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Efficacy and safety of pectoralis muscle flap combined rectus abdominis muscle sheath fasciocutaneous flap for reconstruction of sternal infection

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Abstract

Few studies have assessed the efficacy and safety of reconstruction of sternal infection using a pectoralis muscle flap combined with a rectus abdominis muscle (RAM) sheath fasciocutaneous flap. We report here our experience with this procedure to reconstruct the sternal defect in patients (n = 46) with a deep sternal wound infection (DSWI) after cardiac surgery. After wound reconstruction, the proportion of prolonged mechanical ventilation use and intensive care unit (ICU) stay were 17.4% (n = 8) and 21.7% (n = 10), respectively. The 30-day all-cause mortality was 15.2%; recurrence rate was 17.4%; postoperative complications were 15.2%; and median hospital stay was 31 (0-157) days. Multivariate logistic regression analysis revealed that hypertension (β = 21.32, 95%CI 4.955-37.68, P = .014), drainage-tube use (β = 0.944, 95%CI 0.273-1.614, P = .008), and prolonged intensive care unit stay (β = 53.65, 95%CI 31.353-75.938, P < .001) were significantly correlated with hospital stay. In conclusion, a procedure including surgical debridement, sternal reconstruction with bilateral PM and RAM sheath flap, long-term antibiotics, and adequate drainage is a beneficial technique in the reconstruction of deep sternal wound infection after cardiac surgery. Duration of drainage tube use may be as an index for a hospital stay or wound healing.

KEYWORDS

pectoralis myocutaneous flap, rectus abdominis fasciocutaneous flap, sternal closure, sternal reconstruction, sternal wound infection

Abbreviations: DSWI, deep sternal wound infection; ICU, intensive care unit; RAM, rectus abdominis muscle; VAC, vacuum-assisted closure.

Chieh-Ming Yu, Chia-Meng Yu, and Wen-Teng Yao contributed equally to this research as co-first authors.

Key Messages

- flap reconstruction for treatment of DSWI has been used for decades, but ours is the first study to describe the clinical presentation, microbiological characteristics, and outcomes of reconstruction using bilateral pectoralis myocutaneous flap and RAM sheath fasciocutaneous flap
- a procedure including surgical debridement, sternal reconstruction with bilateral PM and RAM sheath flap, long-term antibiotics, and adequate drainage is a beneficial technique in the reconstruction of deep sternal wound infection after cardiac surgery
- duration of drainage tube use may be as an index for a hospital stay or wound healing

1 | INTRODUCTION

Deep sternal wound infection (DSWI) or sternal osteomyelitis occurs in about 0.8% to 8% of patients after median sternotomy,[1] and these complications contribute to morbidity and mortality[2-4] of the operation; the mortality rate has been reported as high as 7% to 47%.[2] However, sternotomy has been commonly performed in thoracic surgery and cardiac operations since it was first described, in 1957, by Julian et al.[5] Consequently, many therapeutic options and combinations to treat DSWI or sternal osteomyelitis after median sternotomy have been advanced.

The treatment of DSWI ordinarily starts with closed mediastinal antibiotic irrigation.[6] If the defect is small and the sternum is in fair condition, it can close by primary intention, but sometimes, after debridement, it is too big to close primarily. Moreover, the constant movement of the chest makes spontaneous closure unlikely. For these reasons, it is necessary to reconstruct the sternum with mobilised tissue, such as muscle or omentum, from another part of the body. Two strategies – single-stage procedures and two-stage procedures – have been reported.[7,8] The two-stage procedure requires vacuum-assisted closure (VAC) between debridement and reconstruction, whereas the single-stage procedure reconstructs the sternum soon after debridement; which of these procedures is the better one is controversial. A reported advantage of the single-stage produce is shorter hospital stay and postoperative intensive care, but other recent studies have recommended VAC therapy.[9,10] The improved outcomes with VAC therapy have been attributed to increased peri-sternal blood flow by increasing arteriole dilation and reducing bacterial loads; enhancing granulation tissue formation; and approximating the wound edges and stabilising the chest wall.[11,12] VAC alone has been used for the treatment of sternal wounds as an alternative to operation.[11,13]

There is no standard recommendation or guideline for the preferred type of flap to reconstruct the sternum; muscle flaps and omental flaps are two types in use. A higher mortality rate and rate of complications, such as complete or partial flap loss, hematoma, arm or shoulder weakness, and chronic chest wall pain have been reported more often after the reconstruction with muscle flaps than with omental flaps. A high incidence (>17.5%) of re-exploration for recurrent sternal infection after muscle flap use also has been reported.[14] With its adequate blood supply and rich lymphatic system, the omentum would seem to be advantageous for reconstruction of the sternum and filling the dead space after debridement.[15] However, the omentum must be harvested by laparoscopy, which may not be appropriate for many patients.[16] The most commonly reported complication (< 5%) after reconstruction with omental flaps has been abdominal or diaphragmatic hernia.[14] Because of these considerations, omental transposition has been used less often than muscle flaps since they were introduced.[15] The pectoralis major (PM) muscle,[13,16] rectus abdominis muscle (RAM),[17] latissimus dorsi muscle,[18] and other muscles have been used to reconstruct the sternal wound defect.

Muscle flaps and omental flaps are sometimes used together; however, the combination has been associated with relatively high flap-associated complication rates.[19,20] Among all flaps that have been used to reconstruct the defect of the sternum wound, pectoralis major flaps seem to be the preferred source.[21] However, few studies have assessed the efficacy and safety of reconstruction of sternums with a pectoralis muscle flap combined with the anterior layer of RAM sheath fasciocutaneous flap in cardiac surgery patients who have a post-sternotomy infection. Therefore, we report, in this case series, our experience with bilateral pectoralis muscle flap combined with the bilateral anterior layer of RAM sheath fasciocutaneous flap for reconstruction of the sternal wound defect in patients with DSWI after cardiac surgery.

2 | METHODS

2.1 | Patients and study design

A retrospective chart review was performed on all patients (n = 46) referred to a single plastic surgeon from 2014 to 2020 for treatment of a DSWI (sternum osteomyelitis and/or anterior mediastinitis) after median sternotomy for cardiovascular surgery at Mackay Memorial Hospital, Taipei, Taiwan. Those who developed signs of DSWI, were received for wound reconstruction using bilateral pectoralis myocutaneous flap and upper part of the bilateral anterior layer of RAM sheath fasciocutaneous flap, long-term antibiotics, and adequate drainage with closed-suction drainage tube. The study protocol was approved by the ethics committee of the MacKay Memorial Hospital (No. 20MMHIS168e). All patients with DSWI were treated according to the same protocol.

2.2 | Surgical procedure

All patients were operated on by a single plastic surgeon, using a standard technique for bilateral advancement method, which allowed the harvest of enough bilateral pectoralis myocutaneous flap and upper part of the bilateral anterior layer of RAM sheath fasciocutaneous flap to cover the entire sternal wound defect. The surgical procedure included wound debridement, wound reconstruction, and suture removal. For wound debridement, the ulcer wound and the poorly healed area under the skin were completely removed from the soft tissue above the sternum. As much of the sternum as possible was retained; only a small specimen was taken for pathological examination. Most of the internal fixator that was on the sternum at the cardiac surgery was removed, especially when poor healing or infection was evident. However, one or two internal fixators with apparent good healing were retained to avoid dead space caused by sternum separation, which would have prolonged the healing time. For wound reconstruction, the pectoralis advancement myocutaneous flaps were placed on both sides of the sub-PM muscle plane of dissection to approximately the distance of the nipple, and the caudal part without PM muscle was covered with bilateral anterior layer of RAM sheath fasciocutaneous flap. The muscle and subcutaneous tissues were sewn with 1-0 and 2-0 monofilament absorbable suture on both sides of myocutaneous flaps, and 4-0 nylon was used to sew the skin. Up to 3 15-Fr channel drains with silicone suction reservoir were placed

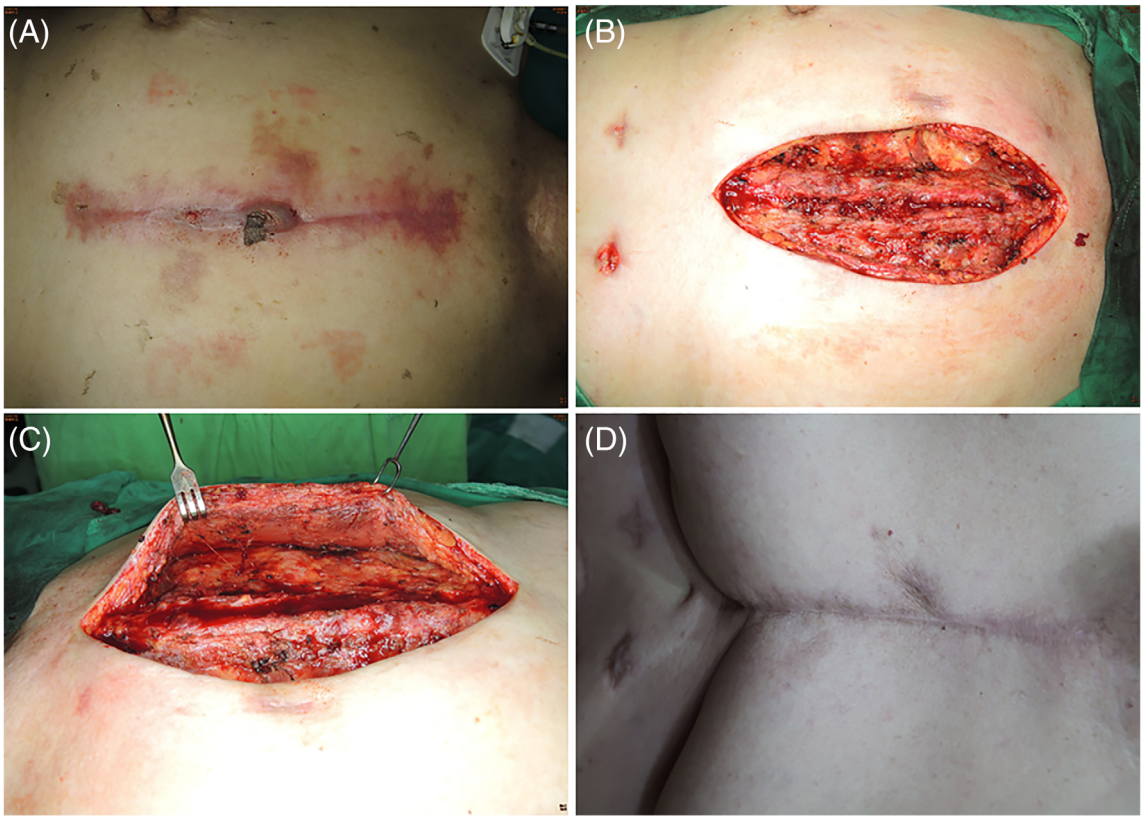

FIGURE 1 (A) Sternal wound with deep infection after cardiac surgery. (B) Sternal wound after debridement. (C) The pectoralis advancement myocutaneous flaps were placed on both sides of the sub-PM muscle plane of dissection to approximately the distance of the nipple, and the caudal part without PM muscle was covered with an anterior layer of RAM sheath fasciocutaneous flap. (D) The sternal wound healing at 2-years follow-up

in the sub-PM muscle plain, under the midline and below the flap on both sides. The channel drains below the flaps were unplugged after 7 days, and the channel drain in the middle was unplugged based on the amount of drainage, which was usually <15 mL/day. The 4-0 nylon sutures of all wounds were removed on day 14 of post-operation. Figure 1 showed the pre-operation, intra-operation, and post-operation images.

2.3 | Antibiotic and drainage tube use

Surgical debridement also tried to preserve the sternum without extensive sequestrectomy. After wound reconstruction surgery, long-term (2 months) antibiotic and adequate drainage were used for the treatment of sternum osteomyelitis and anterior mediastinitis in all patients. According to guideline of sternum osteomyelitis and anterior mediastinitis, patients received broad-spectrum penicillin or quinolone initially, then antibiotics according to the wound culture report. In addition, we also performed adequate drainage with a closed-suction drainage tube, which could promote wound healing and reduce sternal wound complications.[22] When sternum osteomyelitis and anterior mediastinitis gradually improved and the drainage amount (15 mL/day) was reduced to the extent, we remove the drainage tube. Consequently, the duration of the drainage tube use may represent the healing time.

TABLE 1 Clinical characteristic of patients receiving a reconstructive operation with pectoralis muscle flap and RAM sheath

	Total n = 46
Age, year, median (range)	65 (40-88)
Gender, n (%)	
Female	26 (56.5%)
Male	20 (43.5%)
BMI, n (%)	
<27	36 (78.3%)
27-30	7 (15.2%)
>30	3 (6.5%)
Alcohol use, n (%)	4 (8.7%)
Smoking, n (%)	8 (17.4%)
Comorbidity, n (%)	37 (80.4%)
Hypertension	25 (54.3%)
Diabetes	31 (67.4%)
ESRD	17 (37.0%)
IMA use, n (%)	30 (65.2%)

Abbreviations: ESRD, end-stage renal disease; IMA, internal mammary artery; RAM, rectus abdominis muscle.

2.4 | Outcomes

The demographics, clinical data, and postoperative outcomes were obtained from the patients' electronic medical records. The primary outcomes were wound recurrence, 30-day all-cause mortality, and hospital stay. We also evaluated the association of these outcomes with patients' characteristics.

2.5 | Statistical analysis

The results are presented as the frequency and percentage or the median unless otherwise indicated. Risk factors for 30-day mortality and postoperative recurrence were evaluated with multivariate logistic regression analyses. Risk factors for the length of hospital stay were evaluated with multivariate generalised linear regression analyses. The 95% confidence intervals of all the comparisons are also reported. In all instances, a two-tailed *P*-value <.05 was considered statistical significance.

3 | RESULTS

3.1 | Patient characteristics

Patient's clinical characteristics are listed in Table 1. Forty-six patients had bilateral pectoralis myocutaneous flaps and RAM sheath fasciocutaneous flap inserted; 20 (43.5%) were males, and 26 (56.5%) were females, with

TABLE 2 Surgical outcomes of patients receiving a reconstructive operation with pectoralis muscle flap and RAM sheath

	Total n = 46
Re-exploration for bleeding, n (%)	4 (8.7%)
Prolonged MV use, n (%)	8 (17.4%)
Prolonged ICU stay, n (%)	10 (21.7%)
Hospital stay, day, median (range)	31 (0-157)
ASA physical status score, median (range)	3 (2-4)
Recurrence, n (%)	8 (17.4%)
Mortality, n (%)	7 (15.2%)
Postoperative complications, n (%)	7 (15.2%)
Reoperation for postoperative complication, n (%)	4 (8.7%)
Drainage tube use, day, median (range)	12 (2-34)

Abbreviations: ASA, American Society of Anesthesiologists; ICU, intensive care unit; MV, mechanical ventilation; RAM, rectus abdominis muscle.

a median age of 65 (40-88) years. The cardiac surgical procedures performed were 34 cases of coronary artery bypass graft and 12 cases of valve surgery. Over 80% of the patients had comorbidities (diabetes, hypertension, or end-stage renal disease), and 85% had positive bacterial cultures.

3.2 | Surgical outcomes

The surgical outcomes of the patients who received a reconstructive operation are given in Table 2. During wound reconstruction, 4 (8.7%) patients received re-exploration for bleeding. After wound reconstruction, the proportion of prolonged mechanical ventilation use and ICU stay were 17.4% (n = 8) and 21.7% (n = 10), respectively. The 30-day all-cause mortality was 15.2%; recurrence rate was 17.4%; median length of drainage tube use was 12 (2-34) days; and median hospital stay was 31 (0-157) days. There were no cases with life-threatening postoperative complications (a complication with grade IV or higher defined according to the Clavien-Dindo classification of surgical complications).[23] In the remaining seven patients, there were one or more postoperative complications. Most of the complications were wound problems like prolonged drain tube insertion (>30 days) (n = 5) or minor wound necrosis (n = 2).

TABLE 3 Association of hospital stay with patients' characteristics

Variables	β (95%CI)	*P*-value
Age	0.115 (−0.579, 0.808)	.732
Gender/male	17.037 (−0.369, 34.443)	.055
BMI	7.430 (−10.011, 24.871)	.381
Alcohol use	4.642 (−19.940, 29.224)	.696
Smoking	10.270 (−16.075, 36.615)	.423
Comorbidity		
Hypertension	21.316 (4.955, 37.677)	.014*
Diabetes	12.525 (−4.985, 30.034)	.150
ESRD	0.923 (−16.964, 18.811)	.915
IMA use	1.761 (−18.441, 21.963)	.857
Length of drainage tube use	0.944 (0.273, 1.614)	.008*
Re-exploration for bleeding	13.321 (−16.614, 43.257)	.362
Prolonged MV use	21.670 (−6.201, 49.541)	.120
ASA physical status score	11.353 (−14.762, 37.468)	.373

Abbreviations: ASA, American Society of Anesthesiologists; ESRD, end-stage renal disease; ICU, intensive care unit; IMA, internal mammary artery; MV, mechanical ventilation.
*$P < .05$.

3.3 | Association of surgical outcomes with patients' characteristics

Multivariate logistic regression analysis revealed that most patients' characteristics, including age, gender, body mass index, alcohol use, smoking, hypertension, diabetes, end-stage renal disease, ASA-physical status, internal mammary artery use, drainage tube use, re-exploration for bleeding, and prolonged mechanical ventilation use, were not significantly associated with 30-day all-cause mortality or recurrence of wound infection (all $P > .05$, Table S1 and Table 2). Multivariate linear regression analysis revealed that hypertension (β = 21.316, 95% CI 4.955-37.677, $P = .014$) and length of drainage-tube use (β = 0.944, 95% CI 0.273-1.614, $P = .008$) were positively associated with hospital stay (Table 3).

4 | DISCUSSION

Flap reconstruction for treatment of DSWI has been used for decades, but ours is the first study to describe the clinical presentation, microbiological characteristics, and outcomes of reconstruction using bilateral pectoralis myocutaneous flap and RAM sheath fasciocutaneous flap. Flap reconstruction was introduced by Jurkiewicz et al.[24] The authors used pectoralis major flaps, and, if muscle tissue was insufficient to cover the dead space, greater omentum flaps. Initially, these flaps were used when conventional closed irrigation failed. Regional latissimus dorsi or rectus abdominis flaps or free flaps now are also used. In the 1980s, before the introduction of negative-pressure wound therapy dressing,[6] flaps were used as primary treatment, and single-stage flap reconstruction was favoured over catheter wound irrigation. In this series, the outcomes with bilateral pectoralis myocutaneous flap and RAM sheath fasciocutaneous flap in the treatment of DSWI after cardiac surgery were acceptable considering the severity of the condition: 17.4% recurrence, 15.2% mortality, 17.4% prolonged mechanical ventilator use, 21.7% prolonged ICU stay, 15.2% postoperative complications, and the median hospital stay of 31 (0-157) days. Hypertension, drainage tube use, and prolonged ICU stay were found independent risk factors for length of hospital stay.

Sternal wound infection is a complex wound, and its treatment is challenging for surgeons.[25] Several surgical options have been proposed for the treatment of sternal

wound dehiscence, including primary synthesis with metal wires, titanium plates, and sternal reconstruction, using muscle or omental flaps.[14,16,26,27] The use of bilateral pectoralis major muscle flaps has had better rates of stabilisation of the chest wall than has had sternal reconstruction with metal wires.[27] Eventually, it was found that a portion of the anterior fascia of the rectus abdominis muscle could be dissected and attached to the caudal part of the pectoralis major myocutaneous flap to facilitate wound closure. Alternatively, only the cephalic portion of the rectus abdominis muscle can be transposed, which has been reported to have a decreased risk of postoperative herniation of the abdominal wall.[28] In our experience, sternal reconstruction with bilateral pectoralis myocutaneous flap and the anterior layer of the RAM sheath fasciocutaneous flap improved stability of the thoracic wall in patients with large sternal defects. Our RAM sheath fasciocutaneous flap did not contain RAM, consequently, we did not worry about the risk of harvesting RAM-related hernia[29] or hindering spontaneous breathing.[30] Particularly, our patients had a lower rate of postoperative complications (15.2%) than that in previous reports.[31-33] This implicates that sternal reconstruction with bilateral pectoralis myocutaneous flap and the bilateral anterior layer of the RAM sheath fasciocutaneous flap may be a greater safety.

The incidence of sternal incision infection (sternal wound infections) after median sternal incision can be as high as 3% to 5%.[34] According to the severity of the disease, the infection can be superficial or deep. Superficial infections are those of skin, subcutaneous tissue, and pectoralis major fascia, with a mortality rate of 0.5% to 4.4%.[35] Deep infections are those of tissue or space below the subcutaneous tissue – costochondritis, sternal osteomyelitis, and mediastinitis – with reported mortality rates of 7% to 47%.[2] Several studies have investigated a possible association between the type of flap used and mortality.[9,14] With the type of combined pectoralis and rectus abdominus flap we used, the 30-day mortality was 15.2% in patients with sternal osteomyelitis, and 8 (17.4%) patients had wound recurrence, which is consistent with the previous reports.[9,14] The mortality rate in our series may be increased in part because of the advanced age of the patients and frequent cardiovascular comorbidities, which are prominent risk factors for deep sternal wound infection.[36] Given the complexity and poor prognosis of DSWI after cardiac surgery, we feel that the bilateral pectoralis myocutaneous flap and bilateral anterior layer of RAM sheath fasciocutaneous flap approach is a reliable approach.

It is recognised that postoperative risks and donor site morbidity are acceptable after flap surgery for sternal infections. Nevertheless, Zacharias et al[37] have concluded that flap reconstruction should be limited to patients with large defects, uncontrolled mediastinal bleeding, or both; in their study, 33 patients' sternal wounds healed with debridement, antibiotics, and delayed closure, whereas five patients with more significant infections required flap reconstruction, 4 of whom required re-operation for sequelae of reconstructive surgery, and 2 died.[37] Others[38-40] have opined that musculocutaneous flaps should be reserved for high-risk patients who fail other treatments. In our series, postoperative complication required re-operation rate after combined flap surgery was (8.7%), compared with a re-operation rate of 30.8% in a previous study,[41] indicating that pectoralis muscle flap combined rectus abdominis muscle sheath fasciocutaneous flap may be a beneficial strategy for sternal reconstruction.

For many years, well-vascularized omental[42] or pectoral muscle[25] flaps have provided stable coverage to the sternotomy wound after radical debridement. These treatment strategies have increased long-term success from 50%[3,4] to now 90% to 99%.[42,43] The average length of hospital stay has dropped from 84 days to under 13 days,[44] which is impressive since DSWI can cause a morbidity rate of up to 50%, with a prolonged hospital stay and an increased cost of care.[3,4] In the present study, the median hospital stay was 31 days in patients with DSWI who received a sternal reconstruction using a bilateral pectoralis myocutaneous flap and a rectus abdominis muscle sheath fasciocutaneous flap. The long hospital stay can be explained in part by the advanced age of the patients and many cardiovascular comorbidities, which might be prominent risk factors for a prolonged stay.

Several risk factors, both patient- and procedure-dependent have been identified for DSWI. Preoperative or patient factors include diabetes mellitus, obesity, smoking, chronic obstructive pulmonary disease, low left ventricular ejection fraction, and renal failure.[26] Intraoperative factors such as length of surgery and the use of bilateral internal mammary artery conduits have been considered important for the development of DSWI.[26] Postoperative factors such as prolonged ventilation, redo-operation, the requirement of transfusion, and prolonged use of inotropic drugs have been found associated with DSWI in some studies.[26] The present study also found were high proportions of smoking, diabetes, hypertension, end-stage renal disease, and internal mammary artery use in patients with DSWI. Interestingly, not reported in previous studies, we found that hypertension and duration of drainage tube use were significantly associated with a hospital stay, although these DSWI-related risk factors were not significantly associated with 30-day mortality and postoperative recurrence. The previous study reports that hypertension is positively associated with wound closure complications (hematoma, partial

flap loss, total flap loss, nonpurulent wound dehiscence, abdominal hernia, or re-exploration for wound necrosis) in patient with sternal infection after reconstruction with muscle flap.[45] Additional evidence also reveals that incorrect management of chest drains may lead to a number of complications which can result in increased morbidity, extended hospital stay, and, in some cases, mortality.[46] Recently, Li et al[47] demonstrated that the volume of drainage and the duration of drainage in patients with minimally invasive cardiac surgery who received early prophylactic anticoagulation were significantly more than the control group, and the poor wound healing and the postoperative hospitalisation time were also significantly increased in patients received early prophylactic anticoagulation, indicating that the duration of drainage is associated with poor wound healing and hospital stay. In the present study, drainage tube was removed, when the drainage amount is less than 15 mL/day, which means (a) the dead space under the flap has been fully healed; (b) the inflammatory phase of the wound healing process has been passed, indicating that the infection status has been controlled. Although no previous study reports the association of duration of drainage tube use and hospital stay in patients with sternal reconstructive surgery, prolonged drainage tube insertion also implies that the infection is less easily controlled, which may explain the prolonged hospital stay. Thus, we suggest that the duration of drainage tube use may be as an index for prediction of hospital stay or wound healing in DSWI patients after reconstruction using bilateral pectoralis myocutaneous flap and bilateral anterior sheath of rectus abdominis muscle sheath fasciocutaneous flap.

In addition to flap coverage, another option for sternal wound closure is negative pressure wound therapy (NPWT; also known as VAC), resulting in wound fluid drainage, reduction of bacterial colonisation, dilation of arterioles, and granulation formation.[48,49] Previous studies have found that the clinical effect of VAC is comparable to traditional closed drainage or open packaging, which can improve sternal wound healing, reinfection rate, ICU stay and possible mortality.[48,49] However, the VAC system itself can become a reservoir of microorganisms and may lead to the emergence of multi-drug-resistant microorganisms, such as gram-negative bacilli and yeasts.[50] Recently, an incision management system, Prevena, improves the outcome of DSWI surgical treatment with monolateral pectoralis major muscle flap in a high-risk patient population.[51] In addition, Torto et al also report that DSWI patients who received a combination of NPWT with the monolateral pectoralis major muscle flap have a high coverage effectiveness and guarantee the saving of contralateral muscles with its functionality and the possibility of its use in case of failure.[52]

In the present study, long-term antibiotics and adequate drainage with a closed-suction drainage tube were used for the treatment of sternum osteomyelitis and anterior mediastinitis in all patients after wound reconstruction surgery. We observed a lower rate of postoperative complications, re-infection, and mortality. According to these findings, we suggest that the procedure including surgical debridement (but conservation removal of the infected sternum), sternal reconstruction with bilateral PM and RAM sheath flap, long-term antibiotics, and adequate drainage may be a good strategy for the treatment of sternal infection after wound reconstruction.

5 | LIMITATION

We acknowledge that our report has limitations: It is a small series from a single surgeon, so its general applicability is unknown. Also, it is a retrospective study, thus subject to the biases of such a study design. Nonetheless, the study contributes useful information about one treatment modality of the challenging problem of post-cardiac operation deep sternal infections.

6 | CONCLUSION

The procedure including surgical debridement, sternal reconstruction with bilateral PM and RAM sheath flap, long-term antibiotics, and adequate drainage is a beneficial technique in the reconstruction of deep sternal wound infection after cardiac surgery, even in older patients. Duration of drainage tube use may be as an index for a hospital stay or wound healing. Results of this single-site study should be assessed in studies of larger patient populations in multiple centers with longer follow-up periods.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are included within the article and its supplementary information files.

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SUPPORTING INFORMATION

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