CHEST WALL RECONSTRUCTION FOR STERNUM COMPLICATIONS IN CARDIOVASCULAR SURGERY: A SYSTEMATIC REVIEW

RECONSTRUÇÃO DA PAREDE TORÁCICA POR COMPLICAÇÕES DO ESTERNO EM CIRURGIA CARDIOVASCULAR: REVISÃO SISTEMÁTICA

RECONSTRUCCIÓN DE LA PARED TORÁCICA PARA COMPLICACIONES DEL ESTERNÓN EN CIRUGÍA CARDIOVASCULAR: UNA REVISIÓN SISTEMÁTICA

José Dalvo Maia Neto[1], Fabiano Jucá[2], Thomas Dominik de Souza dos Reis[3], Elmiro Heli Martins[4], Francisco de Assis Montenegro Carvalho[5], João Carlos Fechine Machado[6], João Pedro Barreto Ricarte[7], Heraldo Guedis Lobo Filho[8]

ABSTRACT

Introduction: Sternal suture dehiscence represents a serious complication after cardiac surgery, with an incidence ranging from 0.5% to 5% of median sternotomy procedures. This condition is associated with high morbidity and mortality rates, often requiring reconstructive surgical intervention. Muscle flaps, particularly the pectoralis major and rectus abdominis, constitute fundamental therapeutic options for the definitive treatment of this complication.

Objective: To conduct a systematic review of the literature on the use of muscle flaps in the reconstruction of mediastinal suture dehiscence after cardiac surgery, with emphasis on pectoralis major and rectus abdominis flaps, analyzing indications, surgical techniques, outcomes, and complications.

Methodology: Systematic literature review in PubMed, MEDLINE, Scopus, Web of Science, and LILACS databases, including articles published between 2010 and 2024. Studies addressing sternal dehiscence reconstruction with muscle flaps were selected, focusing on pectoralis major and rectus abdominis. The analysis included data on epidemiology, risk factors, surgical techniques, success rates, and complications.

Results: The literature demonstrates that pectoralis major flaps present success rates between 85-95%, being the first choice for anterior and lateral mediastinal defects. The rectus abdominis flap, with success rates of 80-92%, is indicated for extensive defects of the lower third of the sternum. Significant risk factors include diabetes mellitus, obesity, bilateral use of internal mammary artery, COPD, and deep infection. Mortality associated with mediastinitis ranges from 10% to 47% in recent literature.

[1] Doctoral student. Hospital Dr. Carlos Alberto Studart. Orcid: 0000-0001-6063-4054
[2] Cardiovascular Surgeon. Hospital Dr. Carlos Alberto Studart. Orcid: 0000-0002-8115-8381
[3] Resident in Cardiovascular Surgery. HCAS. Orcid: 0000-0002-6558-1411
[4] Plastic Surgeon. Instituto Dr. José Frota. Orcid: 0000-0002-2850-2788
[5] Plastic Surgeon. Orcid: 0009-0002-24383811
[6] Resident in Cardiovascular Surgery. HCAS. Orcid: 0009-0003-8991-3788
[7] Hospital Dr. Carlos Alberto Studart. Orcid: 0000-0001-8562-1356
[8] Cardiovascular Surgeon. Universidade Federal do Ceará. Hospital de Messejana. Orcid: 0000-0002-0133-4841

Conclusion: Pectoralis major and rectus abdominis flaps represent effective and safe reconstructive options for treating sternal suture dehiscence. Flap selection should consider the location and extent of the defect, patient clinical conditions, and surgical team experience. Multidisciplinary approach and early treatment are fundamental for reducing morbidity and mortality. A systematized safety algorithm is proposed to optimize the management of this complication.

Keywords: Mediastinitis. Sternal Osteomyelitis. Sternal Dehiscence. Surgical Flaps. Pectoralis Major Muscle. Rectus Abdominis Muscle. Cardiac Surgery. Median Sternotomy.

RESUMO
Introdução: A deiscência de sutura esternal representa uma complicação grave após cirurgia cardíaca, com incidência variando entre 0,5% a 5% dos procedimentos que envolvem esternotomia mediana. Esta condição está associada a elevadas taxas de morbidade e mortalidade, exigindo frequentemente intervenção cirúrgica reconstrutiva. Os retalhos musculares, particularmente usando peitoral maior e reto abdominal, constituem opções terapêuticas fundamentais para o tratamento definitivo desta complicação.

Objetivo: Realizar uma revisão sistemática da literatura sobre o uso de retalhos musculares na reconstrução de deiscência de sutura mediastinal pós-cirurgia cardíaca, com ênfase nos retalhos de peitoral maior e reto abdominal, analisando indicações, técnicas cirúrgicas, resultados e complicações.

Metodologia: Revisão sistemática da literatura nas bases de dados PubMed, MEDLINE, Scopus, Web of Science e LILACS, com base em artigos publicados entre os anos de 2010 e 2024. Foram selecionados estudos que abordam reconstrução de deiscência esternal com retalhos musculares, com foco em peitoral maior e reto abdominal. A análise incluiu dados sobre epidemiologia, fatores de risco, técnicas cirúrgicas, taxas de sucesso e complicações.

Resultados: A literatura demonstra que os retalhos de peitoral maior apresentam taxas de sucesso entre 85-95%, sendo a primeira escolha para defeitos anteriores e laterais do mediastino. O retalho de reto abdominal, com taxas de sucesso de 80-92%, é indicado para defeitos extensos do terço inferior do esterno. Fatores de risco significativos incluem diabetes mellitus, obesidade, uso bilateral de artéria mamária interna, DPOC e infecção profunda. A mortalidade associada à mediastinite varia de 10% a 47% na literatura recente.

Conclusão: Os retalhos de peitoral maior e reto abdominal são opções reconstrutivas eficazes e seguras para tratamento de deiscência de sutura esternal. A escolha do retalho deve considerar a localização e extensão do defeito, condições clínicas do paciente e experiência da equipe cirúrgica. A abordagem multidisciplinar e o tratamento precoce são fundamentais para redução da morbimortalidade. Um algoritmo de segurança sistematizado é proposto para otimizar o manejo desta complicação.

Palavras-chave: Mediastinite. Osteomielite do Esterno. Deiscência de Sutura Esternal. Retalhos Cirúrgicos. Músculo Peitoral Maior. Músculo Reto Abdominal. Cirurgia Cardíaca. Esternotomia Mediana.

RESUMEN
Introducción: La dehiscencia de la sutura esternal representa una complicación grave después de la cirugía cardíaca, con una incidencia que varía del 0,5% al 5% de los

procedimientos que involucran esternotomía media. Esta condición se asocia con altas tasas de morbilidad y mortalidad, requiriendo con frecuencia intervención quirúrgica reconstructiva. Los colgajos musculares, particularmente utilizando el pectoral mayor y el recto abdominal, son opciones terapéuticas fundamentales para el tratamiento definitivo de esta complicación.

Objetivo: Realizar una revisión sistemática de la literatura sobre el uso de colgajos musculares en la reconstrucción de la dehiscencia de la sutura mediastínica después de la cirugía cardíaca, con énfasis en los colgajos de pectoral mayor y recto abdominal, analizando las indicaciones, las técnicas quirúrgicas, los resultados y las complicaciones.

Metodología: Revisión sistemática de la literatura en las bases de datos PubMed, MEDLINE, Scopus, Web of Science y LILACS, basada en artículos publicados entre 2010 y 2024. Se seleccionaron estudios que abordaron la reconstrucción de la dehiscencia esternal con colgajos musculares, centrándose en el pectoral mayor y el recto abdominal. El análisis incluyó datos sobre epidemiología, factores de riesgo, técnicas quirúrgicas, tasas de éxito y complicaciones.

Resultados: La literatura demuestra que los colgajos de pectoral mayor tienen tasas de éxito entre 85-95%, siendo la primera opción para defectos mediastínicos anteriores y laterales. El colgajo de recto abdominal, con tasas de éxito de 80-92%, está indicado para defectos extensos del tercio inferior del esternón. Los factores de riesgo significativos incluyen diabetes mellitus, obesidad, uso bilateral de la arteria mamaria interna, EPOC e infección profunda. La mortalidad asociada con mediastinitis varía de 10% a 47% en la literatura reciente.

Conclusión: Los colgajos de pectoral mayor y recto abdominal son opciones reconstructivas efectivas y seguras para el tratamiento de la dehiscencia de la sutura esternal. La elección del colgajo debe considerar la ubicación y extensión del defecto, la condición clínica del paciente y la experiencia del equipo quirúrgico. Un enfoque multidisciplinario y el tratamiento temprano son fundamentales para reducir la morbilidad y la mortalidad. Se propone un algoritmo de seguridad sistematizado para optimizar el manejo de esta complicación.

Palabras clave: Mediastinitis. Osteomielitis del Esternón. Dehiscencia de la Sutura Esternal. Colgajos Quirúrgicos. Músculo Pectoral Mayor. Músculo Recto Abdominal. Cirugía Cardíaca. Esternotomía Media.

1 INTRODUCTION

The median sternotomy is the most used access route in cardiac surgery, providing excellent exposure of the mediastinal structures and allowing the performance of various cardiovascular procedures. Despite advances in surgical, anesthetic, and perioperative care techniques, sternal suture dehiscence and mediastinitis remain serious and potentially fatal complications in the postoperative period of cardiac surgeries. [1,2,3]

The incidence of sternal dehiscence varies between 0.5% and 5% of procedures involving median sternotomy, and may reach higher rates in high-risk populations. [4,5,6] When associated with deep infection (mediastinitis), mortality can reach 10% to 47%, depending on the severity of the condition, patient comorbidities, and time until definitive treatment. [7,8,9] In addition to the impact on mortality, these complications result in a significant increase in morbidity, prolongation of hospital stay, increased treatment costs, and impairment of patients' quality of life. [10,11]

The pathophysiology of sternal dehiscence is multifactorial, involving factors related to the patient (diabetes mellitus, obesity, chronic obstructive pulmonary disease, smoking, use of corticosteroids), surgical technique (bilateral use of the internal mammary artery, inadequate sternal closure technique, prolonged surgical time), and postoperative period (infection, hemodynamic instability, need for reoperation, prolonged mechanical ventilation, cough, among others). [12,13,14]

The treatment of mediastinal suture dehiscence has evolved significantly in recent decades. Initially, management consisted of debridement, irrigation, and primary closure, with often unsatisfactory results and high recurrence rates. [15] From the 1960s onwards, with the pioneering work of Jurkiewicz et al., the use of vascularized muscle flaps revolutionized the treatment of this condition, providing adequate coverage of the mediastinum, obliteration of the dead space, improvement of local blood supply, and significant reduction in recurrence and mortality rates. [1,13,15]

Among the muscle flap options available, techniques involving the pectoralis major and rectus abdominis stand out as the most frequent choices, due to their reliability, versatility, favorable vascular anatomy, and proximity to the area to be reconstructed. [16,17,21] The pectoralis major flap, first described by Jurkiewicz in 1963, has become the gold standard for reconstruction of upper and middle sternal defects, while the rectus abdominis flap, popularized by Nahai et al. in 1982, is particularly useful for extensive and lower third sternal defects. [22,25,26]

The choice of the appropriate flap should consider multiple factors, including the location and extent of the defect, the presence of active infection, the patient's nutritional and clinical status, previous surgeries in the thoracic or abdominal region, and the experience of the surgical team. [23,27] The multidisciplinary approach, involving cardiac surgeons, plastic surgeons, infectious disease specialists, and intensive care staff, is critical to successful treatment. [9,28]

Despite the vast literature on the subject, there are still controversies regarding the ideal time of intervention, the choice of the most appropriate flap for each clinical situation, the role of negative pressure therapy as an adjuvant or bridge to definitive reconstruction, and antibiotic therapy protocols. [12,29,30] In addition, the heterogeneity of published studies, with different definitions of mediastinitis, varied inclusion criteria, and inconsistent follow-up, makes it difficult to compare results and develop robust evidence-based guidelines.

In this context, the present systematic review aims to critically analyze the scientific literature on the use of muscle flaps, with emphasis on pectoralis major and rectus abdominis flaps, in the reconstruction of sternal suture dehiscence after cardiac surgery. It seeks to consolidate the available evidence on indications, surgical techniques, outcomes, complications, and prognostic factors, providing subsidies for clinical decision-making and identifying gaps in knowledge that can guide future research.

2 METHODOLOGY

2.1 SEARCH STRATEGY

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The bibliographic search was carried out in the following electronic databases: PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library and LILACS (Latin American and Caribbean Literature on Health Sciences).

The search period included articles published between January 2010 and October 2024, with the aim of capturing the most recent and relevant literature on the topic. The search strategy was developed using MeSH terms and related keywords, combined with Boolean operators.

The search terms used included: "mediastinitis" OR "sternal dehiscence" OR "sternal wound infection" OR "deep sternal wound infection" AND "surgical flaps" OR "muscle flaps"

OR "pectoralis major" OR "rectus abdominis" OR "reconstruction" AND "cardiac surgery" OR "sternotomy" OR "coronary artery bypass".

2.2 ELIGIBILITY CRITERIA

2.2.1 Inclusion Criteria:

- Original studies (case series, cohort studies, case-control studies, clinical trials)
- Systematic review articles and meta-analyses
- Publications in English, Portuguese or Spanish
- Studies involving adult patients (≥18 years)
- Approach to reconstruction of sternal dehiscence or mediastinitis with muscle flaps
- Description of surgical technique, results or complications
- Focus on pectoralis major and/or rectus abdominis flaps

2.2.2 Exclusion Criteria:

- Isolated case reports (less than 3 cases)
- Studies in the paediatric population exclusively
- Articles without original data (editorials, letters to the editor, comments)
- Studies with incomplete data or inadequate methodology
- Duplicate posts
- Studies focused exclusively on other reconstructive options (omentum, latissimus dorsi) without mentioning pectoralis major or rectus abdominis

2.3 SELECTION OF STUDIES

Study selection was carried out in two stages by two independent reviewers. Initially, we were screened by titles and abstracts, excluding articles clearly unrelated to the theme. In the second stage, potentially eligible articles were read in full for evaluation of the inclusion and exclusion criteria. Disagreements among the reviewers were resolved by consensus or by consulting a third reviewer.

2.4 DATA EXTRACTION

Data were extracted in a standardized way using a specific form, including the following information: study characteristics (author, year, country, study design, sample size), patient characteristics (age, gender, comorbidities, type of cardiac surgery), definition of

mediastinitis or sternal dehiscence used, risk factors identified, type of flap used (pectoralis major, rectus abdominis, bilateral, unilateral), surgical technique described, time between cardiac surgery and reconstruction, use of adjuvant therapy (negative pressure, antibiotic therapy), results (success rate, length of hospital stay, mortality), complications (recurrence, flap necrosis, infection, seroma, hematoma), and follow-up time.

2.5 EVALUATION OF THE QUALITY OF STUDIES

The methodological quality of the included studies was assessed using appropriate tools for each type of study design: Newcastle-Ottawa Scale for observational studies, Cochrane Risk of Bias Tool for randomised controlled trials, and AMSTAR-2 for systematic reviews.

2.6 SUMMARY OF THE DATA

Due to the heterogeneity of the included studies (different definitions, populations, surgical techniques, and outcomes), we chose to perform a narrative synthesis of the data, with a descriptive presentation of the main findings. When possible, aggregate success, complication, and mortality rates were calculated.

2.7 MICROBIOLOGY AND DIAGNOSIS

The microbiology of post-sternotomy mediastinitis is predominantly bacterial, with Staphylococcus aureus (including methicillin-resistant strains - MRSA) being the most frequently isolated pathogen, accounting for 30-50% of cases. [8,9] Coagulase-negative Staphylococcus accounts for 15-30% of cases, followed by gram-negative bacilli (Escherichia coli, Klebsiella, Pseudomonas) in 15-25% and polymicrobial infections in 10-20% of cases.

The diagnosis of mediastinitis is based on clinical, laboratory, and imaging criteria. [3,8,9] The most commonly used diagnostic criteria include sternal instability on palpation, purulent drainage through the sternal wound, persistent fever (>38°C) after the 5th postoperative day, persistent or recurrent leukocytosis, disproportionate sternal pain, and signs of local inflammation (erythema, edema, heat).

Among the laboratory criteria, persistent elevation of inflammatory markers (CRP, ESR, procalcitonin), positive culture of sternal or mediastinal secretion, and positive blood culture with a compatible pathogen stand out. [9,12] Imaging criteria include CT scan showing

mediastinal fluid collection, gas in the mediastinum after 2 weeks postoperatively, soft tissue enhancement, and sternal osteomyelitis. [3,8]

The temporal classification of mediastinitis is clinically relevant: early (up to 2 weeks after surgery, usually related to intraoperative contamination) and late (after 2 weeks, usually related to bacteremia or secondary contamination). [3,27]

2.8 PRINCIPLES OF PROCESSING

The treatment of mediastinal suture dehiscence and mediastinitis requires a multidisciplinary and aggressive approach. [9,13,15] The fundamental principles include:

- **Surgical Debridement:** Complete removal of all necrotic, devitalized, or infected tissue, including compromised sternal bone, necrotic costal cartilages, and devitalized soft tissues.[13,15,26] Debridement should be radical and repeated as many times as necessary until viable and well-vascularized tissue is obtained.
- **Infection Control:** Broad-spectrum antibiotic therapy initially, adjusted according to culture and antibiogram results.[5,9] The duration of antibiotic treatment varies from 4 to 6 weeks, depending on the severity of the infection and clinical response.
- **Sternal Stabilization:** When possible, maintenance or restoration of sternal stability through rigid fixation with plates and screws, especially in cases of dehiscence without significant infection.[16:18]
- **Dead Space Obliteration:** Filling of the mediastinal defect with vascularized tissue (muscle flaps) to obliterate the dead space, improve local blood supply, and facilitate healing.[1,13,15,21]

The timing of the definitive reconstruction is controversial in the literature. Traditionally, late reconstruction after complete control of the infection was advocated. However, more recent studies have shown that early reconstruction (within 7-14 days of diagnosis) is associated with better outcomes, shorter hospital stays, and reduced mortality. [13,15,27,28]

Vacuum-Assisted Closure (VAC) therapy has been used as an adjunct to treatment, either as a bridge to definitive reconstruction or as primary therapy in selected cases. [12,29,30] Studies have shown that VAC promotes edema reduction, exudate removal, stimulation of granulation tissue formation, and reduction of bacterial load. However, its use alone without definitive reconstruction is associated with higher recurrence rates.

2.9 PECTORALIS MAJOR FLAP

The pectoralis major flap represents the most widely used reconstructive option for the treatment of sternal dehiscence and mediastinitis, and is considered the gold standard for defects of the upper and middle third of the sternum. [1,13,17,21]

2.9.1 Anatomy and Vascularization

The pectoralis major muscle is a broad, flat muscle that forms the anterior wall of the armpit and most of the anterior contour of the chest. [21,24] It originates from the clavicle (clavicular portion), the sternum and costal cartilages (esternocostal portion) and the aponeurosis of the external oblique muscle (abdominal portion), inserting into the lateral lip of the intertubercular groove of the humerus.

The vascularization of the pectoralis major muscle is twofold, originating from the thoracoacromial artery (dominant pedicle, branch of the axillary artery, penetrates the muscle in its superior portion), lateral thoracic artery (branch of the axillary artery, provides additional supply to the lateral portion) and perforating the internal mammary artery (provides supply to the medial portion, often compromised in cardiac surgery). [20,21,24]

Figure 1

*Vascular Anatomy of the Thoracoacromial Artery*
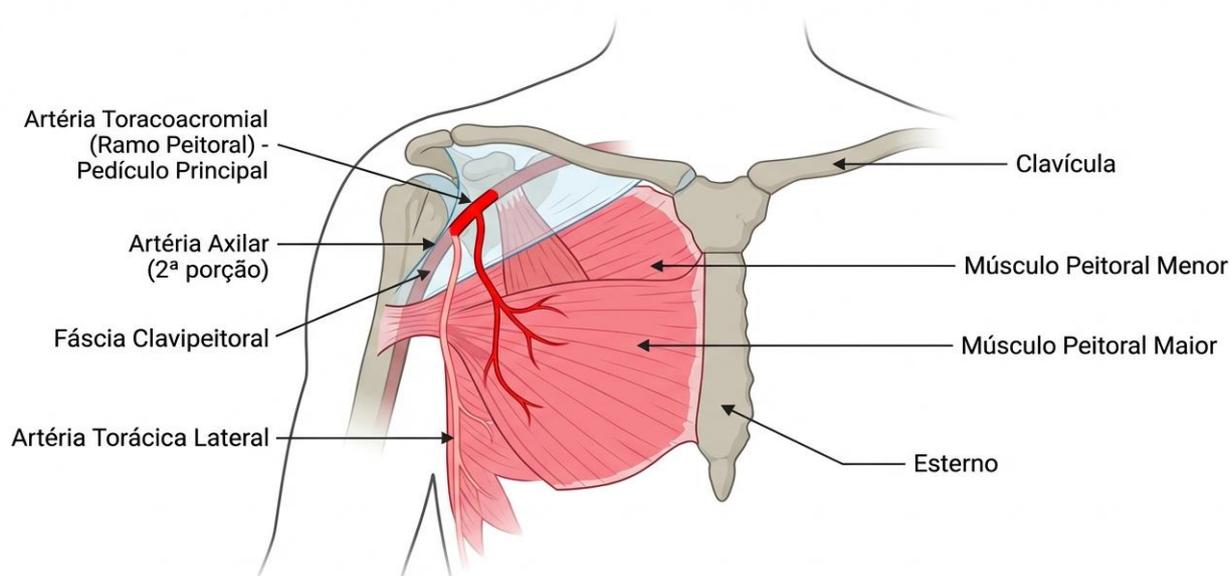
Source: José Dalvo Maia Neto Created BioRender

2.9.2 Surgical Technique

The pectoralis major flap can be performed unilaterally or bilaterally, depending on the extent of the defect. [17,21,22] The standard technique includes: (1) Incision with extension of the median incision or creation of lateral incisions for adequate exposure; (2) Dissection identifying the limits of the muscle, initiated laterally in the deltopectoral sulcus, preserving the cephalic vein, with detachment of its sternal and costal origin, preserving the superior thoracoacromial pedicle; (3) Medial transposition over the sternal defect, with midline suture in bilateral cases; (4) Fixation to the remaining sternum, costal cartilages, or adjacent tissues with absorbable sutures; (5) Closure with proper drainage and tension-free skin closure. [17,21,22]

Figure 2

Schematic drawing of the Pectoral flap
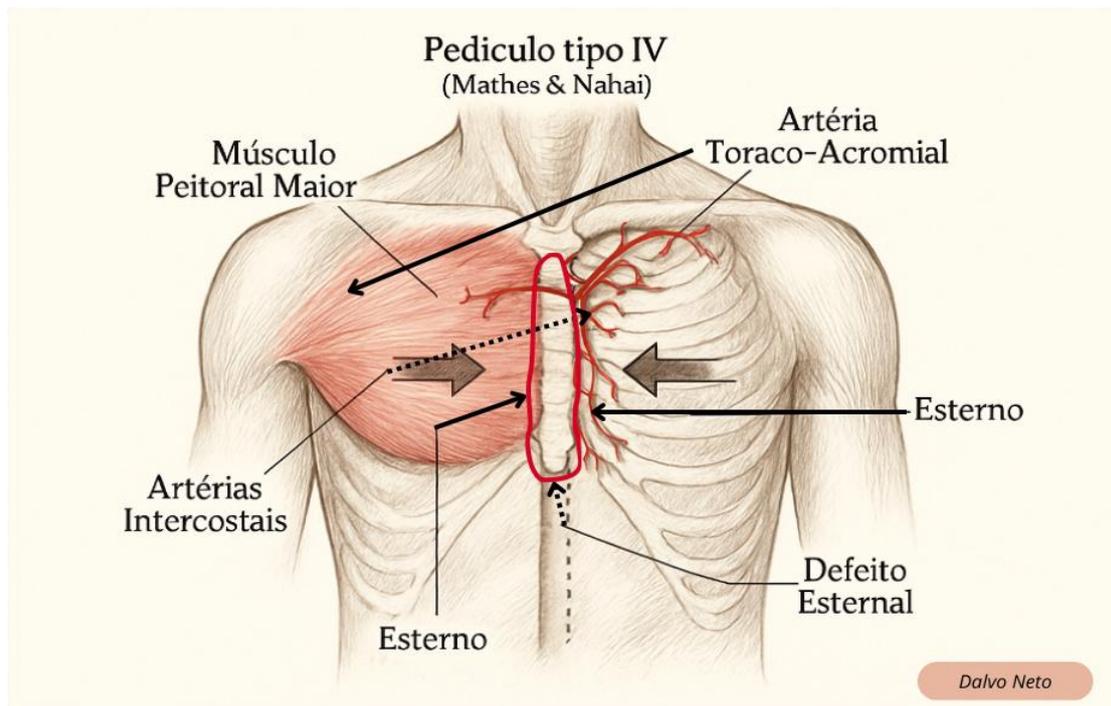
Source: José Dalvo Maia Neto created BioRender

2.9.3 Indications

Upper and middle sternal defects, mediastinitis after median sternotomy, sternal dehiscence without significant infection, sternal osteomyelitis, and exposure of cardiovascular structures. [13,17,21,23]

2.9.4 Results

The literature shows success rates for the pectoralis major flap ranging from 85% to 95%. [13,15,17,21] Primary success rate of 85-95%, mortality of 5-15%, infection recurrence of 5-10%, and need for reintervention of 10-20%.

2.9.5 Complications

Partial flap necrosis (3-8%), seroma (10-15%), hematoma (5-10%), recurrent infection (5-10%), functional deficit of the upper limb (rare, usually minimal), and variable aesthetic deformity, usually well tolerated. [17,21,23]
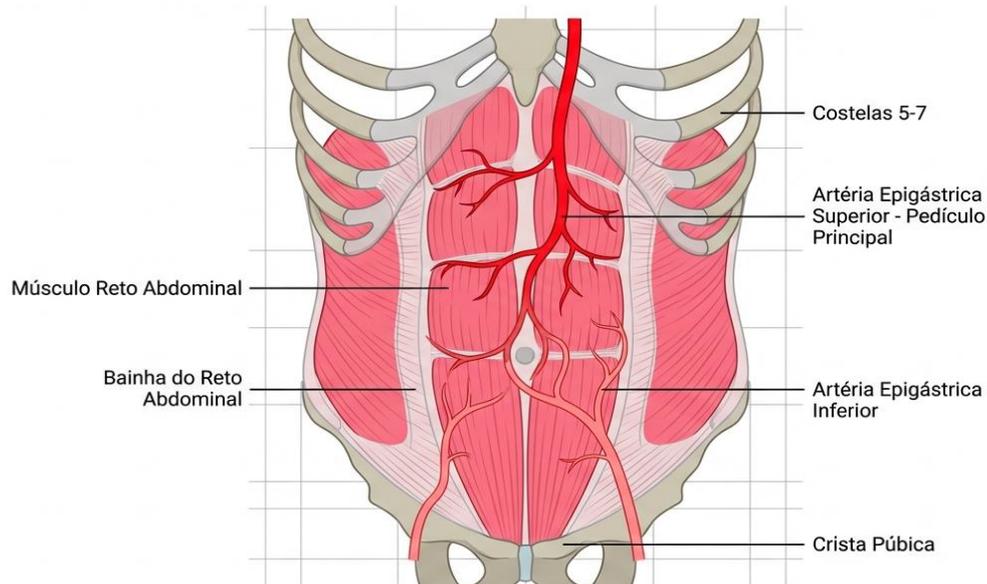
2.10 RECTUS ABDOMINIS FLAP

The rectus abdominis flap represents an excellent reconstructive option for extensive sternal defects, particularly of the lower third, and in situations where the pectoralis major flap is not available or insufficient. [22,23,25,26]

2.10.1 Anatomy and Vascularization

The rectus abdominis muscle is a long, flat muscle that extends from the xiphoid process and costal cartilages 5-7 to the pubic symphysis. [24,25] It is surrounded by the rectus abdominis sheath and has tendon intersections that divide it into segments. Vascularization originates from the superior epigastric artery (branch of the internal thoracic artery, vascular pedicle for the superior pedicled flap), inferior epigastric artery (branch of the external iliac artery), and intercostal and lumbar arteries (provide additional supply through perforators). [24,25]

Figure 3

Vascular Anatomy of the Superior Epigastric Artery

Costelas 5-7

Artéria Epigástrica Superior - Pedículo Principal

Músculo Reto Abdominal

Bainha do Reto Abdominal

Artéria Epigástrica Inferior

Crista Púbica

Source: José Dalvo Maia Neto created BioRender

2.10.2 Surgical Technique

The rectus abdominis flap for sternal reconstruction is typically performed as a superior pedicled flap, based on the superior epigastric artery. [22,25,26] The technique includes: (1) Vertical or paramedian incision over the muscle, from the costal margin to the infraumbilical region; (2) Dissection with opening of the anterior sheath and dissection of the muscle of its posterior sheath or peritoneum, from inferior to superior, connecting the inferior epigastric pedicle; (3) Complete mobilization preserving the superior epigastric pedicle, which may include adjacent costal cartilage; (4) Superior transposition through the subcutaneous tunnel to the sternal defect; (5) Attachment to the sternum, cartilage or adjacent tissues; (6) Abdominal closure of the anterior sheath with nonabsorbable sutures, with the possible use of prosthetic mesh in significant defects; (7) Proper drainage and skin closure without tension. [22,25,26]

Figure 4

Schematic drawing of the V.R.A.M. Retail
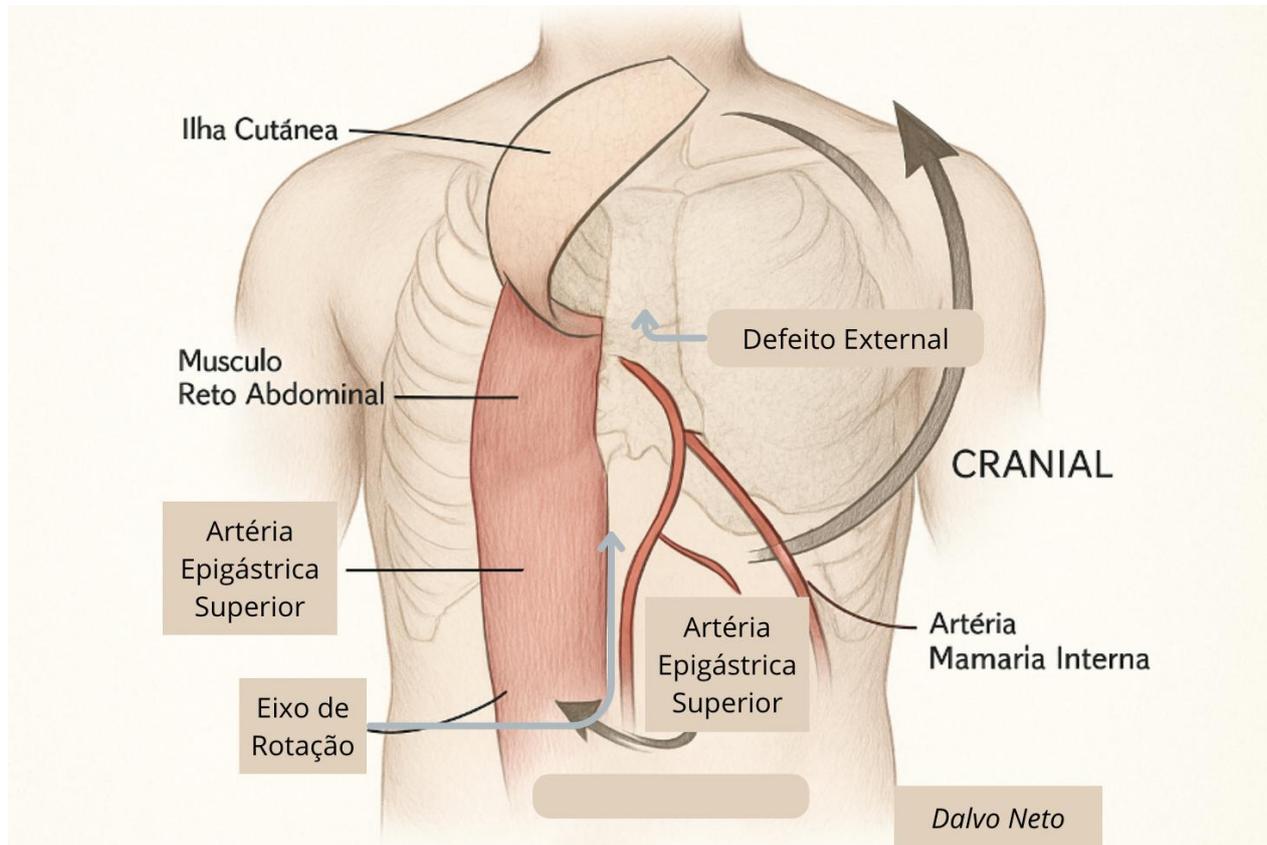
Source: created by Josë Dalvo Maia Neto with BioRender

2.10.3 Indications

Extensive defects of the sternum (particularly lower third), failure or unavailability of the pectoralis major flap, defects extending to the xiphoid process or epigastric region, need for large tissue volume, and reconstruction after extensive tumor resection. [23,25,26]

2.10.4 Results

The literature shows success rates for the rectus abdominis flap ranging from 80% to 92%: primary success rate of 80-92%, mortality of 8-18%, recurrence of infection of 8-15%, and need for reintervention of 15-25%. [25,26,27]

2.10.5 Complications

Partial necrosis of the flap (5-12%), seroma (15-25%), hematoma (8-15%), recurrent infection (8-15%), abdominal hernia (5-15%, specific complication of the donor site), abdominal wall weakness (20-30%), and variable abdominal aesthetic deformity. [23,25,26]

2.11 COMPARISON BETWEEN FLAPS

The choice between pectoralis major flap and rectus abdominis must consider multiple factors. [23] For the localization of the defect, the pectoralis major is preferable for the upper and middle third of the sternum, while the rectus abdominis is more suitable for the lower third and xiphoid region. [21,25] For small to moderate defects, unilateral pectoralis major is usually sufficient, while extensive defects require bilateral pectoralis major or rectus abdominis. [17,23]

Bilateral use of the internal mammary artery may compromise both flaps, but generally the pectoralis major remains viable. [19,20] Regarding the morbidity of the donor site, the pectoralis major has lower morbidity and minimal functional deficit, while the rectus abdominis has higher morbidity with risk of hernia and abdominal weakness. [23,25] The success rate of pectoralis major is slightly higher (85–95% vs 80–92%). [13,15,17,21,25,26] Technically, the pectoralis major is simpler with less surgical time, while the rectus abdominis is more complex and requires careful abdominal closure. [23]

Table 1

Results of Surgical Interventions with Muscle Flaps

Retail Type	No of Cases	Success Rate (%)	Complications (%)	Mortality (%)	Hospitalization time (days)
Unilateral Greater Pectoralis	145-320	85-95	10-15	5-10	18-25
Bilateral Pectoralis Major	80-180	88-96	12-18	8-12	20-28
Unilateral Rectus Abdominis	65-150	80-90	15-25	10-15	22-30
Bilateral Rectus Abdominis	25-60	82-92	18-28	12-18	25-35
Patchwork Combination	15-45	78-88	20-32	15-20	28-40

Source: Compilation of data from the reviewed literature (2010-2024).

Table 2

Comparison between Pectoralis Major and Rectus Abdominis Flaps

Feature	Pectoralis Major	Rectus Abdominis
Main Indication	Upper and middle third defects	Lower third and extensive defects
Success Rate	85-95%	80-92%
Technical Complexity	Low to moderate	Moderate to high
Surgical Time	120-180 minutes	180-240 minutes

Morbidity Donor Site	Low (5-10%)	Moderate to high (15-25%)
Functional Deficit	Minimum (<5%)	Moderate (20-30%)
Risk of Hernia	Not applicable	Yes (5-15%)
Tissue Volume	Moderate	Large
Arc of Rotation	Excellent	Good
Impact on Prior Surgery	Moderate (bilateral AMI)	Alto (abdominal surgery)
Aesthetic Deformity	Mild to moderate	Moderate to severe
Preference for Bilateral	First choice	Second choice

Source: Comparative analysis based on a systematic review of the literature.

3 DISCUSSION

Sternal suture dehiscence and post-sternotomy mediastinitis continue to pose significant challenges in contemporary cardiac surgery, despite advances in surgical techniques, perioperative care, and antibiotic therapy. [1,9] This systematic review consolidates the current evidence on the use of muscle flaps, particularly pectoralis major and rectus abdominis, demonstrating that these reconstructive options constitute the gold standard for the definitive treatment of this serious complication.

The analysis of the literature reveals that, although the incidence of sternal dehiscence has remained relatively stable in recent decades (0.5-5%), the associated mortality has shown a significant reduction, from approximately 50% in the 1970s-1980s to 10-20% in the most recent studies. [6,7,8,11,27] This improvement in outcomes can be attributed to multiple factors: early recognition of the complication, multidisciplinary approach, more aggressive debridement, early reconstruction with vascularized muscle flaps, targeted antibiotic therapy, and better intensive care. [9,13,15,28]

The pectoralis major flap emerged as the most used and studied reconstructive option, with consistently high success rates (85-95%) in multiple series. [13,15,17,21] Its advantages include reliable vascular anatomy, proximity to the defect, relative technical ease, low morbidity of the donor site, and the possibility of bilateral performance for extensive defects. Preservation of the thoracoacromial pedicle is critical to flap viability, and the surgical technique should emphasize careful dissection and vascular preservation. [21,24]

A relevant issue in the literature is the impact of bilateral use of the internal mammary artery on the viability of the pectoralis major flap. Traditionally, it was considered that bilateral use would significantly compromise the vascularization of the muscle, making it unsuitable for reconstruction. [19] However, more recent anatomical and clinical studies have shown that, although there is a reduction in medial blood supply, the dominant thoracoacromial pedicle generally maintains adequate vascularization for most of the muscle. [20,21]

The rectus abdominis flap, although less widely used than the pectoralis major, represents a valuable option, particularly for defects of the lower third of the sternum, extensive defects, or when the pectoralis major is not available. [23,25,26] Reported success rates (80-92%) are slightly lower than those of pectoralis major, possibly due to greater technical complexity, greater dissection extension, and selection of more complex cases.

The timing of the definitive reconstruction is a controversial aspect in the literature. Historically, late reconstruction was advocated after complete control of the infection. [15] However, more recent studies have shown that early reconstruction (within 7-14 days of diagnosis) is associated with better outcomes, shorter hospital stays, and reduced mortality. [13,27,28]

Negative pressure therapy (VAC) has been increasingly used in the management of sternal dehiscence and mediastinitis. [12,29,30] Its role can be as a primary therapy, as a bridge to definitive reconstruction, or as a post-reconstruction adjuvant. The literature shows that VAC promotes edema reduction, exudate removal, stimulation of granulation tissue formation, and reduction of bacterial load. However, studies indicate that isolated use without definitive reconstruction is associated with higher recurrence rates. [29,30]

The identification of risk factors and the implementation of preventive strategies are essential to reduce the incidence of this complication. [5,9,10,11] Evidence-based prevention protocols include: strict perioperative blood glucose control, judicious use of bilateral internal mammary artery with preference for skeletonization techniques, adequate sternal closure technique, adequate skin preparation, appropriate antibiotic prophylaxis, and optimized management of comorbidities.

The multidisciplinary approach is essential for successful treatment. The collaboration between cardiac surgeons, plastic surgeons, infectious disease specialists, intensivists, nutritionists and physiotherapists allows for integrated and optimized management. [9,13,27,28]

4 CONCLUSION

Sternal suture dehiscence and post-sternotomy mediastinitis represent serious complications that require early recognition and aggressive multidisciplinary treatment. The present systematic review of the literature demonstrates that pectoralis major and rectus abdominis muscle flaps are effective, safe, and reliable reconstructive options, with success rates between 80-95% and reduced mortality when compared to historical approaches.

4.1 SUMMARY OF THE EVIDENCE

The contemporary scientific literature extensively deals with post-dehiscence reconstructions of sternal sutures, consolidating robust evidence on various aspects of this complication. Studies consistently demonstrate that the pectoralis major flap remains the first choice for defects of the upper and middle third of the sternum, presenting significant advantages in terms of technical simplicity, shorter surgical time, reliable vascular anatomy, and reduced morbidity of the donor site. The rectus abdominis flap, in turn, is reserved for specific situations such as extensive defects of the lower third, unavailability of the pectoralis major, or the need for greater tissue volume.

The temporal evolution of the treatment of this complication reflects significant advances in pathophysiological and technical knowledge. The transition from conservative approaches with debridement and primary closure to early reconstructions with vascularized flaps has resulted in a dramatic reduction in mortality, from approximately 50% to 10-20% in recent decades. This progress highlights the importance of early definitive treatment, adequate obliteration of dead space, and restoration of local blood supply through vascularized tissue.

The identification and stratification of risk factors remain fundamental for prevention and proper management. Diabetes mellitus, obesity, bilateral internal mammary artery use, COPD, smoking, and reoperation due to bleeding consistently emerge as independent predictive factors of sternal complications. Perioperative optimization of these modifiable factors, particularly strict glycemic control, represents an essential preventive strategy.

4.2 POST-STERNAL DEHISCENCE SAFETY AND RESCUE ALGORITHM

Based on the critical analysis of the literature and the best available evidence, a systematized safety algorithm is proposed for the management of patients with sternal suture dehiscence after cardiac surgery. This protocol aims to standardize the approach, minimize delays in definitive treatment, and optimize clinical outcomes:

4.2.1 Phase 1: Early Recognition and Diagnosis (0-24 Hours)

- Active surveillance for warning signs: sternal instability on palpation, purulent drainage, persistent fever (>38°C after day 5), recurrent leukocytosis, disproportionate sternal pain
- Daily physical examination with systematic sternal palpation

- Monitoring of inflammatory markers (CRP, leukocytes, procalcitonin)
- Collection of cultures (sternal discharge, blood culture) at the slightest sign of infection
- Contrast-enhanced chest CT scan in suspected cases (assess collection, mediastinal gas, osteomyelitis)

4.2.2 Phase 2: Multidisciplinary Stratification and Activation (24-48 Hours)
- Once the diagnosis is confirmed, IMMEDIATELY call a multidisciplinary team: cardiac surgeon, plastic surgeon, infectious disease specialist, intensivist
- Stratify severity: Type I (superficial dehiscence without deep infection), Type II (dehiscence with instability but no overt infection), Type III (mediastinitis with instability and active infection)
- Initiate empiric broad-spectrum antibiotic therapy: vancomycin + piperacillin-tazobactam (adjust after cultures)
- Clinical optimization: tight glycemic control (blood glucose 120-180 mg/dL), nutritional support, correction of anemia and fluid and electrolyte disturbances
- Joint surgical planning between cardiac and plastic surgery: define timing, flap type, need for transient VAC

4.2.3 Phase 3: Aggressive surgical debridement (48-72 hours)
- Early surgical approach (ideally within 48-72h of definitive diagnosis)
- Radical debridement: remove ALL necrotic, devitalized, or frankly infected tissue
- Resection of compromised sternal bone, necrotic costal cartilages, and devitalized soft tissues
- Removal of steel wires if there is deep infection or osteomyelitis
- Copious irrigation with saline solution (minimum 6-9 liters)
- Collection of multiple cultures (bone, deep tissue, secretion)
- Intraoperative evaluation of defect extent and reconstruction planning
- Options: (a) Immediate reconstruction if the bed is clean and the patient is stable; (b) Temporary VAC if significant contamination, wait 48-72h for second time

4.2.4 Phase 4: Definitive Reconstruction with Muscle Flap (3-14 Days)
- Ideal timing: early reconstruction (7-14 days) associated with better outcomes

- Retail selection based on decision-making algorithm:
- → Upper/middle third defect + stable patient = Unilateral Pectoralis Major
- → Extensive Upper Thirds/Middle Defect = Bilateral Pectoralis Major
- → Lower third/xiphoid defect = unilateral rectus abdominis
- → Extensive Defect Entire Sternum = Combination or Bilateral
- → Pectoralis Major or Unavailable Failure = Rectus Abdominis
- Rigorous surgical technique: preservation of the dominant vascular pedicle, tension-free transposition, complete dead space obliteration
- Proper attachment of the muscle to adjacent tissues
- Efficient drainage (suction drains)
- Tension-free skin closure

4.2.5 Phase 5: Post-reconstruction management and follow-up

- Prolonged antibiotic therapy: minimum 4-6 weeks (adjusted for cultures and clinical course)
- Close monitoring for signs of residual or recurrent infection
- Drain management: maintain up to <30 mL/24h
- Surgical wound care: occlusive dressing, avoid excessive manipulation
- Relative chest immobilization: avoid sudden upper extremity movements in the first 2 weeks
- Optimized nutritional support: albumin >3.0 g/dL, positive nitrogen balance
- Gradual respiratory physiotherapy, avoiding high-impact maneuvers initially
- Tight glycemic control maintained
- Outpatient follow-up: 7 days, 14 days, 30 days, 90 days, and 6 months
- Flap viability assessment, infection recurrence, affected limb function, quality of life

Figure 5

5-phase external dehiscence treatment algorithm, safety and rescue protocol for post-cardiac surgery management
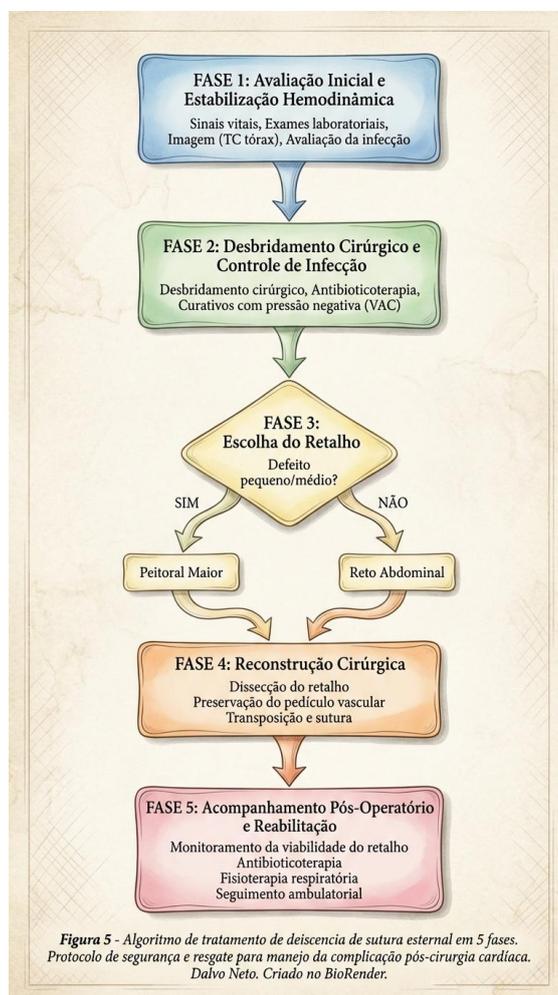
Source: José Dalvo Maia Neto created at BioRender

5 FINAL CONSIDERATIONS

The implementation of this security algorithm requires adequate infrastructure, trained staff, and efficient communication between the specialties involved. Centers that perform highly complex cardiac surgery must establish clear institutional protocols, with care flowcharts, criteria for activating the multidisciplinary team, and measurable quality indicators.

The continuing education of care teams, including nursing and physiotherapy, is essential for the early recognition of warning signs and timely implementation of rescue measures. Audit programs and systematic feedback of institutional results allow the identification of opportunities for improvement and continuous refinement of protocols.

In summary, sternal suture dehiscence and post-sternotomy mediastinitis, although potentially devastating complications, can be successfully managed when approached in a

systematized, early and multidisciplinary manner. The pectoralis major and rectus abdominis muscle flaps represent consolidated and effective reconstructive tools. The proposed safety algorithm provides a structured roadmap for optimizing care, with the potential to significantly reduce the morbidity and mortality associated with this severe complication of cardiovascular surgery.

REFERENCES

1. Arnold, P. G., & Pairolero, P. C. (1979). Use of pectoralis major muscle flaps to repair defects of anterior chest wall. Plastic and Reconstructive Surgery, 63(2), 205–213.

2. Ascherman, J. A., Patel, S. M., Malhotra, S. M., & Smith, C. R. (2004). Management of sternal wounds with bilateral pectoralis major myocutaneous advancement flaps in 114 consecutively treated patients: Refinements in technique and outcomes analysis. Plastic and Reconstructive Surgery, 114(3), 676–683.

3. Cayci, C., Russo, M., Cheung, A. T., & Kurlansky, P. (2008). Risk analysis of deep sternal wound infections and their impact on hospital mortality. Annals of Plastic Surgery, 61(3), 294–301.

4. Cicilioni, O. J., Jr., Stieg, F. H., 3rd, & Papanicolaou, G. (2005). Sternal wound reconstruction with transverse plate fixation. Plastic and Reconstructive Surgery, 115(5), 1297–1303.

5. El Oakley, R. M., & Wright, J. E. (1996). Postoperative mediastinitis: Classification and management. The Annals of Thoracic Surgery, 61(3), 1030–1036.

6. Filsoufi, F., Castillo, J. G., Rahmanian, P. B., & et al. (2009). Epidemiology of deep sternal wound infection in cardiac surgery. Journal of Cardiothoracic and Vascular Anesthesia, 23(4), 488–494.

7. Fleck, T., Moidl, R., Giovanoli, P., & et al. (2004). Early and long-term results of combined muscle flap and vacuum-assisted closure therapy for sternal wound infection following open heart surgery. European Journal of Cardio-Thoracic Surgery, 25(5), 865–870.

8. Greig, A. V., Geh, J. L., Khanduja, V., & Shibu, M. (2007). Choice of flap for the management of deep sternal wound infection: An anatomical classification. Journal of Plastic, Reconstructive & Aesthetic Surgery, 60(4), 372–378.

9. Gummert, J. F., Barten, M. J., Hans, C., & et al. (2002). Mediastinitis and cardiac surgery: An updated risk factor analysis. The Thoracic and Cardiovascular Surgeon, 50(2), 87–91.

10. Jones, G., Jurkiewicz, M. J., Bostwick, J., & et al. (1997). Management of the infected median sternotomy wound with muscle flaps: The Emory 20-year experience. Annals of Surgery, 225(6), 766–776.

11. Jurkiewicz, M. J., Bostwick, J., 3rd, Hester, T. R., Bishop, J. B., & Craver, J. (1980). Infected median sternotomy wound: Successful treatment by muscle flaps. Annals of Surgery, 191(6), 738–744.

12. Kouchoukos, N. T., Wareing, T. H., Murphy, S. F., Pelate, C., & Marshall, W. G., Jr. (1990). Risks of bilateral internal mammary artery bypass grafting. The Annals of Thoracic Surgery, 49(2), 210–217.

13. Lazar, H. L., Salm, T. V., Engelman, R., Orgill, D., & Gordon, S. (2016). Prevention and management of sternal wound infections. The Journal of Thoracic and Cardiovascular Surgery, 152(4), 962–972.

14. Loop, F. D., Lytle, B. W., Cosgrove, D. M., & et al. (1990). Sternal wound complications after isolated coronary artery bypass grafting. The Annals of Thoracic Surgery, 49(2), 179–186.

15. Losanoff, J. E., Jones, J. W., & Richman, B. W. (2002). Primary closure of median sternotomy: Techniques and principles. Cardiovascular Surgery, 10(2), 102–110.

16. Mangram, A. J., Horan, T. C., Pearson, M. L., Silver, L. C., & Jarvis, W. R. (1999). Guideline for prevention of surgical site infection, 1999. Infection Control and Hospital Epidemiology, 20(4), 250–278.

17. Mathes, S. J., & Nahai, F. (1981). Classification of the vascular anatomy of muscles: Experimental and clinical correlation. Plastic and Reconstructive Surgery, 67(2), 177–187.

18. Morisaki, A., Hosono, M., Sasaki, Y., & et al. (2011). Evaluation of risk factors for hospital mortality and current treatment for poststernotomy mediastinitis. General Thoracic and Cardiovascular Surgery, 59(4), 261–267.

19. Nahai, F., Morales, L., Jr., Bone, D. K., & Bostwick, J., 3rd. (1982). Pectoralis major muscle turnover flaps for closure of the infected sternotomy wound with preservation of form and function. Plastic and Reconstructive Surgery, 70(4), 471–474.

20. Nahai, F., Rand, R. P., Hester, T. R., Bostwick, J., 3rd, & Jurkiewicz, M. J. (1989). Primary treatment of the infected sternotomy wound with muscle flaps: A review of 211 consecutive cases. Plastic and Reconstructive Surgery, 84(3), 434–441.

21. Pairolero, P. C., & Arnold, P. G. (1986). Management of infected median sternotomy wounds. The Annals of Thoracic Surgery, 42(1), 1–2.

22. Pessa, M. E., & Welch, M. J. (1988). Rectus abdominis microvascular free flap for treatment of infected median sternotomy wound. Annals of Plastic Surgery, 20(3), 222–224.

23. Petzina, R., Malmsjo, M., Stamm, C., & Hetzer, R. (2010). Major complications during negative pressure wound therapy in poststernotomy mediastinitis after cardiac surgery. The Journal of Thoracic and Cardiovascular Surgery, 140(5), 1133–1136.

24. Ridderstolpe, L., Gill, H., Granfeldt, H., Ahlfeldt, H., & Rutberg, H. (2001). Superficial and deep sternal wound complications: Incidence, risk factors and mortality. European Journal of Cardio-Thoracic Surgery, 20(6), 1168–1175.

25. Schimmer, C., Sommer, S. P., Bensch, M., & Leyh, R. (2007). Primary treatment of deep sternal wound infection after cardiac surgery: A survey of German heart surgery units. Interactive CardioVascular and Thoracic Surgery, 6(6), 708–711.

26. Scully, H. E., Leclerc, Y., Martin, R. D., & et al. (1985). Comparison between antibiotic irrigation and mobilization of pectoral muscle flaps in treatment of deep sternal infections. The Journal of Thoracic and Cardiovascular Surgery, 90(4), 523–531.

27. Seyfer, A. E., Shriver, C. D., Miller, T. R., & Graeber, G. M. (1988). Sternal blood flow after median sternotomy and mobilization of the internal mammary arteries. Surgery, 104(5), 899–904.

28. Sjögren, J., Gustafsson, R., Nilsson, J., Malmsjö, M., & Ingemansson, R. (2005). Clinical outcome after poststernotomy mediastinitis: Vacuum-assisted closure versus conventional treatment. Cardiovascular Surgery, 13(5), 245–252.

29. Voss, B., Bauernschmitt, R., Will, A., & et al. (2008). Sternal reconstruction with titanium plates in complicated sternal dehiscence. European Journal of Cardio-Thoracic Surgery, 34(1), 139–145.

30. Wettstein, R., Erni, D., Berdat, P., Rothenfluh, D., & Banic, A. (2002). Radical sternectomy and primary musculocutaneous flap reconstruction to control sternal osteomyelitis. The Journal of Thoracic and Cardiovascular Surgery, 123(6), 1185–1190.