstruction with Marlex mesh. Only one patient developed an infection, which was treated without need for mesh removal, and no patients experienced long-term paradoxical chest movement [14]. Marlex mesh and other meshes continued to gain popularity. Prosthetic meshes are sutured under tension to provide semirigid chest wall stability, thus avoiding paradoxical motion [24]. They can be used to repair small lateral defects. The advantages of flexible meshes include ease of manipulation, lower risk of seroma formation due to their permeability, and that they are well tolerated [18]. When compared to no stabilization, mesh may significantly decrease the number of days on ventilator support and length of hospital stay; however, the use of mesh has been associated with a 5% increase in infection rate [36]. The biggest drawback is that they require removal in the setting of infection [37]. The infection rate is reported between 10 and 25% [23]. Additionally, if not pulled taught, they can loosen over time and cause paradoxical motion [18]. A rigid construct is needed for anterior and sternal defects to protect the underlying viscera [16]. While the overall complication rates have been shown to be similar between patients undergoing reconstruction with either flexible, rigid, or no prosthesis in a large case series, the rigid prosthetic group demonstrated a significantly higher number of wound complications [28].

The “sandwich” method was devised by Manjit S. Bains in 1980 [38]. Since then, it has been commonly employed for reconstruction of large defects that require a more rigid construct. This involves using methyl methacrylate (MMA), a resin, sandwiched between two layers of mesh.

The construct is usually prepared on the back table and then sutured in place [39••]. The MMA can be poured in situ allowing for improved contouring, but the underlying structures have to be protected as the hardening process is exothermic. The advantages of this rigid construct are that it provides protection to underlying thoracic structures and conforms to the contours of the chest. Additionally, it provides excellent chest wall stability. The disadvantages include pain, infection, hematoma, and seromas [28]. A recent meta-analysis of chest wall reconstruction using MMA found that complications were reported in 13.7% of patients, with infection being the most common complication (5.6%). The MMA sandwich method had significantly lower infection rates (4.4%) compared to non-MMA sandwich (11.7%) [39••].

Titanium mesh has gained popularity in the past twenty years as a reconstructive material. It has many advantages as a synthetic material including low weight, high strength, osseointegration, biocompatibility, and resistance to infection. In a recent retrospective multicenter study of 26 patients who underwent chest wall reconstruction with titanium mesh, one patient had a fracture of the construct and two developed surgical wounds, which did not lead to removal of the mesh [40].

Biological Meshes

Biological meshes are collagen matrices composed of decellularized tissue from human or animal cadavers. There are limited data on the use of biological meshes for chest wall reconstruction. In small comparative studies using human biological mesh for smaller defects, lower complication rates have been reported with the use of biologic mesh compared to synthetic mesh, although not statistically significant [26]. Higher complication rates have been reported with use of non-cross-linked swine dermal collagen prosthesis, but show conserved total lung capacity postoperatively with preservation of integrity of patches on computed tomography imaging at 24 months [41]. The advantages of biological meshes include the ability to be placed directly over viscera and in infected fields. The main disadvantage is their high cost [23]. There are not enough data to know its long-term stability in the chest wall. Most of the research is from the field of abdominal wall reconstruction. More data with larger cohorts and long-term outcomes are required prior to definitive recommendations.

Osteosynthesis Systems

Osteosynthesis systems stabilize chest wall defects via mechanical devices; the most commonly used are titanium based [37]. They are used for reconstruction of anterior, anterolateral, and sternal defects to provide rigid protection to the underlying viscera and provide a good scaffold for myocutaneous flaps [16]. While there are many advantages to titanium, there have also been concerns, including a failure rate of 44% in a retrospective study of 54 patients who underwent chest wall reconstruction with titanium osteosynthesis systems. The failures included either displacement or rupture and were associated with anterior placement or the presence of three or more implants [42].

Three-Dimensional (3D) Printing

The increase in availability and speed, coupled with decreased cost of 3D printers, has led to increasing reports of 3D printed prosthetics, with molding and shaping for chest reconstruction. The most commonly reported material in 3D printing in chest reconstruction applications is titanium. However, a recent study reported outcomes of 3D printed silicone molds [43–46]. Three patients had preoperative imaging which allowed for printing of customized rib and sternum silicone molds. The mold was then sterilized and using intraoperatively to customize a methyl methacrylate construct. Although follow-up was limited to 30 days, no complications were reported [43]. Oswald et al. describe 3D printing a titanium structure for sternal and rib reconstruction in a patient who had previously undergone flap reconstruction without skeletal stabilization and experienced paradoxical chest movement with decreased respiratory function. This was improved with the 3D printed rigid prosthesis [44]. Three-dimensional printed structures are likely to continue to grow in popularity, the long-term outcomes of this method of chest wall reconstruction are still to be determined.

Soft Tissue Reconstruction

Reconstructive options of the soft tissues following resection of a tumor or trauma, as well as reconstruction of defects related to infectious complications or radiation sequelae, are dependent on availability and quality of local and regional tissues. Surgical principles of reconstructing soft tissue defects of the chest wall include obliteration of dead space and reinforcement of vital repairs to restore functional anatomy. Often, skin deficits are not present when embarking on chest wall reconstruction. Pedicled muscle flaps are frequently excellent options for chest wall reconstruction but require thorough assessment of previous surgical scars and resection zones to optimize outcomes. In this section, we will review locoregional options for extrathoracic and intrathoracic reconstruction. For the purposes of considering reconstructive options, extrathoracic chest wall defects may be classified according to location on the chest wall: anterior or sternal defects, anterolateral defects, and posterolateral defects. Reconstructive options for each anatomic zone are summarized in Table 3.

Pedicled Muscle Flaps

Pectoralis major muscle flaps provide an excellent option for anterior chest wall reconstruction and are often considered first line for soft tissue coverage of the sternum. Pectoralis major flaps are more reliably used as transposition flaps based on the thoracoacromial vessels, and partial or complete release of the tendon to the clavicular head will allow for further reach to decrease tension with inset [10]. Transposition on the thoracoacromial pedicle allows for maintenance of innervation to the muscle, therefore preserving muscle bulk [10]. Transposed muscle flaps are reliable in the setting of sacrifice of the internal mammary vessels with previous operations, and allow for future repeat sternotomies as needed [10]. Unilateral or bilateral pectoralis major flaps may have similar outcomes, and use of a unilateral flap when adequate for coverage may decrease morbidity [4, 47, 48]. While pectoralis major transposition flaps are ideal for coverage of the superior two-thirds of the anterior chest wall, they are less reliable and durable for distal sternal coverage. Pectoralis major flaps can also be based solely on the internal mammary vessels and used as a turnover flap. This option must be used with caution as in many sternal procedures the internal mammary vessels are damaged or traumatized though closure with sternal wires or debridement and in our practice is not frequently employed for this reason. Nonetheless, one benefit is that a turnover muscle can be used for lower one-third defects and can be used as a split muscle flap if a proximal or distal portion internal mammary vessels are preserved [24].

Table 3 Reconstructive options for anatomic zones of the chest wall

Chest wall anatomic zone	Reconstructive options
Anterior	Upper 2/3
	Pectoralis major transposition
	Latissimus dorsi ± serratus anterior
	Greater omentum
	Free tissue transfer
	Lower 1/3
	Pectoralis major turnover
	Greater omentum
	Rectus abdominis
	Free tissue transfer
Anterolateral	Latissimus dorsi ± serratus anterior
	Serratus anterior
	External oblique
	Intercostal
	Free tissue transfer
Posterolateral	Latissimus dorsi ± serratus anterior
	Intercostal
	Free tissue transfer

A pedicled latissimus dorsi muscle should be regarded as a workhorse for all zones of chest wall reconstruction. The latissimus dorsi is versatile and may be taken as a muscle flap, musculocutaneous flap, or chimeric flap with components of the subscapular system. The latissimus dorsi may be tunneled beneath the pectoralis major to reach the anterior chest wall and comfortably affords coverage for anterolateral defects [10]. Even in the setting of previous posterior thoracotomy incisions, adequate bulk of the latissimus dorsi often remains for posterolateral reconstruction [49]. The latissimus dorsi is harvested on the neurovascular pedicle of the thoracodorsal artery, and the thoracodorsal nerve may be preserved to retain muscle innervation and bulk. The serratus branch provides an excellent option for additional muscle bulk of the serratus anterior when harvested in conjunction with the latissimus dorsi [10]. A minimum of two to three slips of the serratus anterior should be preserved during harvest to avoid scapular winging.

As the superior epigastric artery and vein are the inferior continuation of the internal mammary system, use of a pedicled rectus abdominis muscle flap should be embarked on with caution. These flaps may be less reliable for anterior chest wall reconstruction if the zone of involvement of tumor resection, trauma, or cardiac operations involves formal harvest of the internal mammary arteries or injury to the pedicle. However, collateral circulation has been shown to exist to the superior epigastric vessels even in the setting of formal internal mammary harvest, which may allow for use of this pedicled flap as a secondary option with or without delay [10, 50]. Additionally, rectus muscle flaps may be less robust compared to pectoralis or latissimus flaps as innervation is not maintained with harvest [10]. When a sizeable skin deficit exists, a pedicled rectus abdominis flaps provide versatility with skin paddle harvest and may provide the best musculocutaneous option for anterior and anterolateral chest wall defects.

Although not a muscle flap, the greater omentum may be pedicled based on the gastroepiploic vessels and provides an excellent arc of rotation, reaching across the anterior and anterolateral chest wall and as superior as the neck. The omentum may be used for large chest wall defects and allows for coverage of defects too great for pedicled muscle flap coverage [10]. The omentum will reliably accept a skin graft or will allow for excellent obliteration of dead space below available skin. Due to reliable blood supply which is typically out of the zone of involvement of chest wall pathology, the greater omentum is regarded as an excellent salvage flap for secondary reconstruction. Through either laparoscopic or open harvest, use of an omental flap carries a risk of associated intraabdominal morbidity [51, 52]. Despite requiring entry into the abdominal cavity, the senior author commonly employs an omental flap for obliteration of dead space in the lower sternum following bone debridement for sternal osteomyelitis. This can be performed through a small continuation of the sternotomy incision onto the upper abdomen. The flap can be fashioned to the amount of dead space necessary to fill. The entire omentum can be harvested for large defects by dissecting the gastroepiploic from the greater curvature of the stomach or a smaller portion of the omentum can be taken based on the right, middle, or left epiploic vessels. The omentum thus serves as an extremely versatile option with a robust blood supply. When using only a portion of the omentum, the pedicle can be skeletonized to a very thin stalk allowing for near complete closure of the abdominal fascia and prevention of epigastric hernias. Additionally, other portions of the omentum could be harvested in future settings, if necessary.

Free Tissue Transfer

While pedicled flaps are typically available for chest wall reconstruction, microvascular free flaps may occasionally be needed. Necessity for microvascular tissue transfer has been shown to be associated with larger defect size, but not previous operations, previous radiation, or defect location [25, 53]. A variety of options exist for local recipient vessels, depending on availability and previous pathology. Options for consideration include internal mammary arteries, subclavian arteries, and the subscapular system, including thoracodorsal arteries [53]. For oncologic reconstruction, it is critical for communication between the extirpative and reconstructive teams to preserve the necessary recipient vessels when planning for free tissue transfer [25]. In the setting of sternal resections, for example, the internal mammary vessels are readily in the field. Preservation of an oncologically safe portion of these vessels on one side is often possible and allows for prompt access for recipients for microsurgical reconstruction depending on the size of the defect.

Fasciocutaneous Flaps

Excess fasciocutaneous tissue in the chest wall may exist; however, the use of local fasciocutaneous flaps is seldom employed for more than small subcutaneous defects of the chest wall. Although described historically, reconstruction of anterior defects through mobilization of breast tissue is now largely avoided [54]. Higher complication rates have been reported with the use of fasciocutaneous flaps alone, especially in the setting of radiation [25].

Special Considerations

Intrathoracic Reconstruction

Bronchopleural fistula and empyema may result following pneumonectomy and carry high morbidity and mortality. Postpneumonectomy empyema may be managed with a Clagett or modified Eloesser flap procedure [55, 56]. Ultimately, these intrathoracic and iatrogenic fistulas will require reconstruction. Respiratory failure is the most common complication of patients undergoing reconstruction for intrathoracic fistulas, occurring in 30%, with 20% of patients requiring tracheostomy [57].

Although a pedicled latissimus flap with or without serratus anterior is the preferred flap for intrathoracic reconstruction due to available bulk and low flap failure rates, a serratus flap alone has been reported as the most commonly used flap [57, 58]. This is the result of location of prior posterolateral thoracotomy incisions in patients undergoing intrathoracic reconstruction [57, 58]. The external oblique muscle also presents an alternative option for intrathoracic reconstruction, and can be used as a turnover flap to cover diaphragmatic defects or defects up to the level of the inframammary fold [10]. Intercostal muscle flaps should also be considered as an available option when bulk is not required for reconstruction. Intrathoracic flaps may be introduced into the thoracic cavity through the original thoracotomy incision or through a separate thoracotomy depending on the arc of rotation of the pedicle [59].

Reconstruction in the Setting of Infection

Acute and chronic thoracic infections will challenge the reconstructive surgeon and often involve complex pathology including osteomyelitis, empyemas or fistulas, pneumonectomies, implanted devices, and immuno or vascularly compromised patients. Adequate debridement and hardware removal if indicated, in collaboration with cardiothoracic colleagues, are the key to success in reconstruction in the setting of infections. An average of four debridements is required prior to reconstruction of chronic sternal infections, which will frequently be encountered by the busy reconstructive surgeon [10]. Obtaining cultures and collaborating with infectious disease colleagues are recommended at interval debridements prior to definitive reconstruction. Reconstructive options in the setting of infection remain consistent to sterile settings, with cases of introduction of microorganisms to the sterile peritoneal cavity exceedingly rare in the literature following pedicled omental transfer [51, 60].

Reconstruction of Oncologic Defects

Although considerations for oncologic defects are similar to those previously discussed, oncologic defects will often involve previously radiated tissues or those with anticipated adjuvant radiation. Oncologic defects are more likely to involve skin resection and a skin deficit, and therefore are more likely to require free tissue coverage [25]. Radiation adds an additional challenge to the reconstructive puzzle, and a generous margin of resection should be considered in surgical planning to attempt to inset flaps to healthy tissue outside the zone of injury [10]. Tissue changes related to radiation and extent of osteoradionecrosis should be thoroughly evaluated. A reconstructive algorithm intended for reconstruction of oncologic sternal defects may be extrapolated to oncologic chest wall defects [25]. If neither skeletal reconstruction nor radiation is required, primary closure or fasciocutaneous advancement should be considered as first line coverage. If either skeletal reconstruction or radiation is anticipated, pedicled muscle flaps or omentum should be considered first line. Musculocutaneous flaps such as latissimus dorsi or rectus abdominis, or free tissue transfer, will be required in the setting of skin deficit [25].

Reconstruction of Traumatic Defects

Resuscitation of the trauma patient through Advanced Trauma Life Support (ATLS®) protocols, including intubation and mechanical ventilation if necessary, should be taken prior to addressing traumatic deformities of the chest wall [61]. The Chest Wall Injury Society has developed clear guidelines for surgical stabilization of rib fractures (SSRF). The SSRF guidelines recommend early skeletal stabilization of rib fractures (< 72 h post-trauma) after management of resuscitation and other life-threatening conditions. The goal of early stabilization is to restore chest wall dynamics and prevent paradoxical motion with respiration. Guidelines for SSRF include three or more displaced rib fractures with two or more pulmonary derangements in non-ventilated patients, or failure to wean ventilation in ventilated patients [62]. Reconstruction of soft tissue defects involve similar principles previously discussed, including assurance of adequate debridement prior to reconstruction. If free tissue transfer is required, vessels should be carefully evaluated in the zone of injury [63, 64].

Transplant Physiology

Altered physiology may be present in some chest wall reconstruction patients, leading to increased complication rates and poor wound healing. Treatment of patients who have previously undergone cardiac and/or pulmonary transplantation includes systemic immunosuppression with calcineurin inhibitors (cyclosporine), antimetabolite agents (mycophenolate mofetil), mTOR inhibitors (everolimus, sirolimus), and/or corticosteroids (prednisone) [65]. Inflammatory mediators, as well as cell proliferation, are involved in wound healing mechanisms and may be impacted by these medications [66]. Increased wound infections, decreased tensile strength, decreased rate of reepithelialization, decreased anastomotic breaking strength, and poor wound healing are among the derangements noted [66–68]. Although well documented in animal studies, support for these effects is less clear in human studies and lacking well-designed trials [66]. Supplementation with Vitamin A in patients undergoing treatment with chronic corticosteroids may help to increase collagen synthesis, increase epithelial growth and angiogenesis, and stimulate granulation tissue [69–71].

Conclusion

Involvement of the plastic reconstructive surgeon and use of flap reconstruction have been shown to reduce complication rates and mortality in chest wall reconstruction [72]. Due to the complex nature of these reconstructive problems, complications remain high and secondary options should be considered prior to the primary operation. On average, reconstruction of the chest wall will require 2.3 operations [10]. Prolonged hospital stays, potential need for tracheostomy, cardiac events, and mortality should be expected and discussed preoperatively with patients, although these have all been shown to be lower with flap reconstruction [72].

Compliance with Ethical Guidelines

Conflict of interest Katie Egan, Elisa Emanuelli, and James Butterworth declare that they have no conflict of interest.

Research Involving Human and Animal Rights This article does not contain any studies with human or animal subjects performed by any of the authors.

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