Bilateral Pectoral Myocutaneous Advancement Flaps and Anatomic Sternal Wound Reconstruction in Cyanotic Infants with Mediastinitis

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Abstract ***Objective:*** **The purpose of this study was to assess the results and applicability of a modified chest closure technique employing bilateral pectoral myocutaneous advancement flaps after sternal re-approximation for postoperative mediastinitis in cyanotic infants.** ***Methods:*** **The study population is of a single surgeon's pediatric cardiac experience (n = 253) over a 2-year period. With retrospective hospital chart review six cases with deep sternal wound complications were identified (five mediastinitis and one hypoxemic wound necrosis). Sternal wound reconstruction was done with the above technique in all cases. Follow up was completed by outpatient record review and with telephone interviews.** ***Results:*** **All six cases presented in this paper were neonates or infants with complex cyanotic cardiac malformations. Following chest wall reconstruction all had complete resolution of their mediastinitis with no mortality and no wound healing complications. Three of them have since undergone elective staged repair, with no evidence of residual wound infection. Two babies died during follow-up as a result of progressive respiratory compromise.** ***Conclusion:*** **For postcardiotomy mediastinitis in cyanotic infants we recommend limited debridement and anatomic sternal reconstruction supported by bilateral pectoral myocutaneous advancement flap closure.** *(J Card Surg 2003;18:245-252)*

Postoperative sternal wound infection remains a major source of morbidity, and represents an increased health care cost in patients undergoing cardiac surgery.[1-3] In the history of surgical management of postoperative mediastinitis, the classic methods including open granulation and delayed sternal closure with or without irrigation had only limited success.[4,5] In the mid-1970s, the plastic surgical concept of healthy vascularized tissue transfer started to gain popularity. Successful application of the greater momentum was first described by Lee in 1976,[6] and several reports on the use of muscle flaps followed soon.[7,8] Since then muscle flap transfer has become the standard surgical method for chest wound reconstruction in these life-threatening complications in adults.[9-13]

The utilization of muscle flaps has been shown to be effective in pediatric patients as well, although the number of cases presented in the published series are small.[14-18] The pectoralis major muscle is favored by most, although multiple thoracic scars from previous procedures may limit its availability. In small infants the muscle is very thin, making dissection without injury difficult. The preparation of the multilayer myocutaneous flap described by Hugo et al.[12] is technically easier and could be done without plastic surgical experience. At Vanderbilt University we have

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been using such flaps to reconstruct mediastinal wounds after debridement and sternal re-wiring in selected cases in adults. This report is the application of the same technique in infants.

PATIENTS AND METHODS

Our study population is of a single surgeon's (DCD) pediatric cardiac experience from Vanderbilt University Medical Center over a 2-year period (from July 1998 till June 2000). Of the 253 open heart surgeries performed via sternotomy approach on children of all age groups (1 day to 18 years) six patients were identified, who developed deep sternal wound complications. All six were infants or neonates with complex cyanotic malformations, and with one exception (Fallot tetralogy repair) all had staged palliation with the anticipation of further cardiac repair later on. Five children developed mediastinitis (culture positive in four cases) and one infant had extensive soft tissue and bone edge necrosis in the early postoperative period. In these six cases we have retrospectively reviewed our hospital records analyzing patients' characteristics, surgical management and outcome (Table 1). Follow up was completed with outpatient chart review and by telephone interviews.

Our treatment protocol for cases of mediastinitis in the pediatric population consists of wide reexploration of the entire wound with open packing as initial procedure. The patients are then kept sedated and paralyzed on the ventilator until signs of gross infection subside. Bilateral pectoral myocutaneous flap reconstruction is performed later as a second stage procedure in the operating room (OR). These infants with complex cyanotic lesions have a delicate cardiovascular status after palliative repair. They are less likely to tolerate additional respiratory compromise, and most of them require additional cardiac procedures. Therefore we prefer to perform anatomic chest wound reconstruction whenever possible.

Surgical technique: All previously, superficially placed foreign materials (except cardiac grafts and patches) are removed, and after irrigation soft tissue debridement is completed and wound edges are refreshed. We use a fresh #15 scalpel blade to carry out debridement sparingly—shaving off about 1 mm of the white cartilagenous sternal edges on both sides. Brisk bleeding is not anticipated, but oozing from the periosteum

TABLE 1
Patients' Characteristics, Surgical Details and Outcome

Case No.	Age/Sex	Weight (kg)	Cardiac Repair	Periop. Open Chest Management	Repeat Surgery	Mediastinitis Diagnosed (POD #)	Open Packing (days)	Pathogens Cultured from Mediastinum	Days on Ventilator following Repair	Wound Healing	Subsequent Outcome
1.	5 months/male	6.0	Glenn shunt	No	1	17	1	Culture negative	1	Primary	Fontan operation, 6 months later
2.	6 weeks/male	2.4	Central shunt	No	2	6	3	Staphilococcus aureus	25	Primary	Respiratory arrest (died), 2 months later
3.	6 days/male	4.5	Norwood stage I.	No	2	21	5	Staphilococcus aureus	2	Primary	Glenn shunt, 6 months later
4.	8 months/female	3.8	Fallot IV repair	Yes	5	7	8	Enterobacter, Candida sp.	20	Primary	Respiratory arrest (died), 8 months later
5.	7 days/male	2.6	Norwood (ECMO)	Yes	6	16	21	Enterobacter, Serratia sp.	4	Primary	Glenn shunt, 6 months later
6.	6 months/male	7.2	Hemi-Fontan DKS	Yes	2	–	1	No culture (ischemia)	2	Primary	Follow up 17 months later, awaiting Fontan

Note: Repeat surgery includes number of explorations for various complications, but does not include final chest wall reconstruction procedure.

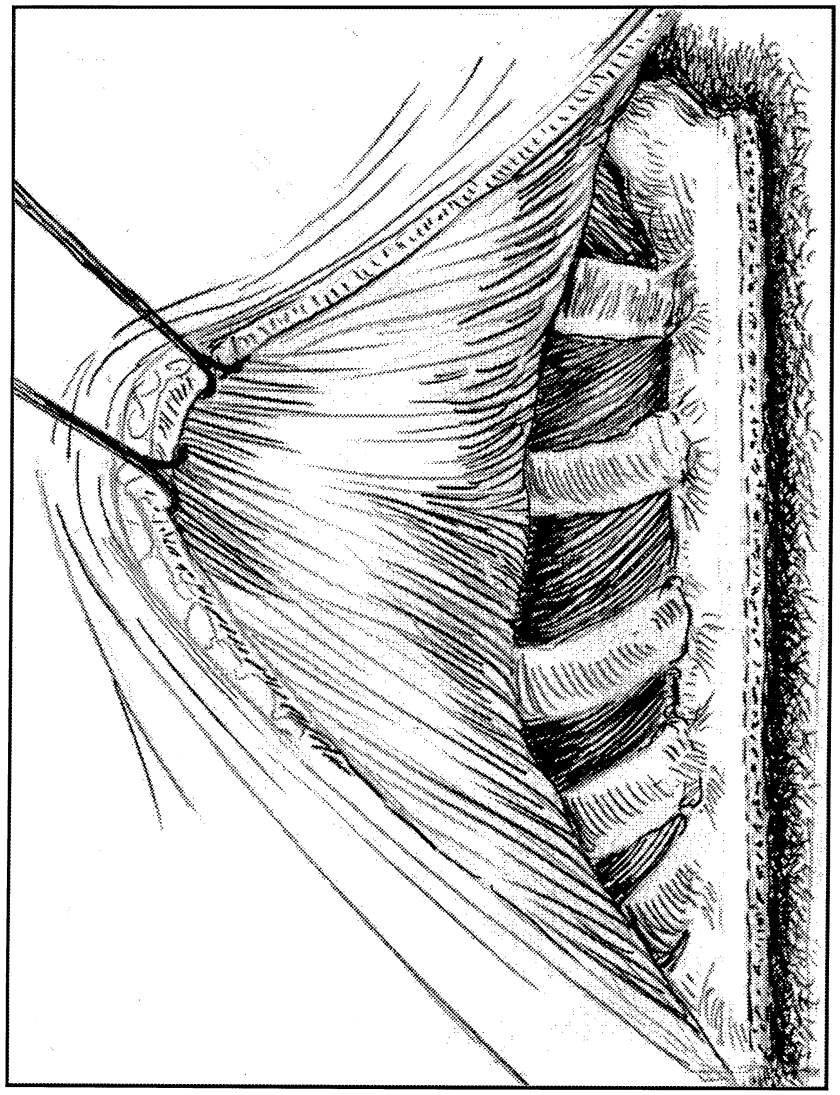

Figure 1. *Dissection of pectoralis myocutaneous flap as one unit (see description in text).*

at this point is a good sign of subsequent healing and therefore the usage of diathermy on the wound edges is avoided. Following debridement both sternal halves are separated from the mediastinal structures behind, entering pleural cavities whenever necessary. Before proceeding with flap dissection, temporary sternal closure is done with one or two silk sutures, while the child's hemodynamic stability is closely monitored. During a period of 5 to 10 minutes all surgical activities are suspended, only anesthetic manipulations are done to adjust volume status and inotropic support as appropriate. If this temporary chest closure is well tolerated, the mediastinum is exposed again and the pectoral myocutaneous flaps are prepared bilaterally.

We follow the technique described by Hugo et al.[12] The surgical dissection of a multilayer myocutaneous pectoralis flap (as single unit) is easier to perform, than dissecting out muscular flaps. With this method the muscle's sternal attachments are elevated first and the perforator vessels are divided with low-voltage electrocautery (Fig. 1). The dissection then continues laterally in a relatively avascular plane between the rib cage and the posterior muscle fascia. In small infants, due to the laxity of the soft tissues, a 2 to 3 cm dissection bilaterally results in sufficient flap

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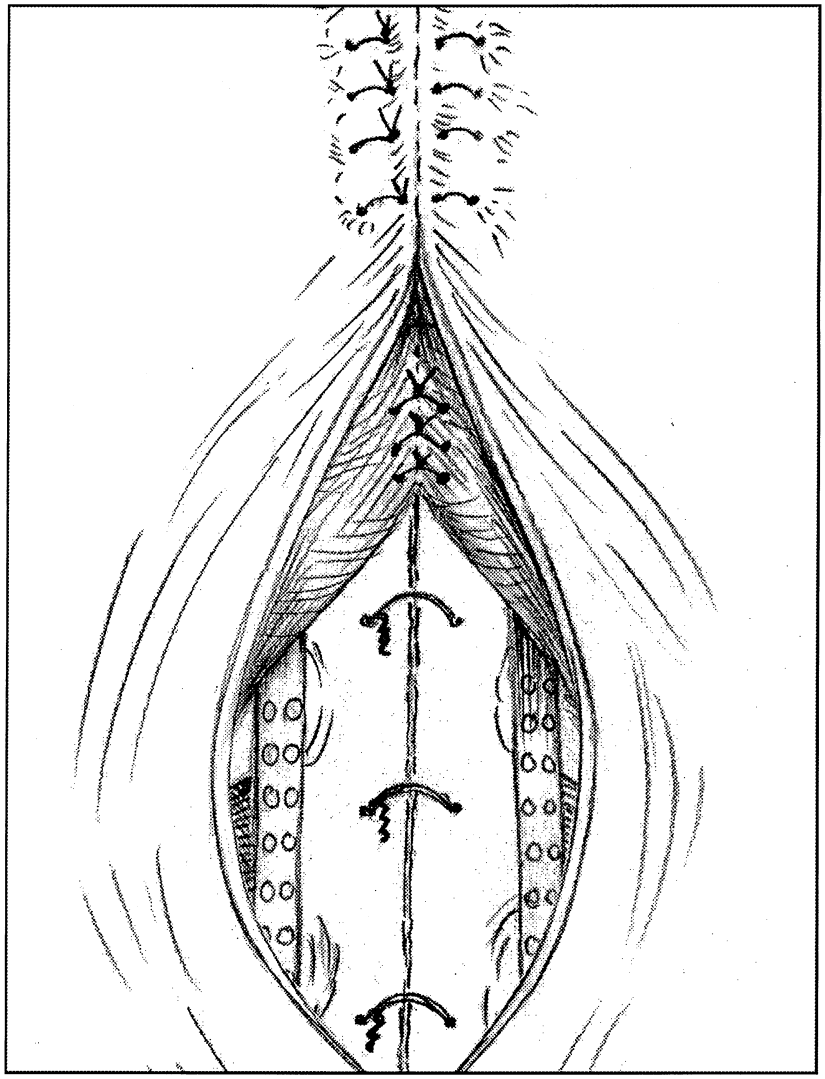

Figure 2. *Anatomic chest wall reconstruction after limited debridement. Closed suction drains are placed bilaterally, and the two flaps are sutured together in two layers.*

length to achieve tension-free closure, especially when the sternum is rewired. Superiorly, depending on the extent of bony debridement, an even limited dissection is satisfactory. In our cases, it was not necessary to free the rectus abdominis anterior fascia together with the pectoralis flaps inferiorly, as suggested by Hugo.[12] In none of our cases did we need to divide the humeral attachments of the pectoralis muscle. As a result, neither the thoracoacromial blood supply, nor the nerve innervation of our "partial" flaps were jeopardized.

At this point repeat irrigation is done with bacitracin solution, and new chest tubes are placed into the mediastinum and pleural cavities. The sternum is rewired and two small-size closed suction drains are placed above the bony chest wall laterally, in order to prevent fluid collection beneath the flaps. The pectoralis muscle edges are sutured together with simple interrupted absorbable sutures, and skin closure is accomplished with retention type Nylon sutures (Fig. 2). The chest tubes are left in place for 2 to 3 days, and the subpectoral suction drains for 5 to 7 days. Intravenous antibiotic treatment is continued for 4 to 6 weeks, based on the recommendation of our infectious consultants.

Our postrepair wound management consist of delayed removal of the closed suction drains after all drainage ceased, and delayed removal of the skin sutures after visually complete healing occurred (12 to 21 days). In one case (case #4), due to the destructive nature of fungal mediastinitis, we employed continuous retrosternal irrigation (0.5% dilute povidone-iodine) for 7 days.

RESULTS

Of the 253 pediatric open heart cases 215 were managed with primary chest closure in the OR, elective open chest management was employed in 34 cases (most of them neonates requiring repair or palliation for complex malformations), and there were four other patients, who had emergency re-exploration in the pediatric intensive care unit and subsequently continued with open chest management. The open mediastinum was sealed with two layers of sterile, antibiotic impregnated plastic drape. Delayed primary chest closure was done either in the OR or in the ICU after a few days of hemodynamic stabilization. Of these 38 patients with open chest management three (7.9%) developed deep sternal wound complications (two cases of mediastinitis and one case of early ischemic tissue necrosis); while in the primary chest closure group there were only three cases of mediastinitis (1.4%, $p < 0.02$, chi-square test).

Patients' characteristics and details of surgical management of these six cases are summarized in Table 1. Two of the babies were neonates, a 6-week-old boy was premature (case #2) and there were three infants the oldest being the only female but developmentally seriously delayed at the age of 8 months (case #5). The mean body weight at the time of the cardiac repair was 4.4 kg (2.4 to 7.2 kg). Five children had complex cyanotic congenital heart defects (hypoplastic left heart syndrome—three cases, #1, #3, and #5; RV hypoplasia with TGA—case #6; double inlet single ventricle with TGA—case #2), and a surgically correctable Fallot tetralogy with underdeveloped pulmonary arteries was repaired in one infant (case #4). The type of cardiac repairs and number of subsequent procedures (excluding pectoral flap supported sternal reconstruction) are listed in Table 1. In three cases the chest was closed primarily after cardiac repair, in the other three cases postoperative open chest management was employed. Two in this latter group (cases #4 and #5) required multiple re-explorations on the ICU (bleeding, resuscitation, and ECMO cannulation/decannulation). In both of these babies delayed primary chest closure was done after stabilization with subsequent wound breakdown and mediastinitis. The last infant (case #6) had a stormy immediate postoperative period due to hemodynamic instability and persistent hypoxemia requiring open resuscitation. After revision of the Glenn shunt his condition stabilized, but extensive wound edge necrosis became obvious by next morning, and a traditional delayed wound closure could not be done without undue tension.

Postoperative mediastinitis developed an average of 13 days after the initial operation, and open wound packing was done for 1 to 21 days (Table 1). Bacterial cultures identified single bacterial infection in two cases, and mixed flora in two additional cases. One child (case #1) developed unequivocal clinical evidence of late mediastinitis (fever, WBC of 21.5, sternal instability and wound discharge) that was culture negative. We found no correlation between postoperative surgical complications requiring re-explorations, the number of days spent on ventilator after chest reconstruction, and subsequent outcome. Four of the six children were weaned from the ventilator 1 to 4 days after stable sternal reconstruction was achieved, whereas two infants remained ventilator dependent for a longer period. These two infants subsequently died due to persistent respiratory problems 2 and 8 months following chest wall reconstruction. Three of the remaining four children have subsequently undergone staged cardiac repair, and the last child was awaiting a completion Fontan procedure at the time of the completion of this study.

All six babies had resolution of their mediastinitis following pectoral flap reconstruction with complete wound healing and no evidence of recurrent wound sepsis, erythema, wound discharge, or sternal instability. All three babies with hypoplastic left heart syndrome survived, and have subsequently undergone staged cardiac repair through the same sternotomy approach. In none of these three children have we found any evidence of residual infectious foci or any growth abnormalities of the thorax. Sternal opening was straightforward without cardiac injury in any case. The child waiting for completion Fontan was last

seen 17 months after the initial cardiac repair and had no chest wall functional or cosmetic defects.

DISCUSSION

In recent series, the incidence of deep sternal wound infection in pediatric cardiac surgical patients varies from 0.5% to 2.0%.[14,17-20] Similar figures (0.9% to 1.6%) are cited for adult patients.[1,2,11,12] Risk factors for sternal wound infection in children include longer preoperative hospital stay, higher preoperative ASA score, postoperative low cardiac output, excessive bleeding requiring reexploration, and duration of ventilator dependence following cardiac repair.[19,20] Elective open chest management, a widely utilized postoperative technique in critically ill infants and neonates, has been quoted as an infectious risk factor by some,[21] whereas others refute its association.[22]

In our series we found a significantly higher incidence of deep sternal wound complication in patients with open chest management (7.9% vs. 1.4%), although the total numbers are small. All six cases presented in this paper had complex cyanotic malformations. We did not have any cases of mediastinitis in pediatric patients undergoing corrective cardiac repair in this series.

Infants with complex cyanotic heart disease are a unique population. Their cardiorespiratory status may be compromised due to persistent desaturation, and they continue to have a delicate balance between systemic perfusion and saturation, even after staged palliation. They also have an immature or even compromised (e.g., Di George syndrome) immune system, making sternal wound infection a potentially life-threatening complication. The principles of wound reconstruction in the face of potential or real infection are the same as for adults. These include adequate debridement and a well-vascularized tissue transfer to promote wound healing. The aim is to achieve mediastinal protection and chest wall stability at the same time. Infants who have undergone staged palliation will require further cardiac repair later on, for which a repeat sternotomy may be the ideal approach.

The pectoralis major muscle is the favored tissue flap for the treatment of postcardiotomy mediastinitis in adults.[8-12] As a broad flat muscle it provides adequate coverage after extensive debridement. It has dual blood supply, the thoracoacromial artery being dominant, and the internal mammary artery intercostal perforator branches that can be divided without sequel. The relative laxity of the thoracoarcomial pedicle and the proximity of the muscle to the sternal wound makes it an ideal choice as advancement or rotation flap. Further mobility could be achieved, when the humeral attachment of the muscle is divided. This latter procedure, as well the turnover flap technique (where viability is based on the perforator branches) requires plastic surgical expertise.[9] Further challenging are neonates and infants, especially if there is a nutritional problem.

Hugo et al.[12] described the technique of myocutaneous pectoral flaps for the treatment of postoperative mediastinitis in adults. The multilayer (myocutaneous) flap could be almost bluntly dissected out to the anterior axillary line in order to achieve satisfactory mobility. In their series of 74 patients, they have used bilateral flaps in lieu of sternal re-closure after extensive bone debridement with good results. However, while their hospital mortality was 9%, with only one death related to persistent wound sepsis, there was a 39% associated morbidity rate, including 8 cases of flap dehiscence. Their method reportedly gave excellent long term cosmetic results and chest wall stability, which has been more of a problem with traditional muscle flaps.[11,23]

Experience from adults can be applied to children. In the five published reports on pediatric sternal wound reconstruction[14-18] there are only 33 cardiac cases reported (Table 2). It is also a heterogeneous population (age range: 1 day to 10 years), and the majority of the children had undergone definitive correction of their cardiac anomalies. When these patients developed postoperative mediastinitis, the principles of debridement and muscle tissue transfer were employed with no attempt to reconstruct the thoracic cage architecture. Two-third of the muscle flaps used were pectoralis flaps, and rectus muscle was utilized in 19 cases. In this combined experience there were two cases of flap dehiscence, and mediastinal sepsis leading to death persisted in only one case. In addition, there were four other cases of late hospital death, presumed to be unrelated to sternal wound complication.

Detailed follow up with functional and cosmetic chest wall evaluation is presented in only one report. Erez et al.[18] described their experience with six neonates. All had total correction of the

TABLE 2
Literature Summary on Pediatric Sternal Wound Reconstruction

Hospital	Year	n	Age Range	Cardiac Procedure Correction/Palliation	Muscle Flaps Pectoral/Rectus	More Than One Flap	Wound or Flap Complications
Emory[14]	1988	13	1 day–7 years	11/2	8/11	6	1 flap dehiscence, 1 wound dehiscence
Yale[15]	1988	4	1 day–7 months	2/2	8/3	4	2 wound hematoma
Univ. of Lousville[16]	1994	7	1 day–10 years	6/1	9/3	1	1 flap dehiscence
North Shore Univ., NY[17]	1997	3	9 months–16 months	2/1	2/2	1	None
Israel[18]	2000	6	2 days–11 days	6/0	7/0	1	None
Vanderbilt	2002	6	6 days–8 months	5/1	12/0	6	None

underlying cardiac condition, therefore, the possibility of later cardiac procedures was not a primary concern. In five of the six cases they used pectoralis turnover flaps, based on the perforating intercostal blood supply. Although in their article they recommend conservative sternal debridement, they did not attempt to reapproximate the sternum in any of the cases. They speculated that the preservation of sternal ossification centers should promote normal bone growth later on. During follow up, however, they noted anterior chest wall deformity and sternal instability in three children (50%), although none of the children had serious respiratory compromise.

In our series all six babies (three infants and three neonates) presented with complex cyanotic malformations, with five cases undergoing palliation. It was felt, that they would not tolerate additional respiratory compromise associated with persistent chest wall instability. Therefore, we preferred anatomic reconstruction with sternal rewiring after limited debridement. Contrary to general belief that avascular cartilage has poor healing potential following infection, we have found in this limited experience a satisfactory sternal bone healing, even in cases of gram negative or fungal infection. This way not only ossification centers are preserved promoting normal growth later on, but due to anatomic reconstruction, redo sternotomy is also possible.

Stahl and Kopf[15] suggested that when an infected sternotomy wound is reconstructed with muscle flaps, thoracotomy approach should be chosen over redo sternotomy. Others have speculated that redo sternotomy through the neovascularized muscle graft would be safe after complete healing;[17] however, up to now no such cases have been reported. In our series all three babies with hypoplastic left heart syndrome have survived without wound healing problems, and all had uncomplicated staged repair done during follow up.

Grant et al[17] suggested that multiple chest wall scars, frequently present in this group of patients, would limit pectoralis flap availability. They strongly recommended the usage of rectus abdominis muscle flap. This technique, and similarly the preparation of a pectoralis muscle flap requires the expertise of a plastic surgeon. In our experience the multilayer myocutaneous pectoralis flap technique described by Hugo[12] may be technically less demanding. Flap mobilization is straightforward, and with bilateral advancement method (simply pulling the edges together in the midline), flap viability is not jeopardized. Due to considerations described above, we have rewired the sternum in all cases, in contradistinction to others. This maneuver has reduced the size of flaps required, even after extensive soft tissue debridement. Therefore, in our experience, there was no need to dissect the flaps far beyond the mammary line. Although our case number is low, the fact that neither flap failure, nor minor wound complications have occurred, supports the safety of this technique.

SUMMARY

In conclusion, we believe that sternal wound reconstruction in small babies with postcardiotomy mediastinitis can be done safely, even in malnourished and critically ill neonates, who have severe cardiopulmonary compromise. We recommend conservative debridement of the sternum with preservation of ossification centers as alike,

followed by anatomic reconstruction. Bone healing should be supported by healthy vascularized tissue transfer. Bilateral pectoral myocutaneous advancement flaps appear to be ideal for this purpose. Such a reconstruction restores normal thoracic cage architecture and prevents the development of additional respiratory compromise associated with sternal instability. In addition to cosmetic results, redo sternotomy is also straightforward, making this technique an excellent choice for complex congenital cases, who need staged cardiac repair later in life.

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