International Journal of Multiphysics
Volume 18, No. 3, 2024
ISSN: 1750-9548

Sternal Wound Reconstruction Following Deep Sternal Wound Infection

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Abstract:

Deep sternal wound infection (DSWI) is one of the most serious complications following median sternotomy in cardiac surgery, associated with significant morbidity, prolonged hospitalization, increased healthcare costs, and elevated mortality rates. Despite advances in perioperative care and infection control measures, DSWI remains a challenging clinical problem. Early diagnosis, aggressive debridement, and appropriate reconstruction strategies are essential for successful management. Various reconstructive options have been described, including muscle and omental flaps, vacuum-assisted closure (VAC) therapy, and rigid sternal fixation techniques. However, the optimal reconstructive approach remains controversial and depends on patient factors, wound characteristics, and institutional experience.

Keywords: Deep sternal wound infection, mediastinitis, sternal reconstruction, muscle flap, omental flap, vacuum-assisted closure, cardiac surgery complications.

Introduction:

Deep sternal wound infections (DSWIs) are serious complications following sternotomy in cardiothoracic surgery, requiring proper reconstruction using local or locoregional flaps like pectoralis major muscle, rectus abdominis muscle, latissimus dorsi muscle, or the omentum. DSWI, characterised by deep infection within the sternum, is a significant concern in cardiac surgery, associated with prolonged hospitalisation, increased costs, and higher morbidity and mortality rates **(1).**

There are different types and classifications of sternal wound infections (SWIs) based on the extent and severity of infection. Superficial SWI involves infection limited to the superficial layers, skin, subcutaneous, and fascia, while deep SWI affects deeper tissues and structures **(2).**

Complicated SWI refers to infections with additional complications like mediastinitis or osteomyelitis. The severity of the disease can range from mild local infection to severe systemic infection with a high risk of complications. The prevalence and incidence of DSWI vary based on patient factors (age and gender), surgical techniques, and preventive measures. The rates range from 1% to 5% among cardiac surgery patients, with higher incidences in those with additional risk factors (obesity, diabetes, smoking, advanced age, and immunosuppression) and prolonged surgical duration **(1).**

Identifying risk factors is crucial for prevention. Patient-related factors and surgical factors (bilateral internal mammary artery grafts, reoperations, and prolonged cardiopulmonary bypass time) increase the risk. Inadequate infection control measures (surgical site preparation, antimicrobial prophylaxis, and wound closure techniques) contribute to SWI development. Diagnosis involves clinical assessment and imaging. Clinical signs (sternal pain, erythema, swelling, purulent discharge, fever, and elevated inflammatory markers) raise suspicion, while imaging (CT scans and MRI) confirms deep-seated infections and assesses involvement **(3).**

Blood cultures and wound cultures can help identify the causative microorganisms. Prompt management is essential, including surgical debridement, drainage of infected fluid collections, sternum reconstruction, and

tailored antibiotic therapy guided by culture results. The choice of antibiotics should cover common pathogens associated with SWI, such as Staphylococcus aureus, including methicillin-resistant strains **(4).**

Therefore, understanding the prevalence, risk factors, classifications, and diagnostic approaches is crucial for preventive measures, early detection, and appropriate management, improving patient outcomes in cardiac surgery **(1).**

The literature outlines the development of DSWI reconstruction methods and potential future improvements to enhance treatment outcomes **(2).**

Past Treatment Options:

Over the past few decades, various treatment methods have been developed for DSWI to improve treatment options and outcomes. These include both simple surgical techniques and more complex plastic surgery procedures. However, there is a lack of agreement on the best approach due to conflicting and inconsistent evidence regarding the superiority of specific procedures **(1).**

In 1963, continuous irrigation and drainage in a closed sternum was developed. This was revolutionary, as it prevented prolonged immobilisation, intubation, and eradicated thoracic instability associated with healing. It also aided in removing and washing out large quantities of clots, fibrin, and other debris. Due to its efficiency and favourable outcomes for patients, it was regarded as the standard therapy for mediastinitis globally until the 1980s **(5).**

The Closed Drainage and Closed Irrigation (CD-CI) technique was described on 38 patient results. Firstly, all necrotic sternal bone and excess cancellous material were removed, following with repeated irrigation of the wound with copious amounts of antiseptic solution. Once the wound had been cleared of fibrinopurulent material, surgeons judged whether local damage would prevent skin closure, and if it did not, then a closed technique was applied **(6).**

The sternal edges were then brought together over one or two infusion catheters and two or three large and multi-fenestrated drainage tubes. The sternum was then rewired shut, and the subcutaneous wound and skin were closed without a drain. Furthermore, postoperatively, the mediastinum was continuously irrigated with 0.5% povidone-iodine solution while simultaneously gently suctioning the wound. Due to reported failure rates of up to 50%, what was once the main technique quickly diminished, since its reliability was in doubt **(1).**

In the late 1980, Lecompte et al. proposed simple closed drainage using Redon catheters (CDRC). Redon catheter drainage, praised for its simplicity and reduced maintenance requirements when compared to closed drainage and irrigation, quickly gained support. Closed drainage using Redon catheters was achieved by placing multiple small catheters into a negatively pressurised bottle at the time of internal debridement **(7).**

In 1989, Durandy et al. described Redon catheter use in 10 patients, with extremely successful closure rates. Durandy et al. described CD-RC as a less aggressive treatment modality compared to what was used before **(7).**

While this technique was less aggressive, subsequent studies, such as those by Kirsch et al., emphasised the importance of aggressive debridement in cases with Methicillin-resistant Staphylococcus aureus (MRSA) or recurrent infections to improve patient outcomes. Furthermore, **Kirsch et al.** described Redon catheter primary closed drainage as the optimal therapy for many patients with poststernotomy mediastinitis. However, he cautioned that it would be more advantageous for patients with Methicillin-resistant Staphylococcus aureus (MRSA) or recurrent infection to proceed with a more aggressive initial debridement and procedure **(8).**

Prophylaxis and Infection Management:

Prophylactic Antibiotics and Effective Infection Control Strategies Are Essential in Reducing Postoperative DSWI Rates. Initially, empiric antibiotic therapy provides broad coverage against various types of bacteria.

Culture-directed antibiotic therapy should be started once microbiological analysis is available, while additional cultures from blood, urine, and sputum may be obtained. Systemic antibiotics are typically administered

for a duration of 6 weeks, with guidance from infectious disease specialists. Antifungal medications may be considered where there is no clinical improvement with antibiotics **(9).**

Intranasal mupirocin and systemic antibiotics have been proven to lower infection risks associated with Staphylococcus aureus, including methicillin-resistant strains. Preoperative skin preparation and rigorous postoperative wound care protocols further enhance protection against infection **(10).**

Current Paradigms in Management:

The current management approaches for deep sternal wound infections (DSWIs) involve both medical and surgical treatments.

Medical and Surgical Treatment:

The management of DSWI relies on two key principles: firstly, the eradication of topical infection and, secondly, the stable osteosynthesis of the sternum. The eradication of topical infection can be achieved with debridement, continuous irrigation, and VAC **(6).**

A wide variety of surgical treatments, on the other hand, are available for sternal wound closure but will mainly focus on closed suction and irrigation, the role of VAC (vacuum-assisted closure), and flap coverage **(5).**

Closed suction and irrigation significantly advanced surgical practice. This technique was improved with closed drainage, where multiple small Redon catheters are placed into a negatively pressurised bottle during sternal debridement, demonstrating reduced 30-day mortality and failure rates compared to other surgical methods **(10).**

VAC is another effective method for tissue repair following DSWI by increasing the parasternal blood flow and facilitating wound edge approximation to offer optimal chest stabilisation. VAC has been promising, particularly for critically ill patients who cannot tolerate extensive reconstructive surgery **(6).**

Although these methods are effective, they often fail to cure the patient. DSWI is a grave complication, imposing significant morbidity and mortality risks. The incidence rates of DSWI are influenced by surgical variables and patient characteristics. Therefore, identifying risk factors and utilising clinical evaluation, along with diagnostic imaging, are essential preventive measures **(11).**

In patients who develop deep sternal wound infection (DSWI) and are considered suitable surgical candidates, definitive sternal reconstruction should be performed following infection eradication, using rigid fixation and flap coverage **(12).**

Sternal Fixation:

Sternal fixation can be achieved with the use of episternal devices such as rigid plate fixation or wire cerclage. Wire cerclage involves the use of stainless steel or titanium wires, which are threaded through predrilled holes in the sternum and twisted to provide stabilization. Rigid plate fixation is also another episternal device, which involves titanium or stainless steel plates secured to the sternum superiorly using screws, enabling rigid fixation of the sternum **(13).**

In managing DSWI, surgical techniques like cerclage wiring and episternal fixation with titanium plates remain critical in maintaining sternal stability. Cerclage wiring is widely used due to its simplicity, cost-effectiveness, and efficacy in most DSWI cases without severe internal instability. For high-risk patients or those with prior sternotomies, episternal fixation using rigid titanium plates offers reduced sternal complications **(11).**

Flap Reconstruction:

Flap reconstruction, considered as the standard therapy for DSWIs, offers early wound closure and reduces mortality. Research has demonstrated a review of 211 sternal infections that are treated with pedicled muscle flaps with a successful wound closure rate of 95% alongside a mortality rate of 5.7%. The omental flap is another useful reconstructive option due to its ability to conform to the deepest recesses of the sternal wound and carries immunologic properties, with data showing superiority over the pectoralis flap in preventing sepsis-related morbidities. In contrast, the rectus abdominis flap is supported due to its convenient dissection process and its

ability to rotate widely. This approach enables the flap to reach both the sternal notch and the lower third of the sternal wound, an area that is commonly associated with postoperative complications **(12).**

The current major methods for DSWI reconstruction depend on whether they are adequate for pectoralis muscle and soft tissues. Both methods discussed will only be plausible under the assumption of adequate debridement and cultures. Pectoralis flaps will be the method of choice when there is sufficient muscle and soft tissues present; otherwise, the omental or rectus flap will be the method of choice **(11).**

Pectoralis major myocutaneous flaps are elevated in the avascular plane just beneath the pectoralis major muscle from the central to the lateral direction. The dissection of the flap is ceased as soon as the flaps can be advanced to the centre with minimal tension, which usually involves dissecting to the area between the midclavicular and anterior axillary lines, whereas the dissection stops just inferior to the clavicle superiorly and deep to the anterior rectus sheath to the level of the xiphoid process inferiorly **(9).**

Closed suction drains will be placed beside each flap, with a third one placed centrally over the mediastinum. Flaps will be sutured together with interrupted no. 2 Vicryl or polysorb sutures, with the pectoralis fascia and the rectus sheath in the same closure layer. The only recognised downside to the pectoralis flap is the limited coverage over the xiphoid and inferior portion of the wound due to the limited extension of the pectoralis major muscle. This, however, can be overcome by bringing the anterior rectus sheath in continuity with the pectoralis major flap **(10).**

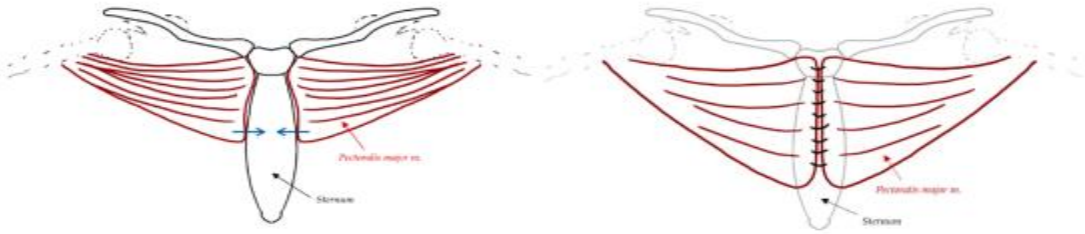

Figure (1): Pectoralis major myocutaneous advancement flaps. Flaps are elevated posterior to the muscle, where it is relatively avascular. Dissection occurs medially to laterally and ends when the muscle reaches the midline with minimal tension. Both flaps are sutured together in the midline with the pectoralis fascia and rectus sheath. (Doty JR. Surgical Atlas of Cardiac Reconstruction. Elsevier Health Sciences; 2014. Figure adapted from Netter-style illustration)

In cases where the pectoralis major muscles are compromised and a patent ipsilateral IMA (internal mammary artery), rectus abdominis muscle can be harvested in the reconstruction of sternal wound defects.

As a pedicled muscle flap based on the SEA (superior epigastric artery), it can be divided at the inferior most portion and rotated superiorly. Fig (2)

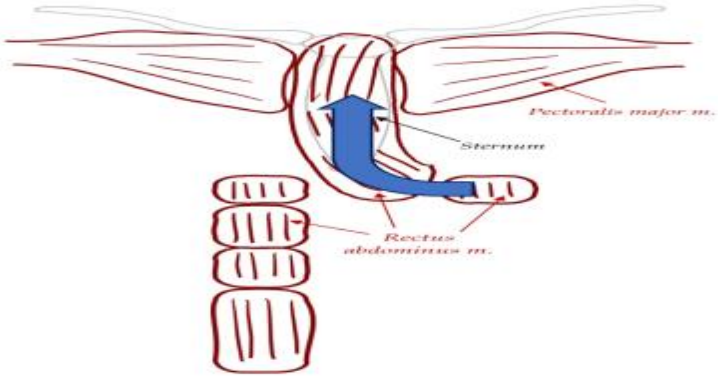

Figure (2): Rectus abdominis flap. This pedicled flap is derived from the rectus abdominis muscle, with its blood supply originating from the superior epigastric artery. The muscle is divided at its inferior aspect and rotated superiorly to cover the sternal defect.

On the other hand, the omental flap remains a strong secondary option for patients with extensive loss of chest wall soft tissue and inadequate skin for closure, especially for lower third infections. Fig. (3) below shows the process of omental flap formation. It remains the second-line intervention due to its difficult harvesting nature (via laparotomy), less tissue bulk provided, and no extra support to chest wall stability. Other considerations for the omentum flap is the necessary creation of an abdominal fascia or diaphragm opening in order for the omentum flap to reach the sternum, with the possible need for skin grafting **(12).**

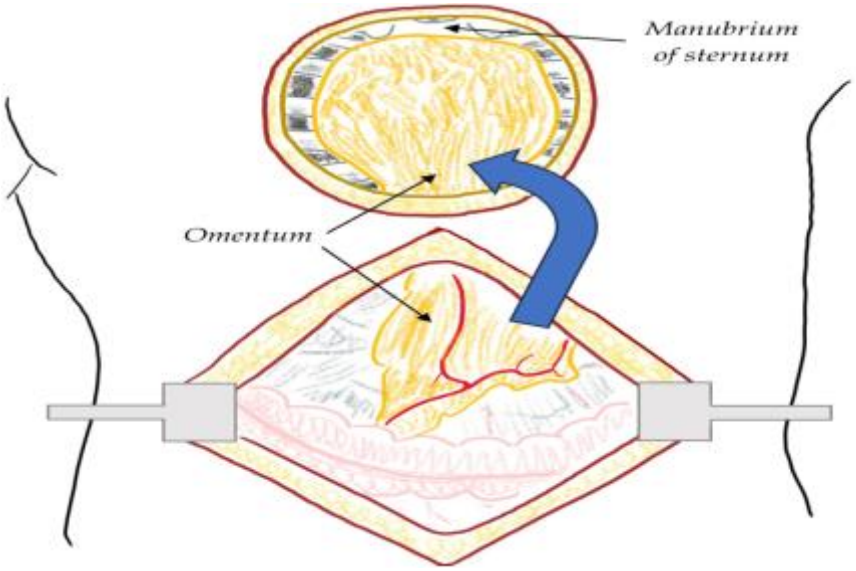

Figure (3): Omental flap. The omentum is harvested from the abdomen, carefully preserving its attachment to the gastroepiploic arteries. It is then transposed to the chest through an opening in the diaphragm or abdominal fascia, allowing it to reach the sternum, where it is utilised to cover and fill the sternal defect.

Advantages and Disadvantages of Sternal Wound Reconstruction:

One of the main advantages of plastic surgery reconstruction for DSWI is improved wound healing. Plastic surgeons utilise muscle flaps, which bring well-vascularised tissue to the wound site, enhancing blood supply and reducing the risk of infection. This approach promotes faster healing, decreases wound complications, and improves overall outcomes. Furthermore, plastic surgeons prioritise aesthetic outcomes and employ meticulous techniques to minimise scarring, resulting in a more cosmetically appealing result. They also focus on recreating a natural sternal appearance using tissue flaps, enhancing patient satisfaction with their postoperative appearance **(1).**

Additionally, plastic surgeons aim to restore full functional integrity by employing techniques that provide stability and protection to the underlying structures, reducing the risk of complications and improving the patient's functional outcome **(9).**

However, there are disadvantages to sternal wound reconstruction from a plastic surgery perspective. Performing these surgeries requires complexity and expertise. Plastic surgeons must have a thorough understanding of the underlying anatomy, wound healing principles, and reconstructive techniques specific to sternal wounds. This specialised knowledge may limit the availability of experienced plastic surgeons who can perform these procedures. Moreover, sternal wound reconstruction surgeries can be prolonged and time-consuming. They involve meticulous dissection, tissue transfer, and suturing, resulting in extended operation times compared to simple wound closure surgeries. Prolonged surgery increases the risk of intraoperative complications and may require more extensive anaesthesia, which carries associated risks **(10).**

The most common risks and complications of complex and prolonged sternal wound reconstruction surgeries include flap necrosis, infection, hematoma, seroma formation, and wound dehiscence. These complications can extend the wound healing time, necessitate additional surgical interventions, and potentially impact the patient's recovery and overall outcome. Due to the specialised care and knowledge required, there may

be a limited availability of plastic surgeons specialising in sternal wound reconstruction, which can result in delays in treatment and limit the options available to patients requiring this procedure **(9).**

Overall, it is important to consider advantages and disadvantages according to each patient's individual factors, such as the extent of the wounds, age, gender, mortalities, etc. Consulting a specialist plastic surgeon is essential to assess the feasibility, risks, and potential benefits of the procedure in each case **(14).**

Table (1): Advantages and disadvantages of sternal wound reconstruction from a plastic surgery perspective **(14)**

Advantages	Disadvantages
Improved wound healing	Complexity and expertise required
Promotes better wound healing	Limited availability of experienced plastic surgeons
Reduced risk of infection	Prolonged and time-consuming surgery
Faster healing and decreased complications	Increased risk of intraoperative complications
Improved aesthetic outcomes	Risk of flap necrosis, infection, hematoma, seroma formation, and wound dehiscence
Enhanced patient satisfaction with appearance	Limited availability of specialised plastic surgeons
Restoration of functional integrity	Delays in treatment due to limited options

Comparison on Types of Flaps/Reconstruction Techniques:

DSWI requires reconstructing sternal wounds using various techniques. Factors such as infection severity, patient comorbidities, and surgeon expertise influence the choice of technique. Treatment involves drainage, debridement, and antibiotics, followed by sternum and tissue reconstruction for organ protection and chest wall stability. The literature offers insights on different flap options and comparative analyses for sternal reconstruction, aiding in selecting appropriate techniques **(4).**

The combination of negative pressure therapy and pectoralis major muscle flap coverage has proven to be an effective treatment for deep sternal wound infections after cardiothoracic surgery **(12).**

Utilising omental flaps and bipectoral musculofascial advancement flaps has been deemed an effective strategy for reconstructing infected sternal wounds in the inferior areas, providing a comprehensive surgical solution. Various flap types can be utilised for sternal reconstruction. Pectoralis major flaps are effective and less invasive than muscle flaps, but they may result in long-term functional impairment. Rectus abdominis flaps are superior to pectoral flaps in terms of coverage of the inferior sternum and can maintain a viable flap even with ipsilateral internal mammary artery (IMA) ligation **(2).**

Omental grafts are beneficial for filling dead spaces and possess large pedicles, rich vascular networks, and lymphatic networks, although they may be susceptible to secondary cancers. Latissimus dorsi flaps involve the intrathoracic transposition of extrathoracic skeletal muscle and are useful for intrathoracic infections associated with airway, lung parenchyma, oesophageal, cardiac, or great vessel complications **(9).**

Tensor fascia lata flaps are suitable for covering the upper third of the sternum and have well-established vascular anatomy. Free flaps and perforator flaps can be employed for significant defects, but they require longer operating times, carry a risk of flap failure, demand microsurgical expertise, and result in higher costs. The vastus lateralis myocutaneous flap has a high success rate, while the rectus abdominis and latissimus dorsi/parascapular flaps have lower success rates. Internal mammary artery perforator flaps have shown promise in sternal reconstruction, but further research is necessary to confirm their efficacy **(12).**

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