Chest wall reconstruction: success of a team approach—a 12-year experience from a tertiary care institution

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Abstract

Background The thoracic cavity was considered as a forbidden area in the past and anyone attempting to meddle with it was expected to be doomed. But the past several decades have seen a marked improvement in the management and reconstruction of complex chest wall defects. This study was undertaken to review our experience in chest wall reconstruction during the past 12 years and to stress upon the importance of a multidisciplinary team approach to this complex problem.

Methods After obtaining the necessary clearance from institutional ethics committee, we did a retrospective review of all case records of chest wall reconstructions (CWR) performed in our institution during a 12-year period from May 2005 to September 2016. Patient characteristics, co-morbidities, operative data and post-operative complications and outcomes were reviewed.

Results During the study period, a total of 32 patients underwent CWR. All patients were assessed, planned, operated and managed by a team consisting of thoracic surgeons, plastic surgeons, intensivists and pulmonologists. Patients were in the age group of 14–72 with a male:female ratio of 15:17. Indications for CWR were neoplasms ($n = 13$ –40.62%), post-sternotomy wound dehiscence ($n = 12$ –37.5%), osteoradionecrosis ($n = 4$ –12.5%), tuberculosis ($n = 2$ –6.25%) and osteomyelitis rib (1/32–3.125%). Inflammatory defects were mostly closed with soft tissue alone whereas skeletal stabilisation with soft tissue cover was required in tumour resections. All were pedicled flaps, the most common being pectoralis major (PM) muscle flap ($n = 12$). Others include latissimus dorsi (LD) muscle ($n = 9$); rectus abdominis (RA) muscle ($n = 2$); transverse rectus abdominis musculocutaneous flap (TRAM) ($n = 2$), deltopectoral (DP) ($n = 1$), omentum ($n = 3$) and breast flap ($n = 3$). Post-operative complications include wound dehiscence (12%), wound infection (21%) and recurrent sinus formation (7%). One partial flap failure was recorded. Post-operative mortality was 3%.

Conclusion Chest wall reconstruction is a complex procedure and each defect needs an individualised approach for optimum outcome. Extensive chest wall resections can be safely undertaken with the support of the reconstructive surgeon and with good critical care back up.

Keywords Chest wall reconstruction · Sternal wound dehiscence · Osteoradionecrosis of sternum

Introduction

Chest wall dysfunction associated with congenital and acquired problems can cause significant morbidity and have rapid life-threatening health issues [1]. The first chest wall

reconstruction was reported by Tansini in 1906, when he described pedicled latissimus dorsi muscle for mastectomy defects. Classical approach for chest wall reconstruction focuses on maintaining thoracic function by restoring structural integrity and minimising chest wall deformity. Management and reconstruction of complex chest wall defects have significantly improved over the past half century and it is a formidable challenge for the reconstructive surgeon.

Over the past century, surgeons have developed a set of principles as well as reconstructive options that generally result in successful closure of the most complicated chest wall wounds. These principles can be applied to thoracic defects resulting from a spectrum of causes from trauma to tumour, infection and radiation injury. The general principles of chest wall reconstruction are (i) adequate

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removal of neoplastic, necrotic or infected tissue; (ii) removal of foreign bodies; (iii) obliteration of dead space with vascularised tissue; (iv) establishment of skeletal stability if necessary; and (v) introduction of healthy, vascularised tissue for coverage of vital organs. Over the years, we recognised the need of a team approach which ensures adequate physical and psychological preparation of the patient including a training on physiotherapy. Proper planning and execution of the surgery and post-operative treatment, including inputs from physiotherapist and dietician, is very vital in getting a good functional outcome.

Aims

1. To review our institutional experience in chest wall reconstruction over a 12-year period
2. To emphasise the importance of multidisciplinary team approach in managing this complex problem

Methods

This study is a retrospective review of 32 chest wall reconstructions done in the department of Cardio Thoracic Surgery, Government Medical College Kottayam, with the collaboration of department of Plastic Surgery, from May 2005 to September 2016. Cases done individually by each department have been excluded. After obtaining the necessary clearance from the institutional ethics committee, we collected the following data from case records—patient characteristics, co-morbidities, details of surgical procedure and post-operative complications. Different reconstructive methods were reviewed and compared. Early post-operative reviews were also collected from records. Patients were contacted over phone for long-term follow-up.

Patients were categorised as per age, gender, indications for CWR, type of defect and type of reconstruction. Based on location, defects were divided into central, lateral and posterior. The central defects include sternal and costal cartilage defects; the lateral defects comprise rib defects up to the lateral border of scapula and the posterior defects were the defects under and medial to scapula. Defects were also categorised according to the nature of underlying pathology—acute, which result from tumour resections and chronic, where there is an underlying infection/inflammatory process going on. Defects were further divided in to full thickness and partial thickness. Reconstruction of the chest wall involves soft tissue cover, with or without skeletal reconstruction.

Pre-operative optimisation of nutritional status, blood parameters and pulmonary function was done with the

help of intensivist, pulmonologist and physiotherapist. A detailed plan regarding resection and reconstruction was made pre-operatively after an inter-departmental discussion. In all the cases, the resection or debridement part was performed by the thoracic surgery team followed by reconstruction by the plastic surgery team. The decision to proceed with skeletal stabilisation is taken by the thoracic surgeon after on-table assessment of the extent of defect, chest wall stability and pre-operative pulmonary function. Type of soft tissue coverage was executed by the plastic surgeon. Immediate post-operative care was done in thoracic surgery intensive care units. It was a routine to ventilate all patients for 4–6 h. However, for some patients, the ventilation got prolonged due to extensive resection and reconstruction, the maximum being 5 days. Wound management was done by the plastic surgeon and respiratory management was done by the intensivist and pulmonologist along with the thoracic surgeon. Cases were assessed for complications like wound dehiscence infection, recurrent sinus formation and partial flap failure. Post-operative mortality is taken as mortality occurring within 30 days post-surgery. Patients were assessed for functional status at 3 months using Medical Research Council (MRC) dyspnoea grading [2].

Results

A total of 32 cases were reviewed. Patients were in the age group of 14 to 72 years. Gender and co-morbidities are detailed in Table 1.

Indications for CWR are detailed in Table 2. The only partial thickness defect in the series was a case of osteomyelitis involving right 3, 4 and 5 ribs at the donor site of pectoralis major myocutaneous (PMMC) flap taken for buccal mucosa reconstruction. The pleural cavity was not breached after debridement and defect was resurfaced with a random fasciocutaneous flap. Twenty-one were central defects involving sternum with or without costal cartilages. Eleven were lateral defects involving one or more ribs. There were no posterior defects in this series.

Table 1 Socio personal details of the patients

Socio personal details	Percentage
Gender	
Male	15 (46.87%)
Female	17 (53.12%)
Co-morbidities	
Hypertension (HTN)	6 (18.75%)
Diabetes mellitus (DM)	7 (21.87%)
Both HTN and DM	6 (18.75%)

Table 2 Indications for CWR

No.	Major indications	Percentage
1.	Tumour resection ($n = 13$) • Carcinoma breast-chest wall recurrence ($n = 4$) • Locally advanced primary breast carcinoma ($n = 2$) • Malignant phyllodial tumour with chest wall infiltration ($n = 2$) • Plasmacytoma ($n = 1$) • Sarcoma ($n = 4$)	40.62
2.	Sternotomy wound dehiscence ($n = 12$)	34.37
3.	Osteoradionecrosis ($n = 4$)	12.5
4.	Tuberculosis chest wall ($n = 2$)	6.25
5.	Osteomyelitis rib ($n = 1$)	3.12

When the aetiology of central and lateral defects was analysed, post-sternotomy wound dehiscence was the commonest cause of central defects and tumour resections accounted for most of the lateral defects (Fig. 1a, b). All the acute defects were results of tumour resections and chronic wounds resulted from deep sternal wound infections (DSWI), osteoradionecrosis (ORN) and chronic infections like tuberculosis and osteomyelitis.

Fig. 1 a Aetiology of central defects. b Aetiology of lateral defects

Types of reconstruction

Skeletal reconstruction

Percentage of cases, who underwent skeletal reconstruction for specific defects, are enumerated in Table 3.

65.6% (21/32) cases were central defects, which ranged from partial loss of sternum to loss of sternum along with adjacent costal cartilages. Only 19% (4/21) of central defects required skeletal reconstruction, of which three were tumour resections and one was an ORN. 37.3% (11/32) cases were lateral defects of which 82% (9/11) required some form of skeletal stabilisation and all were tumour resections.

Need for skeletal stabilisation differed in acute and chronic cases. Chronic cases mostly included post-sternotomy wound dehiscences, ORN and tuberculosis. None of the post-sternotomy wounds required skeletal reconstruction despite having two cases of sternum with adjacent costal cartilage defects. One out of 3 ORN required skeletal reconstruction with mesh, due to its bigger size and loss of adjacent costal cartilages. There were two cases of chest wall tuberculosis and none required skeletal stabilisation. All acute defects resulted from tumour resections. 92.3% (12/13) of post tumour resection defects required skeletal support. They were either large lateral defects with loss of multiple ribs ($n = 9$) or central defects with loss of sternum with or without adjacent costal cartilages ($n = 3$). One case of recurrent breast cancer involved the xiphoid region almost reaching the abdomen and hence did not need skeletal stabilisation.

Out of 13 cases who had some form of skeletal stabilisation, two large central defects needed rigid fixation with rib grafts in addition to mesh (Fig. 2). The rest needed just a polypropylene mesh sutured all around the defect margins to prevent herniation of viscera. In all cases, the mesh was covered by vascular tissue, either from local site or by a distant flap.

Table 3 Skeletal reconstruction in full thickness defects ($n = 31$)

Aetiology	Total number, $N = 31$	Location		Skeletal reconstruction
		Central ($n = 21$)	Lateral ($n = 11$)	
Sternal wound dehiscence	12	12	0	0
Chest wall tumours	13	4	9	12
ORN	4	4	0	1
Tuberculosis	2	1	1	0

Soft tissue reconstruction

The principle of reconstructive ladder was followed in reconstructing each defect; that is, the simplest and best technique is chosen for individual defects. The spectrum of flaps used in this series is shown in Table 4. In 15 cases, soft tissue coverage was achieved by direct skin closure with 12 of them having a muscle or omental flap underneath. Four cases had to have skeletal stabilisation though skin could be closed primarily. In one central defect over lower sternum after excising recurrent carcinoma breast, the abdominal skin flap was mobilised upwards—the reverse abdominoplasty—to achieve primary closure. A split thickness skin graft (SSG) was used over a muscle flap in 9 cases and various flap skin paddles were used for closure in 8 cases.

In most of the defects involving upper two-thirds of sternum, lateral skin edges were mobilised together with the PM muscle to achieve a tension free closure in midline (Fig. 3). In a few cases, muscle and skin were advanced as two separate units. In two cases, division of insertion of PM along anterior axillary line further mobilised the muscle. In one case of upper sternal recurrence of carcinoma breast, a full thickness upper sternal defect was reconstructed with polypropylene mesh and a unilateral PM islanded on its acromio-thoracic pedicle after detaching origin and insertion and covering with an SSG. Another flap used in central defects was omentum ($n = 3$). This was the preferred choice in filling an infected cavity after debridement.

RA muscle, either as such, or with skin paddle (vertical rectus abdominis myocutaneous flap (VRAM)) were the choice for lower sternal defects whereas TRAM flap was used

Fig. 2 Carcinoma breast sternal recurrence. **a** Resected specimen of sternum with ribs. **b** Defect. **c** Skeletal reconstruction with rib and mesh. **d** Primary skin closure

Table 4 Spectrum of flaps used

Flaps used	Number
Pectoralis major—unilateral	2
Pectoralis major—bilateral	10
Latissimus dorsi	5
Omentum + PM	2
Omentum + breast flap	1
TRAM	1
TRAM + LD	1
Rectus abdominis/VRAM	2
Breast flap	2
Deltpectoral	1
Primary closure alone	3

in two large lateral defects. In one case, microvascular anastomosis between the deep inferior epigastric artery of flap was done to thoracodorsal artery to supercharge the flap. In all cases of RA, polypropylene mesh was used to reinforce the anterior abdominal wall.

LD is the second commonest muscle used ($n = 6$), mainly for lateral defects. LD myocutaneous flap was needed in two cases. When muscle alone was used, it was covered with SSG in all situations where local skin was not available for primary closure.

In 3 elderly females with ORN of sternum following irradiation for carcinoma breast, the contra lateral breast was used as a flap for skin closure (Fig. 4). Four cases had a combination of two flaps with or without skeletal stabilisation. Spectrum of flaps used is depicted in Table 3.

Complications and follow-up

Complications were divided into early and late. Wound infection was the commonest early complication which occurred in 6 of our 32 patients. All were managed conservatively as per hospital policy. There was partial loss of a TRAM flap done for a malignant phyllodermal tumour but salvaged on the third day with LD myocutaneous flap. This patient needed prolonged ventilation too. There was no complete flap loss in any case. There was one post-operative death where a female patient with locally advanced breast cancer underwent resection and reconstruction with mesh, LD muscle and SSG, succumbed to respiratory complications in the first week itself.

The late complications anticipated were recurrence of the problem, hernia and late mortality. One patient with a tuberculous bronchopleural fistula and another patient with ORN sternum and constrictive pericarditis had died on follow-up, few months after the surgery. Three out of four patients with

Fig. 3 Sternal wound dehiscence. **a** After debridement. **b** Bilateral PM advanced and sutured in midline. **c** Primary skin closure

recurrent breast cancer could be followed up for 2 years and beyond. One of them died of low blood cell count and its complications at the end of 2 years. Another patient developed recurrence over scalp but survived that. The third patient was asymptomatic at the end of 3 years. One patient with a malignant phyllodermal tumour had subsequent local recurrences, which were treated by excision. Two patients with sternal dehiscence developed recurrent sinus after 3 months, which was managed conservatively.

Considering the overall patient satisfaction after CWR, though we did not apply any scoring system, no patient was found completely dissatisfied with the result on long-term follow-up. The other outcomes measured was functional status by MRC dyspnoea scale at 3 months follow-up. Three patients were lost to follow-up and there was one early mortality. One patient with a tuberculous pleuro-cutaneous fistula and another patient with ORN sternum and constrictive

Fig. 4 ORN sternum. **a** ORN sternum post-mastectomy. **b** After debridement, mesh and omentum to reconstruct defect. **c** Simple mastectomy and advancement of breast skin of normal side

pericarditis had poor grades due to underlying lung and cardiac problems. Both these patients died within a year. The remaining patients had grade 1 (35.7%), grade 2 (53.5%) and grade 3 (3.5%) functional status. The three largest defects were those following tumour resections (malignant phyllodes—2, recurrent breast Carcinoma—1). All of them had MRC grade 2 status at 3 months follow-up.

Discussion

Restoration of chest wall integrity is directly linked to maintaining the basic physiology of life. Success of chest wall reconstruction depends on complete clearance of existing pathology and restoration of the skeletal and soft tissue elements for its proper functioning, with an acceptable cosmesis [3]. Involvement of reconstructive surgeons allows the extirpative surgeon to have more confidence in obtaining wide enough margins to eliminate all possible malignant, contaminated, irradiated or non-viable tissue, which is the key for a long-term result. In all our cases, thoracic surgeons did the clearance part followed by plastic surgeons reconstructing the defect.

Common indications for chest wall reconstruction include infection, tumour resections (primary or recurrent), radiation injury, congenital abnormalities and trauma. The optimum reconstructive option is determined based on size, location and depth of defect, condition of the surrounding tissue and previous surgical procedures. The need for soft tissue and skeletal reconstruction is individualised for each defect. Soft tissue closure could be achieved by direct closure, SSG or by skin paddle of a flap. The choice of flap is based on defect location and condition of wound. Current consensus for skeletal stabilisation is that defects > 5 cm or involving > 4 ribs need skeletal reconstruction unless it is located under the scapula [4]. However, posterior defects below the 4th rib need

reconstruction to prevent scapular entrapment [3]. For defects below the 5th rib, the diaphragm can be reattached to the lowest intact rib and hence do not need skeletal stabilisation [5]. Another determinant of need of skeletal stabilisation is the presence of infection and fibrosis in the wound. Chronic wounds with fibrosis and fixation of mediastinum do well without a prosthetic stabilisation of chest wall whereas acute defects which lack inflammation and fibrosis as in tumour resections need rigid or semirigid fixations depending on its location. The options available for skeletal stabilisation are fascia lata, rib graft, acellular dermal matrix and synthetic materials like polypropylene mesh, polytetrafluoroethylene (PTFE) and Marlex mesh. Methyl methacrylate sandwich is the choice to reconstruct a curved surface and it can be made in the surgical field itself. Titanium plates can also be used for rigid fixation. In our series, we opted for skeletal stabilisation in 13 cases of which 11 cases had a mesh alone and 2 large central defects needed rigid fixation with rib grafts.

Approximate incidence of sternal wound infection following cardiac surgery is 0.5–9% [1]. Major risk factors for sternal dehiscence and subsequent infection are obesity, diabetes, chronic obstructive pulmonary disease (COPD) and bilateral harvest of internal mammary arteries. Pairolero and Arnold classified sternal wounds into 3 categories: class I—early superficial, class II—with purulent mediastinitis, class III—chronic wounds with osteomyelitis [1]. Class I defects may need sternal rewiring if bone stock is good, but it is better avoided in other groups. In a large series study published by Izaddoost and Withers from Texas Heart Institute [6], aggressive debridement and single stage coverage in the early part of study was met with 25% mortality which led them to adopt a less aggressive approach involving wound preparation and optimisation of patient. All our sternal wound dehiscences ($n = 12$) belonged to class III and hence were treated with thorough debridement and a flap to fill the defect. The common flaps used were PM for upper defects, RA for lower

sternal defects and omentum. In our series, muscle flaps were preferred and omentum was used only in cases with severe infection and necrosis and when there was a large cavity to be filled. A meta-analysis of various studies comparing use of muscle flaps and omental flaps failed to prove the superiority of muscle flaps in deep sternal wound infection [7]. None needed skeletal stabilisation since there was adequate stability due to post inflammatory fibrosis of mediastinum.

Chest wall tumours can be primary, locally invasive or metastatic. Sarcomas ($n = 4$) and solitary plasmacytoma of the sternum ($n = 1$) were the primary tumours encountered in our series. Locally advanced breast cancer ($n = 2$) and malignant phyllodermal tumour of breast ($n = 2$) accounted for the locally invasive tumours. We had 4 cases of recurrent breast cancer on chest wall. There were 4 cases of osteoradionecrosis sternum, three of them in breast cancer patients and one in a male patient with lymphoma. According to Tukiainen, 45% of primary chest wall tumours originate from soft tissue and 55% from bone and cartilage [8]. A wide local excision with a 4-cm margin, which will often amount to a full thickness defect, and appropriate reconstruction is the treatment of choice. Locally invasive tumours can be from breast or from underlying lung. Breast is again an important site of origin of metastatic tumours to chest. Even if a curative resection is not possible, there is a definite role for palliative resection in improving quality of life [8]. Three of our patients with recurrent breast cancer involving sternum and ribs could be followed up beyond 2 years and this emphasises role of a radical approach in managing metastatic breast cancer of chest wall. All tumour resections left the chest wall unstable and hence needed skeletal stabilisation with polypropylene mesh and additional rib graft in two cases ($n = 12$). One exception was a recurrent breast cancer over lower sternum, which did not require stabilisation. The soft tissue flaps used were LD and TRAM for lateral defects and PM for central defects.

ORN of sternum can occur particularly after high-dose radiation treatment. Radical resection and reconstruction are feasible and can be lifesaving. While selecting the soft tissue flap, the possible irradiation and compromise of the flap pedicle, if adjacent to radiation field, should always be thought of [9]. Omentum is a good choice in such situations [10]. The contralateral breast flap still has a role in reconstructing anterior defects in a woman with radiation necrosis. According to Gingrass, an ideal candidate would be an elderly woman with a painful ulcer and who would not be bothered about the aesthetic deficiency of transposed breast [11, 12]. We have used this flap in 3 patients and found it very advantageous due to its reliability and ease of harvesting in supine position itself.

All the 3 largest defects in this series were following tumour excisions. Two were lateral defects following resection of recurrent malignant phyllodermal tumour of breast. TRAM + mesh were used for a lateral defect of size 24×15 cm. LD was used to salvage the partial loss of TRAM on the third day. Learning from this, we supercharged the next TRAM flap

done for a similar defect of size 21×18 cm and it survived completely. The third one was a central defect including sternum and ribs, of size 22×10 cm following resection of recurrent breast cancer. It needed a rigid skeletal fixation with rib and mesh over which skin could be closed primarily. All these patients did well functionally (MRC grade 2) at 3 months follow-up. Omentum was used to cover the infected lower sternal area in two cases. RA was not deemed suitable in such cases where usage of mesh in donor site was not advisable.

Complications of chest wall reconstruction result from persistent infection, inadequate debridement, failure to adequately obliterate dead space, visceral fistulae, instability of skeletal fixation and untreated micro-organisms [13]. The complication rate and mortality in our series were comparable with literature.

Limitations of the study

1. Considering the multiplicity of procedures involved, the sample size is small to derive any statistical conclusion.
2. This is a retrospective study which relies heavily on case records. But we hope this study will be helpful for further studies on various aspects of CWR

Conclusion

Chest wall reconstruction is a complex matter as depicted by the varying aetiological and pathological issues we handled, the variety of techniques used in this series and the post-operative issues we faced. A team approach comprising thoracic surgeon, plastic surgeon, pulmonologist, intensivist and physiotherapist enabled us to have a planned and systematic approach to manage this difficult subset of patients. The overall good functional outcome and the good long-term survival following resection and reconstruction of chest wall tumours, especially chest wall recurrences of breast cancer, justifies the radical approach to chest wall resections which is possible only with reconstruction. Since different centres follow different protocols for CWR, there is scope for a meta-analysis of various studies on this topic.

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Compliance with ethical standards

Ethical standards This retrospective review was in concordance to the guidelines of Institutional Review Board of our institution.

Informed consent Informed consent in mother tongue was obtained in all cases.

Conflict of interest The authors declare that they have no conflict of interest.

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