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REVIEW ARTICLE

Reconstructive

Sternal Wound Reconstruction Made Simple

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Summary: Sternal wounds and associated infections represent a complex reconstructive problem in a highly morbid patient population. Through strict adherence to excellent plastic surgical principles, this process can be simplified, allowing safe and effective wound closure. Emphasis is placed on thorough debridement, hardware removal, obtaining adequate tissue cultures, and finally, appropriate flap closure. In most cases, pectoralis major myocutaneous advancement flaps provide excellent coverage while eliminating dead space and providing sternal compression. Secondary flap options, such as the omental flap or rectus abdominis muscle, may occasionally be necessary. This article will provide an overview and simplified approach to sternal wound reconstruction. *(Plast Reconstr Surg Glob Open 2019;7:e2496; doi: 10.1097/GOX.0000000000002488, Published online 28 November 2019.)*

BACKGROUND

Over 400,000 cases of open heart surgery are performed annually in the United States with an incidence of 1%–3% surgical site infections.[1] Superficial sternal wound infections involve skin and superficial soft-tissue structures only and can often be treated with limited courses of antibiotics and local wound care. The remainder of this review will focus on deep sternal wound infections (DSWIs) and deep sternal wound dehiscence, which represent more complex reconstructive problems.[2] DSWI is defined as having (1) positive organism cultured from mediastinal tissue or fluid; (2) evidence of mediastinitis; and (3) presence of chest pain, sternal instability, or fever (>38°C) and purulent fluid from the mediastinum, positive blood culture, or mediastinal culture[3,4] (Table 1). Reported rates of DSWI range from 0.7% to 2.3%.[5] For this review, we define deep sternal wound dehiscence as soft-tissue openings that extend down to sternal bone and hardware.

Exposed sternum in the setting of soft-tissue infection or devascularized bone segments may result in sternal nonunion or osteomyelitis. Known risk factors, such as obesity, chronic obstructive pulmonary disease, diabetes mellitus, tobacco use, internal mammary artery (IMA) harvest, reoperation, and osteoporosis, are frequent in this patient population requiring cardiac surgery and contribute to the development of post-sternotomy wounds[6,7] (Table 2). Although the mortality rate associated with mediastinitis has decreased dramatically with modern therapies, this remains a devastating complication that can be minimized by following the principles of chest wall reconstruction. Although rates of mortality from mediastinitis are reported up to 25%, in recent series, this has dropped to 0.3%–3.4%.[8,9]

Goals of chest wall reconstruction include stable soft-tissue coverage, protection of underlying vital structures and organs, obliteration of dead space, and stabilizing the thoracic skeleton.[10] Herein, we present our simplified approach to chest wall reconstruction, with particular attention to the most common chest wall defects following median sternotomy.

Timing of Sternal Wound Presentation

Pairolero et al[11] and Pairolero and Arnold[12] originally classified sternal wounds into 3 categories based on time to presentation and recommended treatment. They opined that very early wound separations are generally not associated with mediastinitis and are amenable to operative debridement and immediate closure with limited antibiotics. They believed that patients who presented between approximately 1 week and 1 month following median sternotomy often had fulminant mediastinitis and should be operatively debrided with closure delayed until resolution of the infection. Finally, they classified patients presenting after several weeks or months as typically having chronic infections with draining sinus tracts and cartilage or bone infections. Although more modern studies do not adhere strictly to these guidelines, timing and clinical presentation remain similar to their original description.[1]

Goals of the Procedure

When presented with a sternal surgical site infection, initial management includes rapid evaluation to prevent complications associated with DSWI/mediastinitis. Superficial infections can be managed as an outpatient

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provided there is no concern for deeper extension or hardware/bony exposure or contamination. In cases of DSWI, we recommend prompt hospital admission with the following 4 steps: *debridement* and *flap closure*, accompanied by *cultures* and appropriate *antibiotics* (Fig. 1).

A thorough debridement includes aggressive removal of all devitalized superficial tissues and any sternal hardware or wires that may harbor bacteria (Fig. 2). The authors usually open the entirety of the prior incision to facilitate exposure and avoid recurrent infections from inadequate debridement. Extreme caution should be observed when sternal segments are mobile. Postoperative adhesions between the posterior sternum and cardiac structures can easily shear and lead to dreaded complications of ventricle laceration or arterial graft avulsion. For this reason, we recommend that all cases of DSWI substernal debridement be undertaken in conjunction with a cardiac surgeon and with immediate bypass support available. Finally, it is crucial to remove all portions of necrotic bone and cartilage. For any portion of sternal nonunion, the bony surfaces should be removed back to bleeding bone to facilitate contact between healthy segments and promote osseous healing.

Any apparent fluid collections or purulence should be aseptically collected and sent for microbiology. Culture of exposed superficial tissues may provide false-positive results and thus tissue cultures of deeper, infected tissues may improve the meaningful culture yield. In all cases of sternal bone exposure, portions should be sent for tissue culture to determine presence of osteomyelitis. Following thorough irrigation of any infected or nonhealing cavities, post-wash cultures should be taken of residual tissue to tailor postoperative antibiotic therapy.

If debridement is complete and the infection is controlled, we typically proceed immediately with vascularized soft-tissue flap closure (94%–100% of patients).[13,14] However, in select cases of extensive substernal infection beyond the mediastinum or severe hemodynamic instability, we favor a staged approach. In these atypical cases, serial debridement is undertaken until the wound bed appears healthy, and the patient's hemodynamics have stabilized.

Rarely, closure of sternotomy defects using pectoralis major myocutaneous advancement flaps is not advisable due to very high midline tension and/or a paucity of midline soft tissues. In these uncommon cases where the pectoralis flaps will not reach to midline, we have relied on an omental flap (plus skin graft) or a rectus muscle with or without a skin paddle. Although specific flap choices are discussed below, the ideal flap is relatively quick and straightforward to perform, fulfills the aims of eliminating dead space, provides vascularized tissue for improved healing and delivery of antibiotics, covers exposed vital structures, and compresses sternal segments together to promote osseous healing. For these reasons, the pectoralis major myocutaneous flap is our preferred flap for nearly all patients.

If infection is suspected, empiric broad-spectrum antibiotics should be initiated perioperatively and narrowed to specific therapy as microbiology cultures indicate. In cases of osteomyelitis, long-term courses of antibiotics are usually necessary for at least 6 weeks[15] and are guided by consultation with an infectious disease specialist.

Table 1. CDC Criteria for Defining DSWI

Must Have at least *One* of the Following:
1. Positive organism cultured from mediastinal tissue or fluid
2. Gross evidence of mediastinitis
3. One of the following: chest pain, sternal instability, or fever (>38°C)
And either:
a. Purulent fluid from the mediastinum
b. Mediastinal widening on imaging

Table 2. Some Major Risk Factors for the Development of a DSWI following Cardiac Surgery

Some Major Risk Factors for DSWI
Obesity
COPD
Diabetes mellitus
Tobacco use
Internal mammary artery harvest
Reoperation
Prior radiation to sternal region

COPD = chronic obstructive pulmonary disease.

MOST EFFECTIVE PROCEDURES

Pectoralis Major Myocutaneous Flap

The author's preferred choice for coverage of sternotomy defects is bilateral pectoralis major myocutaneous advancement flaps based on the thoracoacromial arteries.[13,14,16–18] These flaps are elevated in the relatively avascular plane just deep to the pectoralis major muscle in a medial to lateral direction (Fig. 3). Dissection is halted as soon as the flaps can be advanced to the midline with minimal tension (which usually involves dissecting to the area between the mid-clavicular and anterior axillary lines; Fig. 4). Superiorly, dissection ends just below the level of the clavicle. At the inferior border of the pectoralis muscle, the plane continues deep to the anterior rectus sheath to the level of the xiphoid process (the rectus abdominis muscle is left intact). After thorough irrigation (we prefer a pulse irrigator with an antibiotic solution), a closed suction drain is placed laterally under each flap and a third drain is often placed centrally over the mediastinum. The flaps are apposed to each other in the midline with interrupted no. 2 Vicryl or Polysorb sutures, including the pectoralis fascia and rectus sheath in the same closure layer. The deep dermis and skin are then closed in layers.

The well-vascularized, pectoralis major advancement flaps are not affected by IMA harvest, maintain a reliable blood supply, and are relatively quick and straightforward to harvest. We have not observed limitations in shoulder mobility, nor observed contour irregularities, when the pectoralis major muscles have been used for this procedure. The major limitation of this flap is often lack of coverage over the xiphoid and inferior portion of the wound

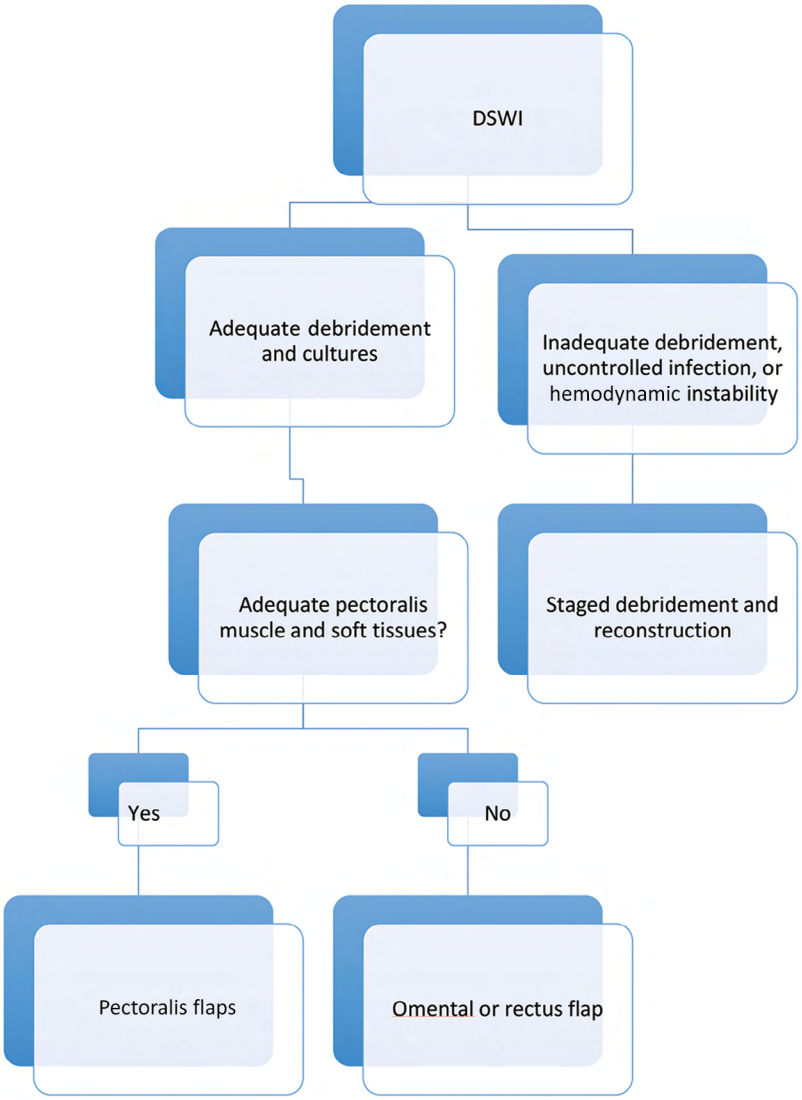

Fig. 1. Algorithm for sternal wound reconstruction.

Fig. 2. Preoperative view of sternal wound with contaminated wire at base.

because the pectoralis major muscles do not extend this far inferiorly, but this concern is overcome by raising the anterior rectus sheath in continuity with the pectoralis major flap. Multiple large series have demonstrated similar frequency and reliability of the pectoralis major myocutaneous advancement flap, including coverage of the lower third of the sternum.[14,19]

Although others have described the use of the pectoralis major turnover flap or split turnover flap (based on the IMA perforators), these options are often unavailable because the blood supply is often in the zone of injury/debridement or utilized as a graft during the time of cardiac surgery. Unlike the myocutaneous advancement flap, the turnover flap requires a much more lengthy and extensive dissection (separating the overlying skin and subcutaneous tissues), requires division of the muscle's humeral insertion, and results in chest wall deformity and decreased pectoralis major muscle function. In cases where the lower third of the sternum requires coverage,

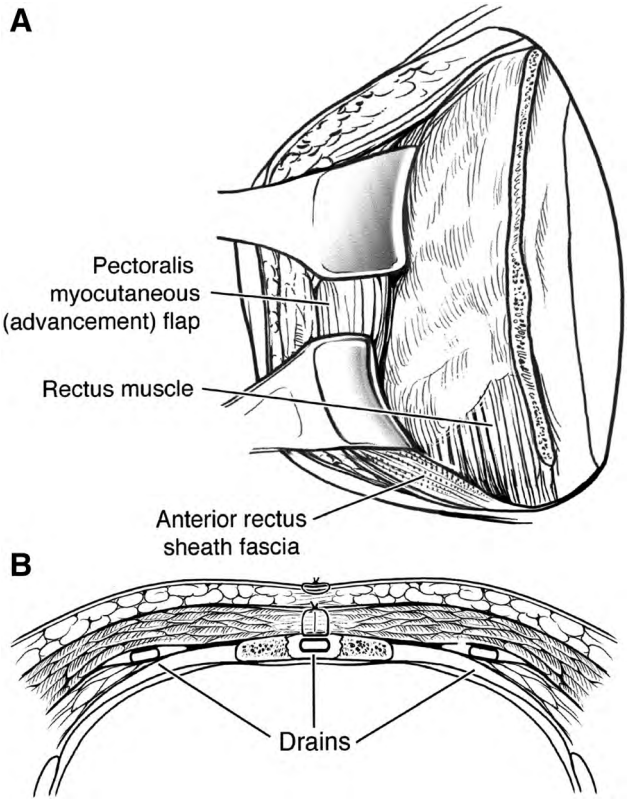

Fig. 3. A, Pectoralis major myocutaneous flap raised along with the superior aspect of the anterior rectus sheath. B, Diagram of pectoralis major flap elevation and layered closure over closed suction drains. Images courtesy of Ascherman et al.[14]

the pectoralis turnover or split pectoralis flap could provide additional benefit.[20] In such cases, concern about viability of the IMA perforators can be tested using a handheld Doppler.

Omental Flap

In patients with extensive loss of chest wall soft tissue and insufficient skin for closure, the omentum remains a reliable secondary option for sternal reconstruction, especially for lower third defects.[21] Transposing omental tissue is also beneficial when a deeper wound is encountered and a large amount of dead space needs to be filled, such as around an aortic graft. The omentum is unaffected by IMA harvest and has an added theoretical benefit of providing vascularized lymph tissue to improve microbial clearance from an infected wound bed. Because its harvest requires laparotomy and potential intra-abdominal complications, and it provides much less tissue bulk, it is not a first-line reconstructive option. Further caution should be exercised in cases of prior abdominal surgery. The omentum can be harvested either laparoscopically or through an upper abdominal midline incision. Unlike closure of the pectoralis advancement flaps in the midline, the omentum provides no benefit to chest wall stability. Other considerations include obligatory creation of an abdominal fascia opening or diaphragmatic defect to allow the omentum to reach the sternum and possible need for skin grafting.[22] Although most studies have not shown worse outcomes after omental flaps compared with muscle flaps, patients requiring omental flap closure tend to be more complex and the procedure is associated with a higher risk of mortality.[23]

Rectus Abdominis Muscle Flap

In cases where the pectoralis major muscles are unavailable and the ipsilateral IMA remains patent, the rectus abdominis muscle can be reliably used for sternal defects with an optional vertically or transversely oriented skin paddle. As a pedicled muscle flap, based on the superior epigastric artery, it can be divided at its inferior most portion and rotated superiorly. There are multiple approaches for harvest, including midline, low transverse, or paramedian incisions.[10]

Compared with pectoralis major advancement flaps, the rectus may provide more robust coverage of inferior sternal defects. However, it does require a second donor site and may entail associated complications such as abdominal wall weakness, bulge, or hernia. Skin grafting is needed if it is not harvested as a myocutaneous flap. Frequent absence of the IMA following CABG, or damage to the IMA during previous sternotomy closure, may limit use of this superiorly based flap. Whereas it is not part of our standard practice, use of ipsilateral rectus abdominis muscle flaps even after IMA

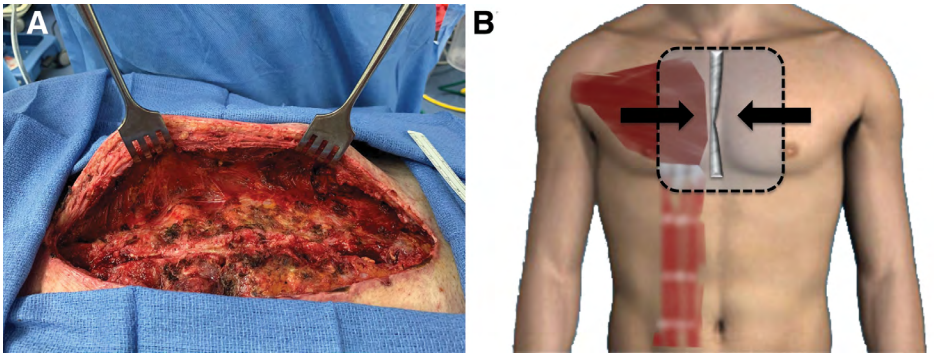

Fig. 4. A, Elevated myocutaneous flap showing adequate dissection to easily advance flap to midline. B, Schematic of sternal wound showing pectoralis muscle location and approximate extent of dissection (dashed lines).

ligation has been described to survive based on the musculophrenic artery and collateralization from the lower intercostal arteries.[24] We find that it is rarely necessary to use the rectus muscle, and that in nearly all cases, sternal wounds can be addressed successfully with pectoralis major flaps.

AVOIDING AND MANAGING MOST DANGEROUS COMPLICATIONS

Major complications following sternal reconstruction have been reported in up to one-third of patients and are similar to those reported for sternal wounds.[6,13,14,22,23] This includes a mortality rate of 3%–8% of patients and failure of reconstruction of up to 17% in some series.[6,14] Associated risk factors are similar to those for development of SWI, such as obesity, chronic obstructive pulmonary disease, renal disease, or use of IMA grafts. In the senior author's experience with over 500 cases of sternal wounds (J.A.A.), using a standard single-stage technique with bilateral pectoralis major myocutaneous advancement flaps with limited undermining, rates of complications can be minimized in this highly morbid patient population.

Preparation is critical, including having available cardiothoracic surgeon support and/or immediate bypass pump availability. In our center, we prefer to perform all cases of sternal debridement and reconstruction in a cardiac capable room with the cardiac surgeon present for the initial debridement. Extreme caution should be exercised in the presence of retrosternal collections, particularly in the postoperative period when adhesions of the ventricles can develop to the posterior sternum. Inadvertent motion of unstable sternal segments may result in shear or avulsion injuries to these structures.

Mediastinitis and recurrent DSWI are additional dreaded complications, which usually result from inadequate debridement or antimicrobial coverage. Our typical postoperative protocol following pectoralis flaps includes avoidance of forceful coughing when possible and limited activation of pectoralis major muscles while transferring or standing. In some cases, a chest binder or surgical bra may offload tension from the midline.

PEARLS AND PITFALLS

Sternal wound reconstruction can be performed safely and effectively with minimal morbidity if strict adherence to several surgical principles is followed. It is critical to perform a thorough debridement of all infected and devitalized tissue, including bone. Osseous debridement should include the bone edge along the entire length of the sternotomy or any bone that could potentially be seeded with bacteria. In cases where foreign bodies cannot be removed (eg, pacing wires, graft material), staged debridement and reconstruction should be considered if there is concern for ongoing infection. However, in most cases, a single-stage debridement and reconstruction can be performed with excellent outcomes.

During elevation of myocutaneous flaps, we have previously shown that limiting lateral dissection to the extent necessary to bring bilateral flaps together with minimal tension in the midline can decrease morbidity.[14,17] We reiterate that the inferior portion of the sternal wound caudal to the pectoralis is the most frequent area of wound healing problems, and raising the rectus fascia in continuity with the pectoralis flap can provide additional soft-tissue coverage. We advocate the use of closed suction drains to aid in eliminating dead space and to evacuate postoperative fluids (Fig. 5).

WHAT PATIENTS SHOULD KNOW BEFORE HAVING THIS PROCEDURE

Although we have found a high success rate for closure of sternal wounds using this straightforward and reliable method, we caution patients that we encounter occasional superficial wound complications (especially at the inferior aspect of the wound) that can usually be treated conservatively with dressing changes only. Because of the frequent finding of osteomyelitis, patients often require a protracted course of intravenous antibiotics. Finally, we caution our patients that they may have a prolonged decrease in central chest wall sensation postoperatively.

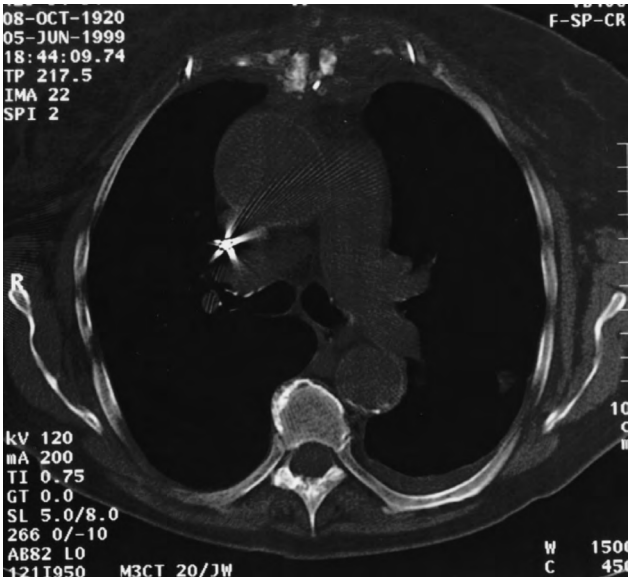

Fig. 5. Computed tomography scan of the chest showing collapse of dead space 8 days after pectoralis advancement flap closure. Three Jackson-Pratt drains are present: one below each flap and one in the mediastinum. Images courtesy of Ascherman et al.[14]

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