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Various Modalities in Management of Chest Wall Defects: A 5 Year Experience

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ABSTRACT

Introduction: Reconstruction of chest wall defects (CWDs) is a challenging surgical problem.

Patients and Methods: During the period between 2011 to 2016, various reconstruction modalities were used to manage 32 patients with different CWDs.

Results: Post sternotomies sternal defects was the commonest cause of CWDs followed by tumous ablation. Loco-regional flaps were the gold standard modality for reconstruction of various CWDs. The total flap survival rate was 96.875%.

Conclusion: Reconstruction modalities should be tailored individually for every case of CWD. Skeletal stabilisation is of great value to control recurrent cases of sternal osteomyelitis and to achieve better post operative respiratory mechanics.

INTRODUCTION

Many patients may present with chest wall tumours, breast, or thoracic pathologies. Surgical excision of those tumours and pathologies sometimes leave a chest wall defect (CWD). Reconstruction of CWD is challenging surgical problem; especially in large full thickness CWDs. Post sternotomy osteomyelitis and tumours ablation are the leading causes for CWDs. Others causes, as post thoracotomies, post mastectomies, post inflammatory, and congenital defects are less common aetiologies for CWDs **[1]**. Reconstruction of CWDs should consider not only resurfacing of the chest skin; but also dead space obliteration, covering of vital structures, eradication of devitalized tissues and chronic infections, and restoration of respiratory mechanics. All these considerations affect the outcome significantly. In our study, various modalities were used for reconstruction of different CWDs. Also, the study emphasised the importance of skeletal stabilisation when indicated; to eradicate chronic infection or to reach better respiratory mechanics during the post-operative period.

PATIENTS AND METHODS

This study was conducted during the period between 2011 and 2016. Patients with reconstructive surgery done for CWDs were included. Thirty two patients with CWDs were operated upon. The study included 13 males and 19 females with CWDs at different locations. The patients' ages ranged from 5 years to 77 years old (mean age ± 52.75 years). Post sternotomy osteomyelitis, tumours ablation, post thoracotomies, post mastectomies, congenital, and post corrosive all were the aetiologies for the CWDs included in this study (Table 1). Number of patients, CWD locations, and reconstruction modalities used are listed in Tables (2,3,4).

Table (1): Aetiologies for CWDs among patients.

Aetiology	Number of cases	Percent
Post sternotomy osteomyelitis	15 patients	46.875
Post tumour ablation and radiotherapy	11 patients	34.375
Post thoracotomy	4	12.5
Congenital bifid sternum	1	3.125
Post corrosive mid line chest defect	1	3.125

Table (2): Fifteen patients with post sternotomy osteomyelitis.

Number of patients	Sternal defect location	Reconstruction modality
11	Lower third	TRAM flap (used in 5 patients) LD flap (used in 2 patients) Omentum flap (used in 3 patients) Bilateral breast flaps (used in 1 patient)
3	Lower 2 thirds	ORIF + right PM flap
1	Whole length	ORIF + direct closure

TRAM : Transverse Rectus Abdominis Myocutaneous flap.
LD : Latissimus Dorsi Flap.
ORIF : Open reduction and internal fixation.
PM : Pectoralis Major flap.

Table (3): Eleven patients with post tumour ablation CWDs.

Number of the patients	CWD location	Aetiology	Reconstruction modality
	Anterior paramedian CWDs	Osteoradionecrosis after cancer breast ablation	TRAM flap + polyprolene mesh (were used in 3 patients)
8	Anterior paramedian CWDs	Osteoradionecrosis after cancer breast ablation	LD flap + polyprolene mesh (were used in 3 patients)
	Anterior paramedian CWDs *	Cancer breast stage IV	Lateral intercostal flap (is used in 2 patients)
1	Huge anterior CWD defect including the clavicle, sternum, and 5 ribs and 3 ribs on the other side	Cancer breast stage IV	Lateral intercostal flap + polyprolene mesh
1	Upper half sternal CWD*	Post squamous cell carcinoma excision	Bilateral PM flap + split thickness skin graft
1	Anterolateral CWD*	Radiation ulcer after cancer breast ablation	Combination of latissimus myocutanous flap and TRAM flap

*Partial thickness CWD.

Table (4): Six patients with miscellaneous aetiologies for CWDs (other than sternotomies and tumour ablation).

Number of the patients	CWD location	Aetiology	Reconstruction modality
1	Upper third of the sternum	Congenital absent manubrium steni	Iliac bone graft + ORIF + bilateral PM flaps
4	Lateral	Post thoracotomy	TRAM flap (used in 2 patients) LD flap (used in 2 patients)
1	Anterior mid line	Post corrosive unstable scarring	Radial forearm free flap

Table 5: Incidence of morbidities and mortalities.

Morbidities and Mortalities	Number of cases
Partial flap necrosis	1
Infection, wound dehiscence	6
Abdominal bulge	2
Seroma	3
Death	1

Multidisciplenary team (MDT) meetings were held involving the cardiothoracic, the general surgery and the plastic surgery teams to discuss the plan of management and expected outcome for all patients.

In conjunction with the cardiothoracic team, excision of radiation ulcer, debridement of necrotic ribs, sternum, clavicle, and removal of hardware if any were done when indicated. Also, the general surgery team underwent mastectomies in cases of cancer breast and assisted in laparotomies needed for omental flap.

The choice of reconstruction modality was determined for each case individually; considering the patient's requirements, the CWD charcteristics, and the surgeon's expertise.

Upper mid line CWDs were reconstructed with pectoralis major (PM) flaps in 2 patients. One of them was presented with congenital absent manubrium sterni, reconstruction of the manubrium was done with iliac bone graft that was fixed with plates and screws and covered with bilateral turn over PM flaps (Fig. 1). The other patient presented with Squamous cell carcinoma (SCC). The excision with safety margins resulted in upper half sternum partial thickness defect. The reconstruction was done with bilateral turn over PM flap and split thickness skin graft (STSG).

Post sternotomy osteomyelitis was the aetiology for 15 patients (Table 2). Four patients presented with whole length or lower 2/3 sternal defects. After sufficient debridement of osteomyelitic bone, fixation with plates and screws were done. In 3 of those patients a PM turn over muscle flap was used to provide appropriate coverage (Fig. 2).

Eleven patients presented with lower 1/3 sternal defects. Reconstruction with Transverse Rectus Abdominis Myocutaneous flaps (TRAM) were used in 5 patients (Figs. 3,4), the latissimus dorsi (LD) flaps were used in 2 patients, the omental flaps were used in 3 patients, and the breast flaps was used only in 1 patient (Fig. 5).

One patient presented with post corrosive partial thickness, sternal whole length defect. Reconstruction was done with radial forearm free flap to provide simultaneous coverage and oesophageal reconstruction.

Six patients presented with anterior parmedian CWDs. The LD and TRAM flaps were used for reconstruction. In all patients, a double layered poly-prolene mesh were used to stabilise the chest wall. Two patients presented with partial thickness anterior paramedian CWD; that were reconstructed with lateral intercostal fasciocutaneous flap.

One patient presented with malignant ulcer after bilateral modified radical mastectomies. Incisional biopsy comfirmed recurrent invasive duct carcinoma. Palliative surgery included resection of the ulcer, the sternum, right upper 5 ribs, left related 3 ribs, and right clavicle. Large left lateral intercostal fasciocutaneous flap was used in addition to a double layered poly-prolene mesh to reconstruct the defect (Fig. 6).

Four patients presented with lateral post thoracotomy CWDs. TRAM flap was used for reconstruction in 2 patients (Fig. 7). The LD flap was used in 2 patients also. One patient presented with anterolateral CWD. After partial TRAM flap loss the LD flap were used to complete CWD coverage and breast reconstruction simultaneously.

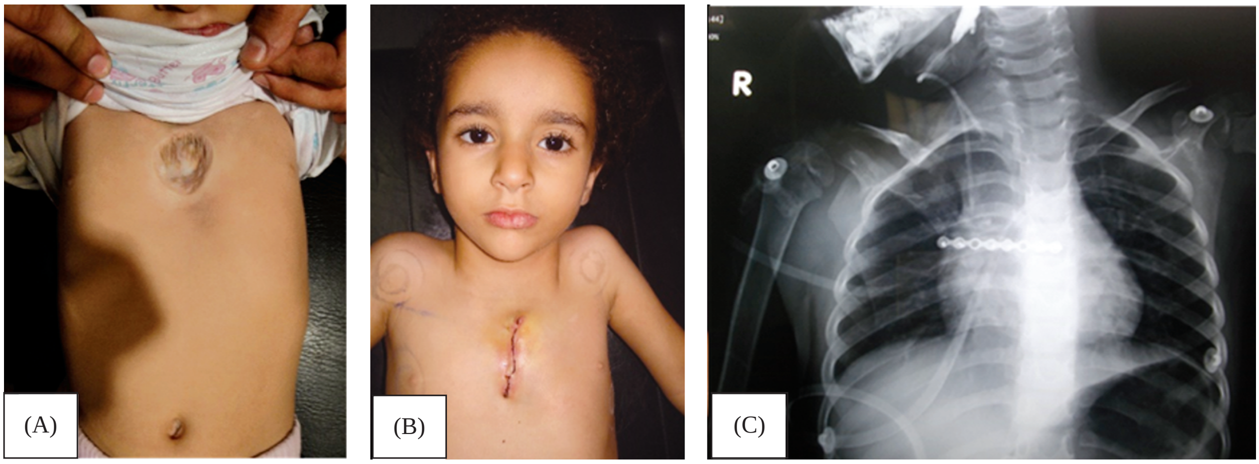
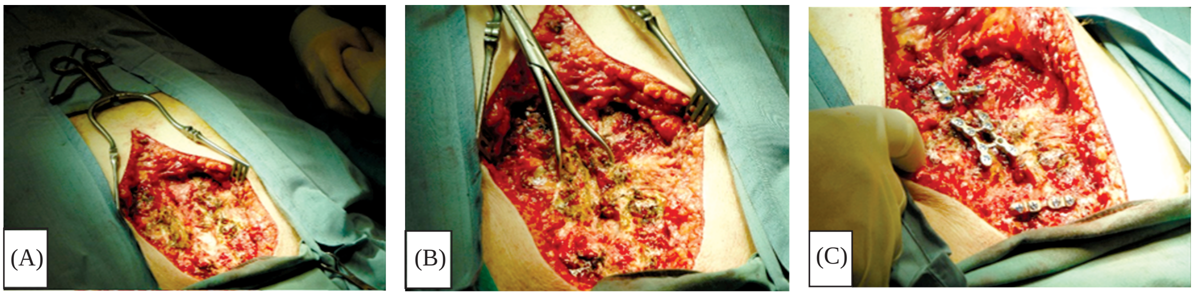


Fig. (1): A- Five years old female patient with congenital absent manubrium sterni. B- One-week post reconstruction with iliac bone graft. The bone graft was fixed with plate and screws and covered with bilateral PM turn over flaps. C- Postoperative chest X-ray showing plate and screws fixing the iliac bone graft.



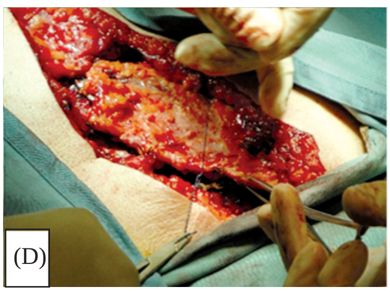


Fig. (2): A- Sixty-four years old male patient with post sternotomy osteomyelitis including the lower 2 thirds of the sternum. B- Bone holding forceps approximating the two halves of the sternum after debridement of osteomyelitic bone. C- Plates and screws were used to fix the two sternal halves. D- Turn over PM flap was used to cover the hardware.

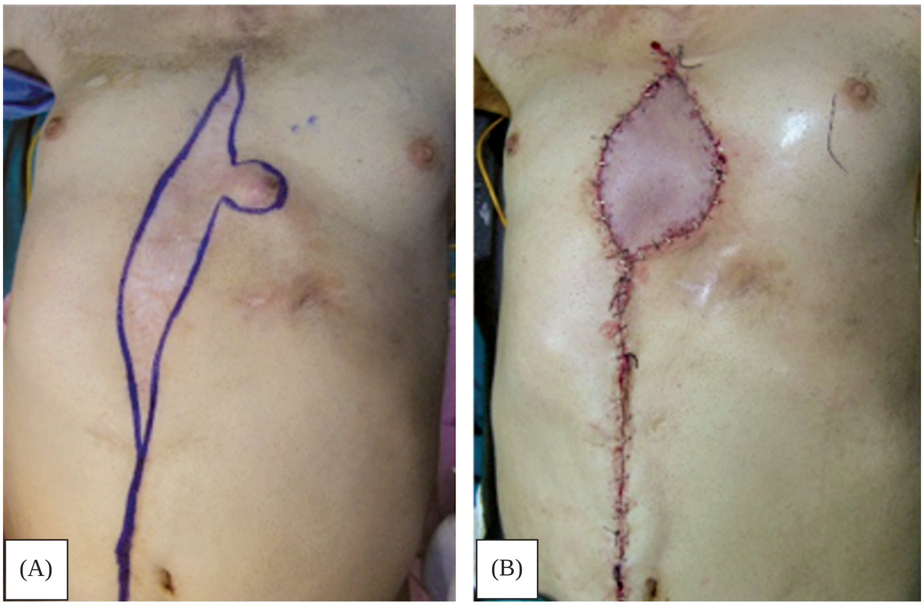


Fig. (3): A- Fifty-three years old male patient with post sternotomy osteomyelitis of lower 1/3 of the sternum. The patient presented with chronic discharging sinus. B- Postoperative photo showing right TRAM flap covering the defect.

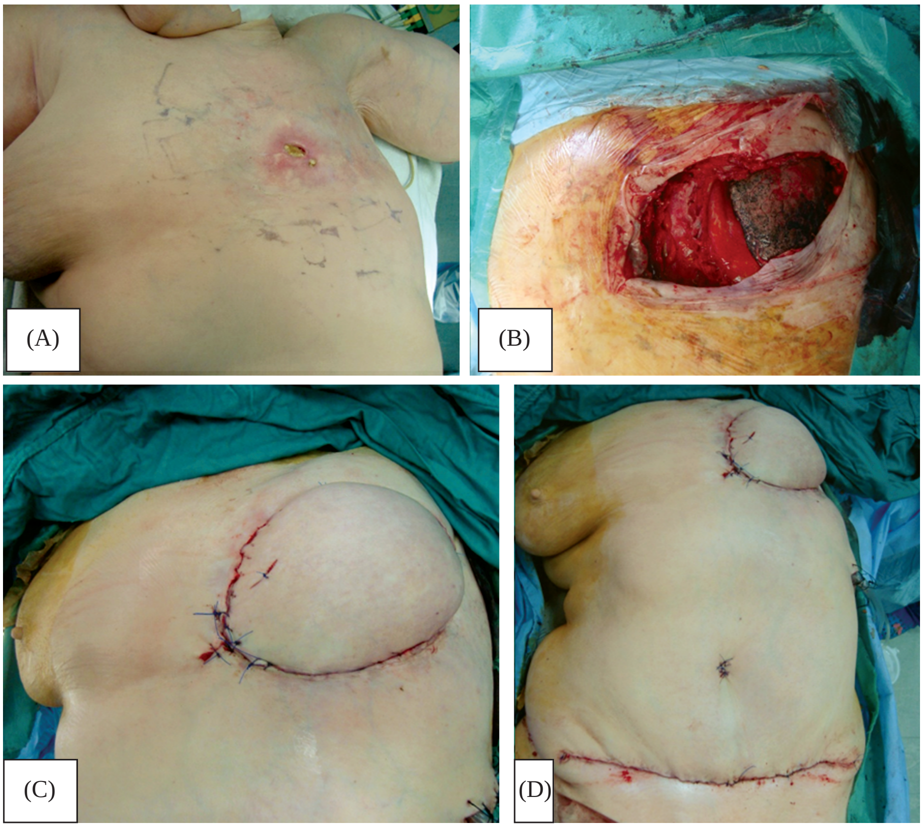


Fig. (4): A- Sixty-three years old female patient with left paramedian chest wall osteoradionecrosis; presented with chronic ulcer. B- Resection of the pathological tissues resulted in large full thickness CWD. C and D- Postoperative photos showing that right TRAM flap was used for reconstruction.

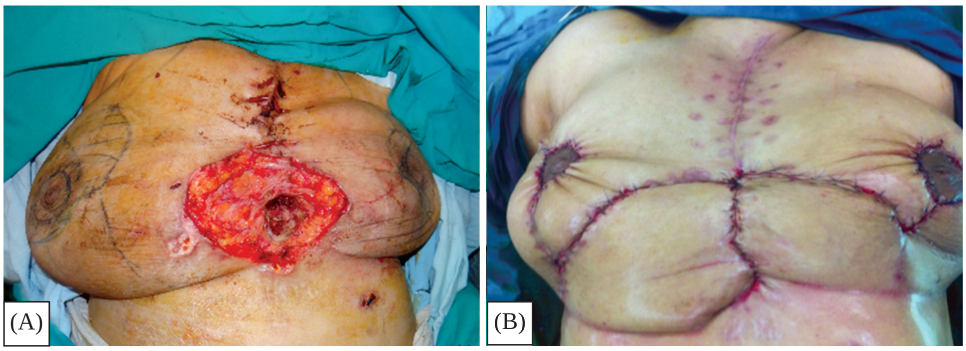


Fig. (5) A- Fifty-seven years old female presented with post sternotomy osteomyelitis of the lower 1/3 of the sternum. B- Postoperative photo showing bilateral inferior pole breast flaps covering the defect.

Fig. (6): A- Fifty-five years old female patient presented with recurrent cancer breast. B- Resection of the pathological tissues resulted into huge CWD. C- Polyprolene mesh is fixed the edges to the defect. D- Left lateral intercostal flap was used for reconstruction.

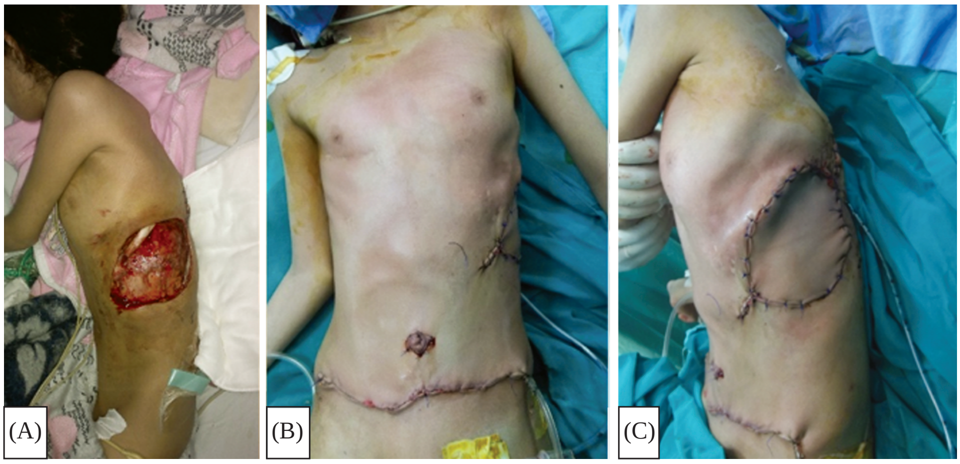


Fig. (7): A- Seven years old female patient presented with left lateral post thoracotomy CWD. B,C- Postoperative photos showing that right TRAM flap was used for reconstruction.

RESULTS

Thirty two patients underwent chest wall reconstruction between 2011 and 2016. Post sternotomy osteomyelitis of the sternum was the most common indication (46.875%) for chest wall reconstruction, followed by tumour ablation sequelae (34.375%) and other indications represented (18.75%) (Table-1). As regards the post tumour ablation CWDs, cancer breast sequelae were the most common aetiology (90.9%) in our study. The most common flap used was the TRAM flap (5/16; 34.375%), followed by the LD flap (8/32; 25%) and PM flap (5/32; 15.625%).

Total flap survival rate was 96.875% with partial flap loss in one case. Loco-regional flaps were the gold standard for reconstruction of various CWDs. In our study, 96.875% of cases were successfully reconstructed with pedicled loco-regional flaps. Free flap was used only in 1 patient (3.33%), when other loco-regional flaps were consumed in previous sessions of reconstruction.

All patients with partial thickness or moderate size full thickness CWDs were satisfied with the resultant aesthetic and functional outcomes. Although, resurfacing of large CWDs were successfully achieved; yet the respiratory functional outcome was adversely affected. Poly-prolene meshes were used for skeletal stabilisation in patients with large CWDs (defects >3 ribs), those patients needed longer periods of mechanical ventilation to support the respiratory functions.

Unfortunately, one patient presented with huge CWD; poly-prolene mesh as a skeletal stabilisation modality was not efficient enough to prevent respiratory failure and death in this patient.

Skeletal stabilization of CWDs by alloplastic materials were done in 12 patients (37.5%). Polyprolene meshes were used in 7 of them suffering from large full thickness CWDs. Rigid fixation with plates and screws was used in 5 patients with sternal defects. In 1 patient, iliac bone graft was fixed to reconstruct the manubrium sterni. In 4 patients with post sternotmy osteomyelitis, rigid fixation with plates and screws were successful to control osteomyelitis without recurrence.

During the follow-up period, all recoded complications were managed conservatively. Except for one case of patial TRAM flap loss that were managed through debridement session and addation of LD flap to achieve reconstruction. The complications recorded were infection, wound dehiscence, seroma, abdominal bulge after TRAM, partial flap necrosis and mortality.

DISCUSSION

The availability of various reconstructive modalities for CWDs; gives the chance to cardiothoracic and tumour surgeons for wider resections; that ensure safer long term management protocols. Certainly, this explains the growing incidence of problematic large full thickness CWDs **[2]**. Management of patients with chest wall pathologies is a challenging surgical problem. As it should include; resection of all pathological tissues, skeletal stabilisation to avoid physiological flail chest, and providing soft tissue coverage with adequate vascularity **[3]**.

Post sternotomy osteomyelitis is the most common aetiology (46.875%, 15/32 patients) in our study for CWDs. This advocates with results of the study done by JonahKua et al., in 2015 (55.6%, 30/54 patients) **[4]**.

Other studies showed that oncologic resection represents the most common cause for CWDs, where primary chest wall tumours e.g. sarcomas are the leading aetiologies. Contagious tumours as lung and breast carcinomas come in the following ranks **[2,3,5,6]**.

On the contarary, our study showed that cancer breast squaelae are the leading causes for the oncologic chest wall resections (90.1% of oncological resections patients, 10/11 patients).

Post-sternotomy osteomyelitis incidence is correlated to patients with coronary artery bypass grafting (CABG) surgery more than other sternotomy indications. Using the internal mammary artery (IMA) in the conventional pedicled fashion decrease the blood supply of the sternum up to 90% **[7]**.

Other risk factors are blamed independently e.g.prolonged surgery time, use of the intra aortic balloon, reoperating the patient with subsequent rewiring, extensive use of electocautery and bone wax, and obesity **[8-14]**.

Not surprisingly, that the lower one third of the sternum is the most common site for sternal osteomyelitis; as it is subcutaneous with no muscle attachement and bearing the highest load of respiratory movements **[15]**.

So, wiring as a fixation modality; is not efficient enough to prevent osteomyelitis in the presence of multiple risk factors. Using Robicsek wires, plates and screw fixation, or even combinations are preffered to prevent median sternotomy diheiscence primarly or secondary in already formed sternal osteomyelitis **[16-23]**.

In our study, plates and screws were used as a fixation modality in patients with recurrent osteomyelitis of the sternum. This rigid type of fixation successfully managed cases of chronic sternal osteomyelitis; provided the availability of soft tissue coverage.

CWDs reconstruction with flaps proved to be more safe, durable and resulted in longer survival rates **[1]**. Successful soft tissue coverage should provide protection for vital structures as lung, heart, and great vessels. Also, it should obletrate dead space, compate infection, cover prosthetic materials used for skeletal stabilisation, and finally resurface the CWDs [3].

The choice of the reconstruction modalitiy should be tailored individually for every single case of CWDs. Our study successfully used TRAM flaps for coverage of CWDs in different locations. The TRAM flap showed many advantages; as it provided highly vascular voluminous bulk of tissues, its arch of rotation supported flap reach to different chest wall territories, and the patient position was not changed during surgery in most of cases. Moreover, TRAM flaps enabled contouring of the lower abdomen; which positively enhanced the aesthetic and psychological outcomes. Many studies didn't use TRAM flap as frist choice during CWDs reconstruction [1,2,4,5,24]. Their rational was the un accepted abdominal donor site morbidity [25], and the unreliability of the flap if the internal thoracic vessels were consumed after (CABG) surgery. This proved not to be accepted by Marin-Gutzke et al., in 2005; as there anatomical, radiological and clinical study showed that the epsilateral TRAM is safe modality in cases of affected IMA. This was explained by the communication between the deep epigastric system and the costomarginal vessels [26].

Davison et al., compared the TRAM flap with pectoralis major flap with rectus sheath extension; in reconstruction of sternal defects. This study showed that the TRAM flap significantly reduced the incidence of sternum lower third dehiscence. Also, their study resulted in diminishing the incidence of abdominal bulges from 50% as mentioned in the litreture into 2% only [27].

Latissimus Dorsi and Pectoralis Major flaps are valuable locoregional flaps in chest reconstruction. The Latissimus Dorsi flap is very versatile flap reaching anterior, anterolateral, lateral, and posterior CWDs [4,6,28].

Pectoralis Major flap is also an efficient alternative for reconstruction of anterior and anteromedial CWDs. For sternal defects, Pectoralis major flap is considered the reconstruction workhorse. It is preffered over Latissimus Dorsi Flap. As Pectoralis Major flap can cover the lower sternum till the xiphoid process based on the thoracoacromial blood supply. Also, using Pectoralis Major flap dose not need changing patient's position during surgery, which may increase the operative time as in case of Latissimus Dorsi flap. Moreover, complications of Latissimus Dorsi flap donor site are not uncommon [29-32].

Omentoplasty is another reconstruction modality that can be used especially for sternal dehiscence. Its proximity to the sternum makes omentoplasty the gold standard reconstruction flap used by cardiothoracic surgeons. Beside this, omentoplasty gives highly vascular bulk of tissues that expresses efficient immunologic and absorbative capabilities [33,34,35].

Complications as hernia formation, spread of infection to the peritoneal cavity, and laparotomy related complications; may make omentoplasty a second choice flap when other flaps are not avalible for chest wall reconstruction [36]. In 2003, Reade et al., started laparoscopic harvesting of ometal flap; that rendered omentoplasty a more safe procedure [37]. In our study, omental flap was used in 3 patients to reconstruct a recurrent lower 1/3 sternal osteomyelitis after failed previous attempts of reconstruction.

Our study successfully used other flaps as inferior pole breast flaps, free radial forearm flap, and combinations of flaps to reconstruct various CWDs. The choice of each reconstruction modality was tailored to fit the patient's general condition and his/her specific requirements.

Skeletal reconstruction aims to protect vital structures, avoid the adverse effect of flail chest wall on respiratory mechanics, correct contour deformity and enhance balanced growth in pediatric age group after chest wall resection.

Reconstruction of large defects helps the patient to avoid grave chest wall deformities of thoracoplasty especially in growing children. In our study, two cases of CWD reconstruction were done in pediatric age group. Assumingly, this will provide balanced skeletal growth of the trunk without iatrogic deformities. Recent longer cohort studies are needed to support this theory. Similarly in previous studies, the degree of scoliosis after thoracotomies was objectively studied [38,39], yet no study evaluated the effect of CWDs reconstruction in the growing population.

Avoiding the adverse effect of flial chest wall on respiratory mechanics is another important indication for skeletal stabilisation. The effect of chest wall resection on respiratory mechanics differs according the location and size of the CWD. Post sternotomy mid line CWDs are more tolerable than acute post sternal tumour excision. Sternal osteomyelitis defects can be managed successfully with debridement and soft tissue coverage only. However, acute sternal defects dramatically affect respiratory mechanics. This makes skeletal reconstruction a mandatory step in many cases **[5,6]**.

Anterior and lateral CWDs are less likely to affect respiration, unless chest wall resection is large enough to produce flial chest with paradoxical movements that adversly affect respiratory mechanics. There is no consensus regards the size of CWD that obligates skeletal reconstruction. Some authors consider a full thickness CWDs with diameter more than 3 ribs (more than 5cm) turn skeletal stabilisation into a lifesaving procedure and/or an essential tool to decrease the post-operative dependency on mechanical ventilation. Fourtaintly, posterior CWDs defects up to 10cm can be closed without skeletal stabilization; this is because of the overlying scapula **[5,6,40-44]**.

To be mentioned, defining the critical CWD that dectates skeletal reconstruction is still a question. In 2004 Chang et al., presented his chest wall reconstruction algorithm; based on a 10 years experience. Chang was the first to use CWD surface area as a critical landmark for skeletal reconstruction. CWDs with surface area more than or equal to 300cm^2 or 4 ribs; were considered the critical size defects that dictated skeletal reconstruction **[28]**.

More studies are needed to specify the objective determinants for skeletal reconstruction. Is it the surface area alone? Or there are other risk factors?. This risk factors could be the resection of the chest wall pillars as sternum and/or clavicle, simeltaneous pneumonectomies, diaphragmatic resection, and the preoperative cardiopulmonary functions.

In our study, using a double layered ployprolene mesh in addition to soft tissue coverage was successful to manage patients with CWDs more than 5cm (>3 ribs). However in one patient, massive chest wall resection resulted in death from respiratory failure. More rigid skeletal stabilisation was advised to avoid respiratory failure in such huge CWDs **[39,45]**.

A diverse of materials are mentioned to be used for chest wall skeletal stabilisation. There is no consensus on the most physiologic or efficacious material. Polytetrafluoroethylene patch, polypropylene mesh, or composite mesh and methyl methacrylate sandwich all were used **[46]**. Not recently, the acellular dermal matrix was also used successfully **[47]**. Long-term clinical studies are needed to determine the appropriate prosthetic material to be used for every CWD.

In conclusion:

Considering the patient’s requirements, the CWD charcteristics, and the surgeon’s expertise; the choice of the reconstruction modalitiy should be tailored individually for every single case of CWD. For successful management of CWDs, we need disposal of all pathological tissues simultaneously with providing soft tissue coverage. Also, this study emphasised the importance of skeletal stabilisation when indicated; to eradicate chronic infection or to achieve better respiratory mechanics during the post-operative period.

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