Current Management of Sternal Wounds

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Learning Objectives: After studying this article, the participant should be able to: 1. Describe the pathogenesis, classification, and risk factors of sternal wound infection. 2. Discuss options for sternal stabilization for the prevention of sternal wound infection, including wiring and plating techniques. 3. Discuss primary surgical reconstructive options for deep sternal wound infection and the use of adjunctive methods, such as negative-pressure wound therapy.

Summary: Poststernotomy sternal wound infection remains a life-threatening complication of open cardiac surgery. Successful treatment relies on timely diagnosis and initiation of multidisciplinary, multimodal therapy. (*Plast. Reconstr. Surg.* 148: 1012e, 2021.)

Sternal wound infection is a serious complication of cardiac surgery, with a reported incidence ranging between 1 and 4 percent in the literature.[1,2] Sternal wound infection may lead to catastrophic outcomes such as sepsis, mediastinitis, ventricular rupture, bypass graft erosion, and chronic osteomyelitis. Although the development of minimally invasive and transcatheter procedures has reduced its incidence, the associated mortality has been reported to be as high as 35 percent, with studies showing up to a threefold increased risk of death in a 4-year follow-up period.[3,4] In the setting of changing indications for open cardiac surgery, older and sicker surgical candidates, and innovations in reconstructive options, there is a growing need for a comprehensive review of the growing literature capturing the evolving management of sternal wound infection (Table 1).

CLASSIFICATION OF STERNAL WOUND COMPLICATIONS

Poststernotomy complications can be classified as sternal dehiscence and sternal wound infections, which in turn can be defined as superficial and deep. Sternal dehiscence is a gap in bony reapproximation, which may or may not be accompanied by infection. Superficial sternal wound infection is defined as a complication restricted to the skin, subcutaneous tissue, and the pectoralis fascia with no bony involvement, and can usually be managed with antibiotics and local wound care. Deep sternal wound infection, in contrast, requires more aggressive treatment and is defined by the Centers for Disease Control and Prevention as involvement of the deep soft tissues with fulfillment of at least one of the following criteria: (1) mediastinal tissue or fluid positive for organisms; (2) gross or histopathologic evidence of mediastinitis; and (3) fever (>38.0°C), sternal instability, or chest pain accompanied by either purulent mediastinal drainage or mediastinal widening observed on imaging.[5]

SHIFTING TRENDS IN CARDIAC SURGERY

Technological advances and health epidemiologic shifts have led to major changes in the indications and procedural composition of cardiac surgery. As a result of the explosive rise in the volume of transcatheter aortic valve replacement procedures since its approval by the U.S. Food and Drug Administration in 2011, there has been a decrease in the procedural volume of isolated surgical aortic valve replacement and combined aortic valve replacement between 2013 and 2016.[6] The annual volume of coronary artery bypass grafting, the most

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Table 1. Key Studies Surrounding Prevention and Management of Sternal Wound Infection

Study	Study Type/ Design	No.	Intervention Studied	Summary of Findings
Hamman et al., 2014	Randomized controlled trial	1866	Topical vancomycin, calcium-thrombin, and platelet-rich plasma vs. no treatment	Intraoperative application of triple-component combined topical paste to sternal edges shown to significantly reduce the risk of DSWI.
Lazar et al., 2014	Randomized controlled trial	3265	Topical vancomycin, perioperative antibiotics, and glycemic control vs. latter two only	Intraoperative application of topical vancomycin to sternal edges and postoperative IV insulin (to maintain serum glucose of 120–180 mg/dl) shown to significantly reduce the risk of SSWI and DSWI.
Kowalewski et al., 2017	Meta-analysis	20,039	Topical vancomycin	Intraoperative topical vancomycin shown to significantly reduction in SWI rate.
Narang et al., 2009	Prospective study	200	Robiscek closure vs. routine sternal wound closure	Robiscek closure shown to significantly decrease the incidence of sternal dehiscence in high-risk patients.
Schimmer et al., 2008	Randomized controlled trial	815	Robiscek closure vs. conventional sternal closure	Robiscek closure did not demonstrate significant improvement in incidence of sternal dehiscence.
Allen et al., 2017	Randomized controlled trial	236	Rigid plate fixation vs. wire cerclage	RPF shown to be associated with improved sternal healing, fewer sternal complications at no significant additional cost.
Tam et al., 2018	Meta-analysis	1452	Rigid plate fixation vs. wire cerclage	RPF shown to be associated with decreased perioperative mortality and decreased sternal complications in high-risk patients
Wu et al., 2016	Retrospective study, MarketScan database	1335	Early vs. delayed sternal debridement	Patients undergoing delayed débridement (>7 days from diagnosis of DSWI) shown to have greater number of admissions and total hospital days compared to counterparts undergoing early débridement (same day as diagnosis).
Fuchs et al., 2005	Retrospective study	68	NPWT vs. conventional treatment	Compared to open packing of wound, NPWT found to significantly improve survival and reduce time to freedom from positive mediastinal microbiological cultures, time to rewiring, in-hospital stay.
Petzina et al., 2010	Retrospective study	118	NPWT vs. conventional treatment	NPWT found to significantly reduce mortality and sternal reinfection rate.
Song et al., 2003	Retrospective study	35	NPWT vs. conventional treatment	Compared to conventional serial dressing changes, NPWT found to be associated with fewer dressing changes and average number of soft-tissue flaps required for definitive closure with trend toward shorter interval between débridement and closure.
Brandt and Alvarez, 2002	Retrospective study	21	Immediate flap reconstruction vs. conventional treatment (i.e., closed drainage/tube irrigation)	Immediate bilateral pectoralis major myocutaneous advancement flap with greater omental transposition shown to be associated with lower complication, reoperation, and 30-day mortality rates; fewer intensive care unit readmissions; shorter total hospital stay.
Ascherman et al., 2004	Retrospective study	114	Bilateral pectoralis major muscle flap	Single-surgeon series of 104 cases managed with single-stage débridement and bilateral pectoralis major advancement flaps demonstrate perioperative morbidity and mortality rates of 16.7% and 7.9%, respectively.
Lindsey, 2002	Retrospective study	48	Pectoralis major muscle flap	Demonstrated a significantly higher incidence of wound complications among those undergoing sternal closure 4 days or less from initial débridement.
Vyas et al., 2013	Retrospective study	140	Omental flap reconstruction by means of laparotomy incision vs. transdiaphragmatic opening	Rates of ventral hernias found to be comparable between two harvest techniques, but with author observations of increased operative speed and reduced blood loss with transdiaphragmatic harvest.

DSWI, deep sternal wound infection; IV, intravenous; SSWI, superficial sternal wound infection; SWI, sternal wound infection; RPF, rigid plate fixation; NPWT, negative-pressure wound therapy.

commonly performed cardiac surgical procedure, has also declined despite more hospitals performing this procedure—a phenomenon attributed to improved results of noninvasive treatment and widespread availability of nonsurgical alternatives such as advanced percutaneous coronary intervention stenting.[7–9] A higher proportion of patients undergoing coronary artery bypass grafting now have comorbidities such as diabetes, heart failure, or other risk factors for postoperative complications such as nonelective status or history of prior percutaneous coronary intervention.[6] Such changes highlight the increasing need for interdisciplinary coordination between the primary cardiac surgery team, infectious disease consultants, and the plastic and reconstructive surgeon in the management of sternal wound infection.

MICROBIOLOGY

Staphylococcus species are the most commonly cultured organism associated with cardiac surgical wound infections, with the majority arising from the patient's nasal flora. Experts recommend preoperative nasal swabs for culture or polymerase chain reaction testing for *S. aureus* carrier status, in addition to preoperative intranasal mupirocin for all patients with documented or unknown carrier status.[10] Intranasal mupirocin achieves decolonization of methicillin-susceptible *S. aureus* in greater than 90 percent of carriers but in only approximately 50 percent of those colonized with methicillin-resistant *S. aureus.*[11–13] In addition to a single-center prospective study documenting a 66.6 percent reduction in sternal wound infection incidence with prophylactic mupirocin, a randomized, double-blind, multicenter trial demonstrated that mupirocin ointment and chlorhexidine gluconate soap together significantly reduced the incidence of deep sternal wound infection among both cardiac and noncardiac surgical patients.[14,15]

Current recommended perioperative antibiotics include an antistaphylococcal cephalosporin antibiotic administrated within 60 minutes of surgery, with a repeated dose for operations longer than 4 hours and continued for no more than 48 hours, substitution with vancomycin for those allergic to beta-lactam agents or with a high risk for methicillin-resistant *S. aureus*, and addition of an agent with activity against Gram-negative pathogens (i.e., aminoglycosides) for one preoperative dose. Experts currently advise the application of topical antibiotics on sternal edges on opening and before closing all sternotomies for cardiac procedures, although this has been studied with mixed results.[10] Two nonrandomized prospective studies have demonstrated reduction in sternal wound infection using topical vancomycin combined with other modalities, including platelet-rich plasma paste and systemic perioperative antibiotics and stringent glycemic control.[16,17] However, a recent large single-center retrospective analysis failed to demonstrate a reduction in deep sternal wound infections with use of topical vancomycin paste as a single intervention.[18] A meta-analysis including these studies concluded that topical vancomycin yields a significant reduction in the risk of sternal wound infection rates.[19] Similarly, although two randomized controlled trials have failed to demonstrated a significant impact of gentamicin-collagen sponges on sternal complication rates, a recent meta-analysis quoted a significant 38 percent reduction in sternal wound infections with this adjunct therapy, underscoring the need for further studies to elucidate long-term benefits.[20–22]

RISK FACTORS

Patient-related risk factors for sternal wound infection include diabetes mellitus, obesity, chronic obstructive pulmonary disease, and peripheral artery disease, whereas intraoperative risk factors include bilateral internal mammary artery harvesting, duration of surgery, and reexploration for bleeding.[23] Recent studies have also shown that the risk factor profile for sternal wound infection varies depending on the type of cardiac surgery procedure performed.[2]

Patients with diabetes suffer from poor wound healing and an increased risk of surgical-site infections.[3,24] In a single-center retrospective study of cardiac surgery patients between 1992 and 2006, it was observed that despite a progressive increase in the proportion of diabetic cardiac surgery patients, the association between diabetes and sternal wound infection incidence actually diminished over time—a paradoxical change attributed to the implementation of a stringent perioperative glycemic control protocol.[25] Elevated preoperative serum glucose levels are associated with an increased risk of sternal wound infection, and improvement of this perioperative parameter has been linked to a reduced incidence of wound infection.[26–28] Preoperative optimization of glucose control is recommended in all patients with elevated hemoglobin A1C levels (>7.5 percent) and serum glucose levels (>200 mg/dl), and postoperative optimization by means of continuous insulin infusion in the intensive care unit (target serum glucose <180 mg/dl) for at least 24 hours.[10] At our institution, we use insulin to regulate blood glucose in this manner in all cardiac surgery patients regardless of diabetic status, given the evidence that elevated serum glucose increases the risk of sternal wound infection.

Internal mammary artery grafts, particularly the use of the left internal mammary artery–to–left anterior descending coronary graft, became preferred conduits in cardiac surgery based on documentation of long-term survival and reduction in cardiac events attributable to improved graft patency.[29] Although a large meta-analysis had demonstrated improved survival and outcome with bilateral internal mammary artery grafting and argued for its use as the procedure of choice, the long-term benefits have been called into question by a recent randomized controlled trial that showed a significantly higher rate of sternal wound complications at 6-month follow-up, with no difference in all-cause mortality at 5 and 10 years.[30–32] The most recent 2016 Society of Thoracic Surgeons Clinical Practice Guidelines leave the number and source of the bypass grafts a largely case-by-case decision, recommending that a second skeletonized internal mammary artery conduit be used only in patients who are not at excessive risk of sternal complications and that skeletonized grafts are considered to further mitigate the risk.[33] Although current evidence supports the superiority of coronary artery bypass grafting over percutaneous coronary intervention in diabetic patients, bilateral internal mammary artery grafting in diabetic patients remains controversial and is not routinely used.[34]

Heart transplants are a unique subset of cardiac operations that require special attention. In a retrospective single-surgeon series of 136 sternal construction cases between 2000 and 2007, the incidence of sternal wound infection was nearly 50 percent among heart transplant patients, compared with 6 percent among isolated coronary artery bypass grafting patients. Transplant-related immunosuppression has been thought to be one contributing factor in the increased incidence of sternal wound infection. Interestingly, of the 369 heart transplant cases during the study period, almost 20 percent of those with a history of ventricular assist device implantation or other cardiac procedure developed a sternal wound infection, whereas less than 1 percent of patients with primary heart transplantation did so—suggesting that factors such as ventricular assist device use and multiple sternotomies may also play a role in increasing the risk of sternal wound infection.[35] Finally, sternal wound infections are by no means restricted to cardiac surgery patients and affect those undergoing procedures such as double-lung transplants for conditions such as cystic fibrosis, idiopathic pulmonary fibrosis, and chronic obstructive pulmonary disease. Although largely abandoned for the median sternotomy in cardiac surgery, the transverse thoracosternotomy or "clamshell" incision regained popularity in bilateral lung transplantation as a technique with superior exposure of the mediastinal and hilar structures and the pleural spaces.[36,37] However, this technique has been associated with sternal wound dehiscence, infections, and other complications, highlighting the need for close surveillance of these patients and continued investigation of surgical approaches that ameliorate the risk of such comorbidities.[38,39]

STERNAL STABILIZATION THROUGH WIRING AND PLATING

Sternal reapproximation following cardiac surgery can be achieved through simple transsternal or peristernal wire closure in most low-risk patients. In transsternal wire closure, the most common technique, stainless steel wires are passed through the sternum, whose edges are reapproximated by twisting the ends of the wires anteriorly. In contrast, peristernal wire closure, or wire cerclage, involves passing wires around the sternum instead of through it and is composed of several technical variants (Fig. 1). At our institution, we use a combinatorial approach of transsternal single wires for the manubrium and peristernal cerclage wires for the sternal body. The Robicsek technique, where the wires are woven through the parasternal intercostal spaces with cerclage wires placed laterally, has been thought to provide additional strength and stability, potentially preventing dehiscence and wound infection (Fig. 1).[10,40] Although a prospective review has demonstrated a reduction in the incidence of sternal dehiscence among high-risk patients, this was not corroborated in a randomized controlled trial encompassing 815 high-risk patients.[41,42] In high-risk patients, prophylactic sternal reinforcement techniques such as rigid plate fixation have been investigated as methods to mitigate the risk of sternal complications (Fig. 1). These conventional methods are joined by relatively newer sternal closure modalities, including biocompatible cable-tie closure systems[43] and lightweight titanium sternal "locking" systems that circumvent the need for screws that may become loose with repetitive sternum movement.[44]

Unfortunately, the literature does not provide a firm consensus on the indications for osseous stabilization in the setting of sternal wound infection. In our experience, bony nonunion can be symptomatically more bothersome in younger and obese patients and may justify sternal stabilization, whereas in elderly patients, there is often enough local scar tissue formation such that bony osteosynthesis is not required. Some retrospective studies have shown the benefits of rigid plate fixation over wire closure, with decreased incidences of wound complications and mediastinitis, and a recent prospective, single-blind, multicenter trial of 236 patients showed that sternotomy closure with rigid plate fixation resulted in significantly improved sternal healing and fewer sternal complications at no additional cost compared with conventional wire cerclage.[45,46] A recent meta-analysis of three randomized controlled trials and five observational studies demonstrated a

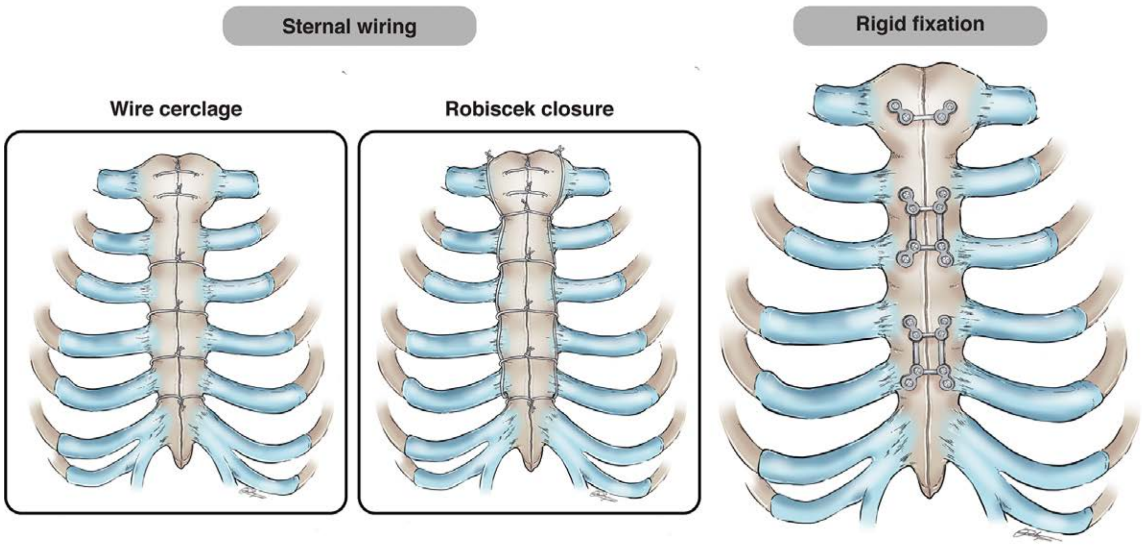

Fig. 1. Techniques for sternal stabilization through sternal rewiring and plating. Following cardiac surgery, sternal reapproximation can be achieved through several techniques, including transsternal (not shown) or peristernal wire closure (wire cerclage), with the Robiscek closure as a variant of the latter. Rigid fixation can also be pursued in high-risk patients to provide additional sternal reinforcement.

significant reduction in the incidence of sternal complications and decreased perioperative mortality with rigid plate fixation, although the former was only demonstrated in high-risk patients.[47] This contrasts with the results of a recent retrospective study through the American College of Surgeons National Surgical Quality Improvement Program, which demonstrated increased rates of perioperative complications with rigid plate fixation, including need for transfusions, prolonged ventilation, and reoperations or readmissions, highlighting the need to contextualize the potential benefits of rigid plate fixation in risks that may compromise the overall hospital course.[48]

DEEP STERNAL WOUND INFECTIONS: OPTIMIZING MICROBIOLOGICAL DIAGNOSIS AND MEDICAL MANAGEMENT

Critical factors in the treatment of deep sternal wound infection include timely diagnosis (usually involving computed tomographic chest imaging), aggressive drainage, débridement, and the administration of a tailored antibiotic regimen.[49] Indications for early assessment with radiologic imaging include new or ongoing wound drainage, swelling, erythema, or pain, and the presence of a draining fistula tract at the surgical site on examination. Key factors for early diagnosis and prompt triage to surgical management include aggressive débridement of any infected or devitalized tissue and removal of indwelling hardware where possible. To facilitate tailoring of antibiotic therapy, surgical providers should obtain samples of swabs of deep tissue and bony structures, and any removed hardware or prosthetic material, which should be sent for Gram stain and aerobic, anaerobic, and fungal culture. Superficial wound swabs from a draining wound or fistulous tract may have lower specificity, given the possibility of skin contamination, but may nevertheless provide valuable diagnostic data to help guide antibiotic therapy. Blood cultures are essential for all patients with sternal wound infection given the frequency of concurrent bacteremia and endovascular infection. Empiric therapy while awaiting culture results include antistaphylococcal agents (i.e., intravenous vancomycin) and anti–Gram-negative agents (i.e., ceftazidime, cefepime, piperacillin-tazobactam), with potential added coverage of anaerobic organisms (i.e., metronidazole) and *Candida* species (i.e., fluconazole) in high-risk scenarios. Although most antibiotic regimens for sternal wound infection extend for 21 days or longer, the duration ultimately depends on multiple factors, including timing and extent of surgical débridement, presence of residual hardware, causative organisms, and time to sternal closure and healing. A growing body of literature supports early transition from intravenous to oral antibiotic therapy for severe infections such as osteomyelitis and endocarditis, which may provide support for early transition to oral antibiotic therapy after operative débridement for deep sternal wound infection.[50,51]

STERNAL RECONSTRUCTION USING FLAPS

Following initial sternal débridement, sternal closure may be achieved through sternal wiring or plating in the setting of adequate bone stock and absent infection, with flap reconstruction reserved for complicated cases with inadequate bone available. The Assiduous Mediastinal Sternal Debridement and Aimed Management classification system provides an evidence-based classification of appropriate treatment options based on factors such as sternal stability, bone viability, and stock.[52] Flaps may be used for immediate or delayed closure and usually achieve sternal wound closure without the need for bony reapproximation or the use of bone or skin grafts, albeit at the cost of longer total hospital stays.[53] Although it remains difficult to predict which patients will eventually require flap reconstruction following deep sternal wound infection, several studies have demonstrated improved survival outcomes with early sternal flap reconstruction over cases of delayed referral or treatment with sternal rewiring and closed drainage, highlighting the potential importance of the early involvement of the plastic surgeon in optimizing patient outcomes.[54,55]

The pectoralis major flap, the "workhorse" flap in sternal reconstruction, may be based on the thoracoacromial trunk or perforators of the internal mammary artery (Fig. 2). The latter confers additional flexibility with a greater arc of flap location to fill the defect, albeit sometimes at the cost of poorer functional or cosmetic outcomes, particularly in young male patients. Bilateral pectoralis major flaps may be used for large defects. For small defects, we can enable small advancements of the pectoralis major muscle by carefully dissecting away the tissue surrounding the perforators, sparing them to allow the bilateral pectoralis major muscles to advance past the midline (Fig. 3).

The pectoralis major turnover flap, based on the internal mammary perforators, begins with raising the skin and subcutaneous tissue off of the pectoralis major muscle, exposing its anterior surface (Fig. 2). Importantly, internal mammary perforators may not be reliable if the ipsilateral internal mammary artery has been harvested for the purpose of bypass grafting. Although the dissection may be performed with the aid of a lighted retractor, a counterincision near the insertion of the muscle may be helpful for less experienced

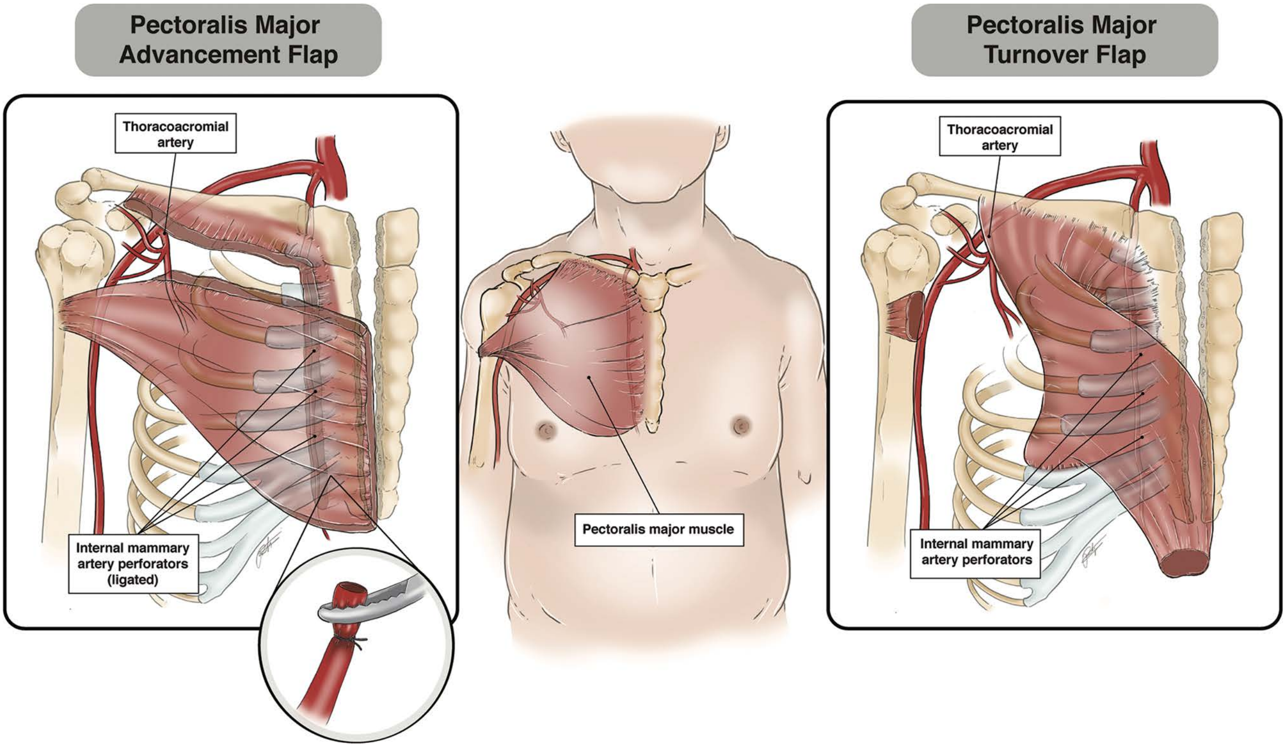

Fig. 2. Pectoralis major flap for sternal reconstruction. The dual blood supply of the pectoralis major muscle allows it to be based on the thoracoacromial trunk (advancement flap) or the internal mammary artery perforators (turnover flap).

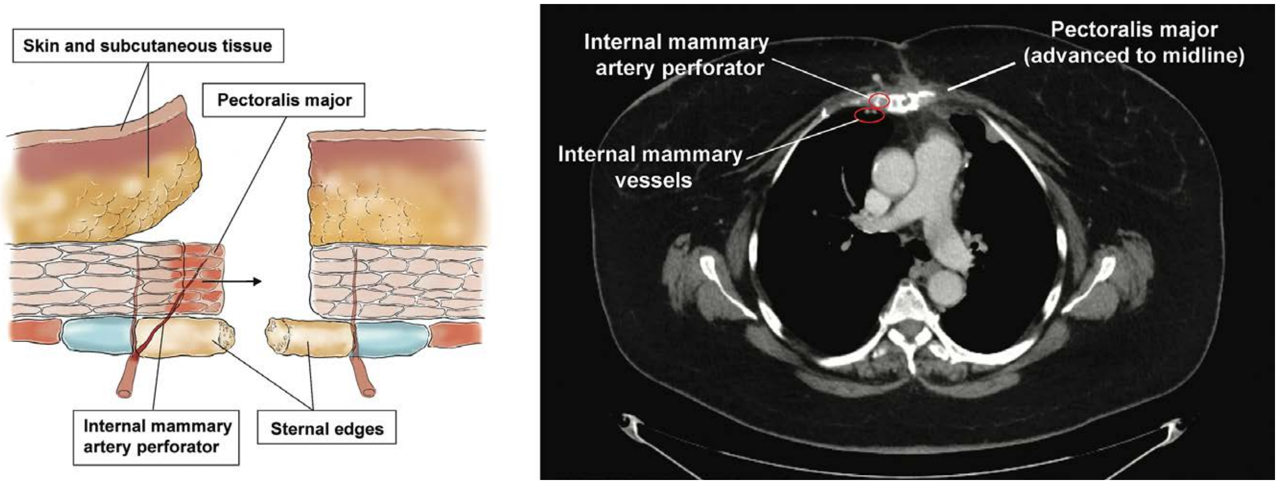

Fig. 3. Perforator-sparing pectoralis major flap for sternal reconstruction. For small sternal defects, the senior author (*left*) dissects away the tissue surrounding the internal mammary artery perforators, allowing the pectoralis major muscle to advance toward the midline while preserving the dual blood supply of the muscle. (*Right*) The axial computed tomographic scan shows preservation of bilateral internal mammary artery flow in a patient undergoing sternal reconstruction with this method.

surgeons or for obese patients. Key landmarks in this operation include the cephalic vein, which can be easily identified and dissected away from the muscle; the medial and lateral pectoral nerves, which are divided; and, finally, the thoracoacromial trunk, which is divided to mobilize the flap. The flap is then easily dissected in the largely avascular plane beneath the pectoralis major muscle until the perforators are identified, which allows the lateral aspect of the muscle to easily reach the xiphoid process.

Pectoralis major advancement flaps, based on the thoracoacromial trunk, require division of the internal mammary artery perforators (Fig. 2). We typically prefer to do this on the left side, where the internal mammary artery has often been used for cardiac surgical bypass and allows for rapid dissection because of the diminished blood supply. The muscle may be divided lateral to the thoracoacromial trunk if additional length is required. In contrast to turnover flaps, the medial and lateral pectoral nerves may be preserved, allowing for some long-term function. Although these advancement flaps lack the bulk of turnover flaps, they can be an excellent option for filling in defects localized to the upper sternum and manubrium.

The omental flap, which can be used alone or in conjunction with other muscle or myocutaneous flaps, provides reliable and well-vascularized tissue coverage to protect the heart, bypass vessels, and other critical structures from the dehisced sternum (Fig. 4).[56] The disadvantages of this option include risks of intraabdominal visceral damage, hernias, and intraperitoneal adhesions as a consequence of the harvesting technique used. We prefer to harvest the omentum through the existing sternotomy incision, which allows us to open the central diaphragm and dissect the omental tissue off the transverse colon under direct visualization. The dissection is continued until the perforators from the greater curvature of the stomach are identified, after which the omentum may be divided with ligatures or an energy device on the left side. Although this generally provides enough omental tissue to fill the mediastinum, additional length can be acquired by dividing the perforators from the greater curvature of the stomach, taking great care to preserve the gastroepiploic arcade. Meticulous closure of the diaphragmatic and anterior fascial defects is, in our experience, the most important step in avoiding a postoperative hernia (while protecting vascular flow to the omentum); however, this remains a risk of this procedure. Although computed tomographic imaging of the chest can help the surgeon estimate the size of the omentum, an accurate prediction is often challenging and may be further hampered by such complications as omental adhesions to the viscera or abdominal wall if there is a history of prior abdominal surgery. Some thin adhesions can easily be divided, but some cases may require the surgeon to open a preexisting scar to remove extensive adhesions under direct visualization.

The rectus abdominis muscle, latissimus dorsi muscle, and free tissue transfers are rarely used but offer viable alternatives when the above are not feasible. The rectus abdominis, in particular,

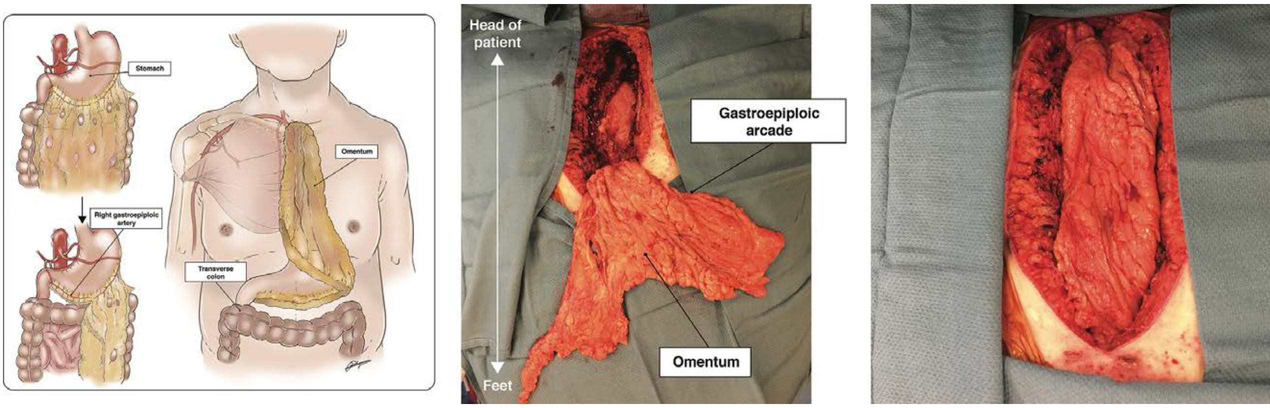

Fig. 4. Omental flap for sternal reconstruction. (*Left*) Harvesting the omental flap involves dissection of the omentum off the transverse colon and identification of the perforators from the greater curvature of the stomach, with careful preservation of the gastroepiploic arcade. Intraoperative images are of a patient who presented with an open sternal wound following emergent chest exploration indicated by cardiac tamponade and cardiac arrest in the setting of a recent open aortic valve replacement. The omental tissue is shown (*center*) following dissection off of the transverse colon and (*right*) after inset into the large sternal defect, with adequate coverage of all critical structures.

may be useful when the sternal defect is located at the caudal edge of the sternum.[57] There is little published evidence surrounding the relative safety and efficacy of the various flap types in the context of sternal wound management, and further investigation is required to definitively compare the long-term outcomes of these various surgical approaches.

SINGLE VERSUS STAGED STERNAL RECONSTRUCTION

The optimal timing of sternal reconstruction remains a point of controversy in sternal wound infection management. Immediate primary closure or closed drainage following initial débridement is hampered by unacceptably high failure rates up to 88.2 percent, but the efficacy and safety of immediate flap reconstruction remains less clear.[58] Two studies have advocated for a combinatorial one-stage method of débridement and immediate bilateral pectoral major advancement flaps, but this is challenged by their relatively high perioperative mortality rate of 9 and 7.9 percent, and similarly high morbidity rates (because of issues such as seromas, wound dehiscence, and flap edge necrosis) of 39 percent and 16.7 percent, respectively.[59,60] Furthermore, a retrospective study by Lindsey of 48 sternal wound closures demonstrated a significantly higher incidence of wound complications among those undergoing sternal closure 4 days or less from initial débridement.[61] In lieu of formal guidelines, some have argued for single-stage immediate reconstruction in cases without purulent infection, and two-stage reconstruction for those with more severe mediastinal infection or any surgeon uncertainty regarding suitability for primary closure.[62] Overall, it remains challenging to achieve timely sternal closure and healing while ensuring avoidance of potentially deadly complications of premature primary closure over uncontrolled sepsis or other extensive infection. Resource availability must also be considered, as initial drainage and débridement procedures may be performed urgently in settings where a full cardiac team is unavailable. In this case, temporization using a negative-pressure wound therapy device and a semielective closure may be optimal.

NEGATIVE-PRESSURE WOUND THERAPY: AN ADJUNCT MODALITY

Negative-pressure wound therapy has emerged as an adjunct tool for sternal wound infection management, used either as a bridge to sternal reconstruction or for definitive closure (Fig. 5).[63,64] As it has evolved from use as a simple draining tool to a wound healing modality, negative-pressure wound therapy has been applied in a number of acute wound types, including sternal wounds, limb trauma, burns, and open abdominal wounds.[65,66] Although the exact mechanisms of negative-pressure wound therapy in wound healing remain elusive, it has been shown to enhance perfusion, granulation tissue formation, bacterial clearance, and edema resolution.[65] Animal sternotomy models have demonstrated enhanced sternal perfusion with negative-pressure wound therapy, and several retrospective studies have demonstrated

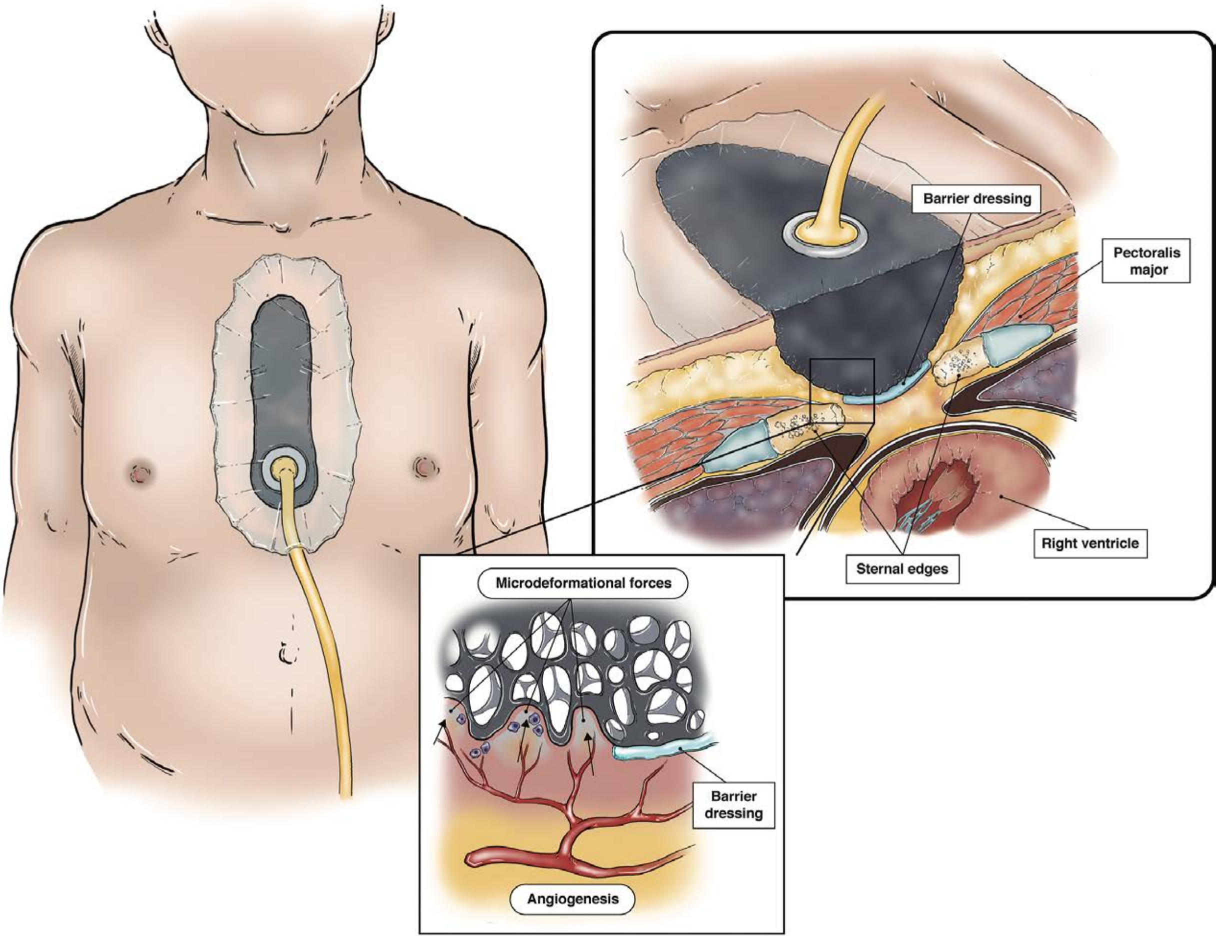

Fig. 5. Negative-pressure wound therapy in the treatment of sternal wound infection. Negative-pressure wound therapy can be used as a bridge to definitive closure in sternal wound infection management. Importantly, a barrier dressing is used to protect the cardiac tissue, vascular grafts, and other critical structures from direct contact with the negative-pressure wound therapy device. Microdeformational forces are thought to induce angiogenesis, enhance granulation tissue formation, and encourage bacterial clearance, thus accelerating wound healing.

significantly shorter time to bacteriologic cure; lowered sternal reinfection rates; and a reduced need for flap reconstruction, reduced need for in-hospital stay, and reduced number of dressing changes.[67–71] In our experience, we have also observed that negative-pressure wound therapy stabilizes the wound to enable safe weaning off of mechanical ventilation in patients requiring more intensive critical care. In the absence of randomized trials comparing negative-pressure wound therapy to other treatment modalities following sternal débridement, further studies are needed to elucidate long-term mortality benefits of this therapy. Furthermore, although recent work has investigated the utility of incisional negative-pressure wound therapy following sternotomy as a method of preventing sternal wound infection, these studies have been limited in number and have thus far failed to show significant reductions in the incidence of sternal complications.[72,73] Previously reported complications with negative-pressure wound therapy treatment include right ventricular rupture and subsequent major bleeding complications, in addition to atrial fibrillation followed by respiratory arrest.[74–77] A barrier dressing between the gauze or foam and the cardiac tissue is necessary to minimize direct negative pressure on the heart and to prevent adherence of the suction surface to the epicardium, cardiovascular bypass grafts, and other critical structures.

CONCLUSIONS

The cause of and risk factors for sternal wound infection are complex, multifactorial, and evolving amidst broader shifts in the landscape of cardiac surgery and patient populations. Although flap reconstruction remains a critical aspect of

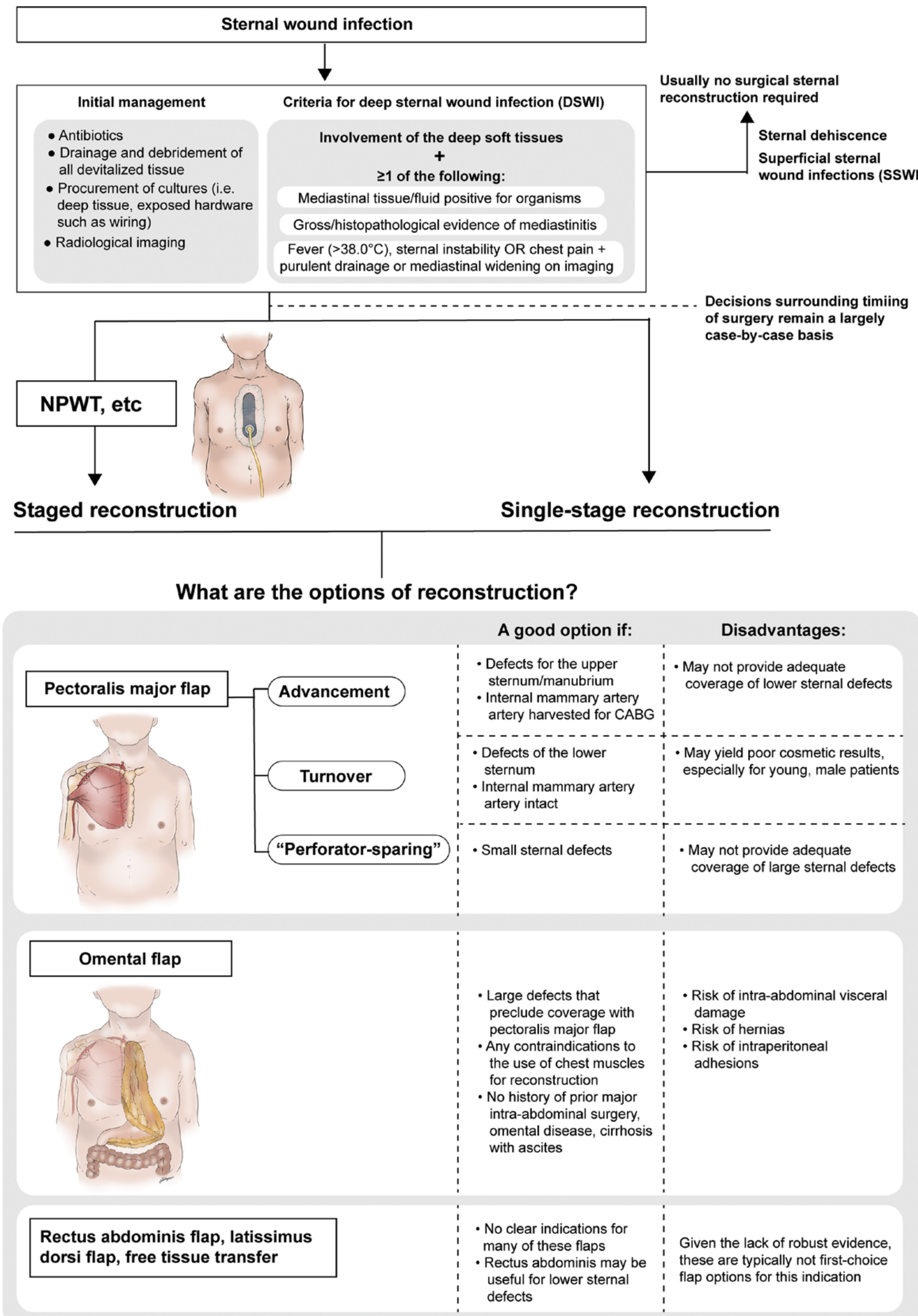

Fig. 6. Approach and currently available methods of sternal wound reconstruction. Management of sternal wound infection begins with the initial steps of empiric antibiotics, drainage and débridement, procurement of tissue samples to facilitate microbiological diagnosis, and radiologic imaging. Cases diagnosed to be deep sternal wound infections (*DSWI*) may be managed as a single-stage or staged reconstruction, with several options for flap-based reconstruction, each with unique advantages and disadvantages. *NPWT*, negative-pressure wound therapy; *CABG*, coronary artery bypass grafting.

surgical management, the synergistic use of negative-pressure wound therapy, perioperative topical administration of antibiotics, and other adjunct methods has shown some promise in treatment and prevention. Options and timing for flap-based reconstruction must be customized to each unique case (Fig. 6). As one of the most devastating complications following open heart surgery, deep sternal wound infection demands collaborative, multidisciplinary care spanning cardiac surgery, plastic and reconstructive surgery, infectious disease, and multiple other supporting team members. [**See Video 1 (online)**, which displays the perspectives from the field of plastic surgery on the management of sternal wound infection. In an interview with the lead author, Dr. Dennis P. Orgill (Plastic Surgery, Brigham and Women's Hospital) describes some of the major evolutions in the plastic surgical management of sternal wound infection over the course of his career. **See Video 2 (online)**, which displays the perspectives from the field of cardiac surgery on the management of sternal wound infection. In an interview with the lead author, Dr. Prem S. Shekar (Cardiac Surgery, Brigham and Women's Hospital) discusses strategies used by his team and institution to reduce the risk of sternal wound infection. **See Video 3 (online)**, which displays the perspectives from the field of infectious disease on the management of sternal wound infection. In an interview with the lead author, Dr. Jennifer A. Johnson (Infectious Disease, Brigham and Women's Hospital) offers avenues for effective collaboration between plastic surgeons and infectious disease specialists in achieving timely diagnosis and management of sternal wound infection.]

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CODING PERSPECTIVE

Coding perspective provided by Dr. Raymond Janevicius is intended to provide coding guidance.

15002	Surgical preparation or creation of recipient site by excision of open wounds, burn eschar, or scar (including subcutaneous tissues), or incisional release of scar contracture, trunk, arms, legs; first 100 cm²
15003	Surgical preparation or creation of recipient site by excision of open wounds, burn eschar, or scar (including subcutaneous tissues), or incisional release of scar contracture, trunk, arms, legs; each additional 100 cm², or part thereof
15734	Muscle, myocutaneous, or fasciocutaneous flap; trunk
20670	Removal of implant; superficial (e.g., buried wire, pin, or rod) (separate procedure)
20680	Removal of implant; deep (e.g., buried wire, pin, screw, metal band, nail,rod, or plate)
21600	Excision of rib, partial
21620	Ostectomy of sternum, partial
21627	Sternal débridement
21630	Radical resection of sternum
21750	Closure of median sternotomy separation with or without débridement (separate procedure)
49904	Omental flap, extra-abdominal (e.g., for reconstruction of sternal and chest wall defects)

- Initial wound débridements are reported with a number of codes.
- If only soft tissue is excised, codes 15002 and 15003 are used, based on surface area excised.
- Sternal débridements/resections are reported by the extent of sternal excision. Use codes 21620, 21627, or 21630.
- Partial rib resections are sometimes necessary and these are described with code 21600.
- Removal of sternal hardware is reported with code 20680. If a sternal débridement or radical resection is performed, the wires and/or plates must be removed, so code 20680 is not separately reported.
- Pectoralis major muscle flaps are described with code 15734, which is reported for muscle flaps or myocutaneous flaps.
- An omental flap is reported with code 49904.

CODING PRINCIPLES (modifiers): If bilateral pectoralis major muscle flaps are performed, this is not considered "bilateral" by CPT rules, so modifier 50 is not appended. Use the "separate procedure" modifier, 59, to indicated that two muscle flaps are performed, as follows:

15734 Right pectoralis major muscle flap
15734-59 Left pectoralis major muscle flap

If the general surgeon harvests the omental flap, and the plastic surgeon transfers and insets the flap, this is a "co-surgeon" procedure, since one CPT code is shared by two surgeons. Each surgeon reports code 49904 with modifier 62.

49904-62 Omental flap, extra-abdominal (general surgeon)
49904-62 Omental flap, extra-abdominal (plastic surgeon)

Disclosure: Raymond Janevicius, M.D. (janeviciusray@comcast.net), is the president of JCC, a firm specializing in coding consulting services for surgeons, government agencies, the insurance industry, attorneys, and other entities.

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