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Reconstructive

Less Invasive Management of Tissue Deficits for Deep Sternal Wound Infections

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Background: The frequency of sternomyelitis after cardiovascular surgery has been reported to be 0.4% -5%.
Methods: The treatment method used for 47 patients (29 male and 18 female) who developed sternomyelitis after sternotomy with tissue defects in the chest was examined retrospectively.
Results: Of the original conditions, the most frequent was coronary artery disease undergoing bypass grafting (22 cases, 46.8%), followed by acute aortic dissection (10 cases, 21.3%). The number of times debridement was performed was: once, 35 cases; twice, 11 cases; 7 times, 1 case; and unknown, 2 cases. The most frequent time of occurrence of sternomyelitis was within 2 weeks after surgery (12 patients, 25.5%). A residual internal thoracic artery remained on both sides in 28 cases (59.6%), and only on the right side in 17 cases (36.2%); there was no remaining one in 2 cases (4.2%). The reconstruction method was a pectoralis major musculocutaneous flap in 31 cases (66.0%), internal mammary artery perforator flap in 7 cases (14.9%), rectus abdominis musculocutaneous flap in 4 cases (8.5%), omentum transplant in 3 cases (6.4%), superior epigastric artery perforator flap in 2 cases (4.3%), external abdominal oblique muscle flap in 1 case (2.1%), and latissimus dorsi musculocutaneous flap in 1 case (2.1%). The internal mammary artery perforator flap and the superior epigastric artery perforator flap have been effective treatment.
Conclusions: In 47 patients, our method of treatment for tissue defects of the chest wall after sternal osteomyelitis was examined, and an algorithm using less invasive management was proposed. *(Plast Reconstr Surg Glob Open 2020;8:e2776; doi: 10.1097/GOX.0000000000002776; Published online 30 April 2020.)*

INTRODUCTION

The frequency of sternomyelitis after cardiovascular surgery has been reported to be 0.4%–5%, and if there is persistence of a foreign body or a sequestrum, it is refractory.[2,3] Moreover, infections in the mediastinum, pericardium, and chest cavity are life threatening. Infection can normally be controlled by performing enough tissue filling on the same site by using sufficient tissues after necrotic tissue debridement.

A musculocutaneous flap, such as a pectoralis major musculocutaneous flap or a rectus abdominis musculocutaneous flap, is often selected for reconstruction of the defect, but surgical invasion increases in patients after cardiac surgery, and using a muscle flap can result in donor-site problems. After cardiac surgery, some of the traditional muscle techniques may not be options due to use of the mammary vessels, thus resulting in higher complication rates.

Local perforator flaps are very useful when the defects are not deep. Our method of treatment for tissue defects of the chest wall after sternal osteomyelitis is examined, and an algorithm using less invasive management is proposed.

MATERIALS AND METHODS

From April 2000 to December 2016, 47 patients with sternomyelitis and mediastinitis after sternotomy were treated at the Saga University Hospital and other related hospitals. The time and number of debridements, presence or absence of residual internal mammary

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arteries, reconstruction methods, and treatment results were examined.

RESULTS

There were 47 cases (29 men and 18 women; age range, 52–88 years; average age, 72.0 years). Of the original diseases and surgeries performed, there were 22 cases (46.8%) of coronary artery bypass grafting (CABG), 10 cases (21.2%) of acute aortic dissection, 5 cases (10.6%) of thoracic aortic aneurysm, 5 cases (10.6%) of aortic valve replacement, 1 case (2.1%) of tricuspid valvuloplasty, 1 case (2.1%) of sternomyelitis caused by irradiation, 1 case (2.1%) due to mucormycosis, 1 case (2.1%) of mitral valve replacement, and 1 case (2.1%) of pulmonary thromboembolism (Table 1, Fig. 1). Debridement was performed after cardiovascular surgery once in 35 cases (74.5%), twice in 11 cases (23.4%), and 7 times in 1 case (2.1%). Three cases occurred within 1 week after surgery; 11 cases in 2 weeks; 3 cases in 3 weeks; 5 cases in 4 weeks; 2 cases in 5 weeks; 4 cases in 6 weeks; 1 case in 7 weeks; 1 case in 8 weeks; 6 cases in 3 months; 1 case in 4 months; 3 cases in 5 months; 2 cases in 7 months; 1 case each in 6, 8, and 9 months; and 1 case each in 4 and 6 years. The most frequent was 2 weeks after surgery. Residual internal mammary arteries remained after surgery on both sides in 26 cases (55.3%) and on the right side in 17 cases (36.2%); there were none in 2 (4.3%), and 2 were unknown (4.3%). The reconstruction method was a pectoralis major musculocutaneous flap in 31 cases (66.0%), an internal mammary artery (IMA) perforator flap in 7 cases (14.9%), a rectus abdominis musculocutaneous flap in 4 cases (8.5%), omentum transplant in 3 cases (6.4%), a superior epigastric artery perforator (SEAP) flap in 2 cases (4.3%), an external abdominal oblique muscle flap

Table 1. Forty-seven Cases of Our Patients

Case	Age (y) and Sex	Current Disease and Surgery	Time of Debridement After Surgery	No. Debridements	Residual IMA	Reconstruction
1	72 M	Tricuspid valvuloplasty	5 W	1	Both	Rt. pectoralis major
2	82 M	Aortic valve replacement	2 W	1	Both	Rt. pectoralis major
3	82 M	Aortic valve replacement	4 W	1	Both	Rt. rectus abdominis
4	63 M	CABG	4 W	1	Right	Rt. pectoralis major
5	81 M	Mucormycosis	2 W	1	Both	Lt. IMA perforator flap
6	79 F	Sternomyelitis caused by irradiation	3 W	1	Both	Lt. IMA perforator flap
7	60 M	CABG	3 W	1	Both	Lt. IMA perforator flap
8	79 F	Aortic valve replacement	3 W	1	Both	Rt. IMA perforator flap
9	75 M	Acute aortic dissection	5 W and 7 W	2	Both	Rt. pectoralis major
10	71 M	CABG	5 W	1	Right	Rt. pectoralis major
11	72 F	Aortic valve replacement	3 M	1	Both	Lt. external abdominal oblique
12	70 M	CABG	1 W	1	Right	Rt. pectoralis major
13	70 M	CABG	5 M	1	Right	Omentum transplant
14	75 M	CABG	2 W	1	Right	Rt. rectus abdominis
15	77 F	CABG	2 W	1	Right	Rt. pectoralis major
16	88 F	Aortic valve replacement	1 W and 3 M	2	Both	Rt. pectoralis major
17	73 M	CABG	2 W and 4 W	2	Right	Rt. IMA perforator flap
18	79 F	CABG	2 W and 5 W	2	Both	Lt. IMA perforator flap
19	86 F	CABG	4 W	1	Right	Rt. pectoralis major
20	75 M	CABG	2 W and 7 W	2	Right	Rt. pectoralis major
21	74 F	Acute aortic dissection	7 M and 8 M	2	Both	Rt. pectoralis major
22	52 M	CABG	1 W and 3 W	2	Both	Rt. pectoralis major
23	F	CABG	2 W	1	Right	Rt. pectoralis major
24	75 F	Acute aortic dissection	7 W	1	Both	Rt. pectoralis major
25	62 M	Acute aortic dissection	7 W	1	Both	Omentum transplant
26	81 M	CABG	3 M	1	Right	Omentum transplant
27	57 M	Acute aortic dissection	4 Y	1	Both	Rt. pectoralis major
28	76 M	Acute aortic dissection	3 M	1	Both	Rt. pectoralis major
29	77 M	Thoracic aortic aneurysm	6 Y	2	Both	Rt. pectoralis major and Rt. latissimus dorsi
30	80 F	Pulmonary thromboembolism	4 W	1	Both	Rt. pectoralis major
31	74 F	CABG	3 M	1	Right	Rt. pectoralis major
32	56 M	CABG	6 W and 3 M	2	Right	Rt. pectoralis major
33	75 M	CABG	3 M	1	None	Rt. pectoralis major
34	58 M	CABG	6 W	1	None	Rt. pectoralis major
35	72 M	Acute aortic dissection	5 M	2	Both	Rt. pectoralis major
36	64 F	Mitral valve replacement	2 M	1	Right	Rt. pectoralis major
37	59 M	Acute aortic dissection	9 M	1	Both	Rt. pectoralis major
38	70 F	Thoracic aortic aneurysm	4 M	1	Both	Rt. pectoralis major
39	81 F	Thoracic aortic aneurysm	6 M	1	Both	Rt. pectoralis major
40	59 M	CABG	2 W	1	Right	Rt. pectoralis major
41	80 F	Acute aortic dissection	8 M	1	Both	Rt. pectoralis major
42	65 M	Thoracic aortic aneurysm	6 W	7	Both	Lt. rectus abdominis and Rt. pectoralis major
43	85 M	Thoracic aortic aneurysm	3 M	1	Both	Rt. pectoralis major
44	64 F	Acute aortic dissection	7 M and 8 M	1	Both	Lt. IMA perforator flap
45	67 F	CABG	2 W	1	Right	Rt. pectoralis major
46	M	CABG	3 W	1	Both	SEAP flap
47	M	CABG	4 W	2	Both	SEAP flap

Age and sex: F, female; M, male. Time: M, months, W, weeks. Lt, left; Rt, right.

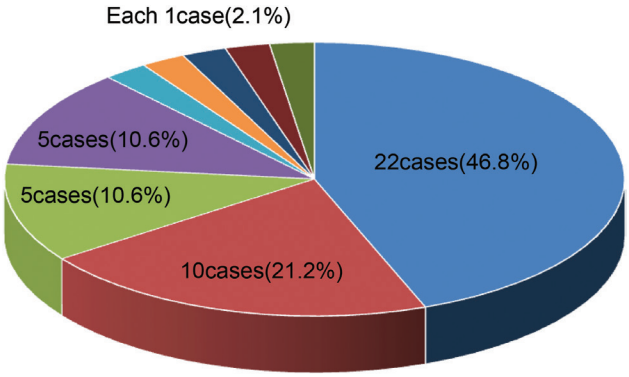

Fig. 1. Of the original diseases and surgeries performed, there were 22 cases (46.8%) of CABG, 10 cases (21.2%) of acute aortic dissection, 5 cases (10.6%) of thoracic aortic aneurysm, 5 cases (10.6%) of aortic valve replacement, 1 case (2.1%) of tricuspid valvuloplasty, 1 case (2.1%) of sternomyelitis caused by irradiation, 1 case (2.1%) due to mucormycosis, 1 case (2.1%) of mitral valve replacement, and 1 case (2.1%) of pulmonary thromboembolism. CABG indicates coronary artery bypass grafting.

in 1 case (2.1%), and a latissimus dorsi musculocutaneous flap in 1 case (2.1%) (Table 1 and Fig. 2). In all cases, the treatment outcome was successful wound coverage. In 45 cases (95.7%), healing occurred with one reconstructive operation, 2 cases (4.3%) showed recurrence, requiring several reconstructions, but these were cases where an artificial blood vessel could not be removed. Recurrence was confirmed in cases reconstructed with a rectus abdominis musculocutaneous flap (1 case) and a pectoralis major musculocutaneous flap (1 case). There were no recurrences in cases of reconstruction with an IMA perforator flap. Recurrences of osteomyelitis were thought to be due to insufficient debridement, and the choice of the flap was not the issue.

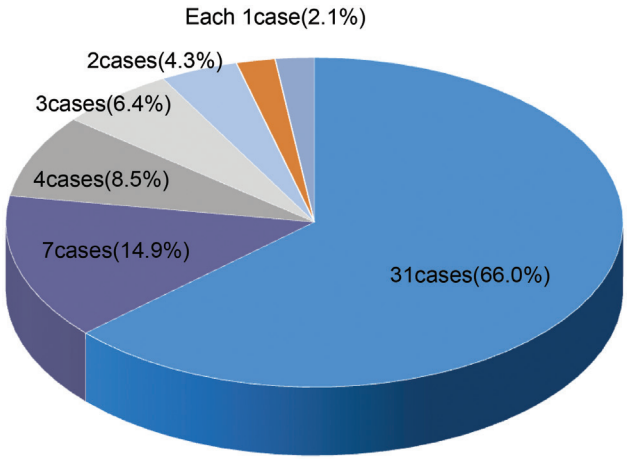

Fig. 2. The reconstruction method was a pectoralis major musculocutaneous flap in 31 cases (66.0%), an internal mammary artery perforator flap in 7 cases (14.9%), a rectus abdominis musculocutaneous flap in 4 cases (8.5%), omentum transplant in 3 cases (6.4%), a superior epigastric artery perforator flap in 2 cases (4.3%), an external abdominal oblique muscle flap in 1 case (2.1%), and a latissimus dorsi musculocutaneous flap in 1 case (2.1%).

In addition, the pectoralis major musculocutaneous flap was used for cases where the defect was large and it took time to raise good granulation, and the IMA perforator flap and the SEAP flap were used in cases where the defect was relatively small and good granulation had risen early.

Case 1

A 64-year-old woman became aware of sudden anterior chest pain and was diagnosed with acute aortic dissection and aortic valve insufficiency. She underwent aortic arch replacement and aortic valve replacement. Seven months after surgery, discharge was confirmed from the median thoracic chest wall, and plastic surgery was consulted.

Culture was positive for methicillin-resistant *Staphylococcus aureus*. After wound cleansing and debridement surgery after drainage, negative pressure wound therapy with instillation and dwell time (NPWTi-d) was started, and the wound site was managed. After about 1 month, the local inflammatory findings showed some improvement. At that time, the skin defect was 15 × 3 cm, and the sternum was exposed in the wound, but the necrotic bone was removed in the previous surgery. On computed tomography, there was no suspicion of abscess remaining in the mediastinum. The signs of infection had calmed down, and good granulation was observed. The sternum was covered with granulation tissue, the infection was completely calmed down, and surgery was performed under general anesthesia.

A perforator pedicled propeller flap (with a 13 × 4.5 cm skin island) using the left IMA penetrating branch (left third intercostal) and a left pectoralis major musculocutaneous flap were planned. At the time of surgery, the sternum was resected to the site where bleeding was confirmed. The wound was washed with saline using SURGLAB (Stryker, Kalamazoo, Mich.). The left pectoralis major musculocutaneous flap was then raised and moved to the upper wound. The IMA perforator flap was also raised. Pulsating vasculature was confirmed. The flap was rotated 180 degrees and moved to the defect. The flap color was good during the operation, and simple closure was used for the donor site. The flaps were engrafted, no complications were observed, and no recurrence was observed at 6 months after surgery. The position of the left nipple was shifted slightly downward due to retraction of the donor-site closure, but the flap remained in good position (Fig. 3).

Case 2

A 67-year-old woman underwent cardiac surgery (CABG) due to precordial pain diagnosed as angina pectoris. Two weeks after surgery, discharge was confirmed from the median thoracic chest wall. The culture was positive for methicillin-resistant *Staphylococcus epidermidis*. After drainage and wound debridement, the infection returned. Plastic surgery was consulted, and NPWTi-d therapy was started.

The skin defect was 8 × 3 cm, and bone exposure of the sternum was observed in the wound. Signs of infection

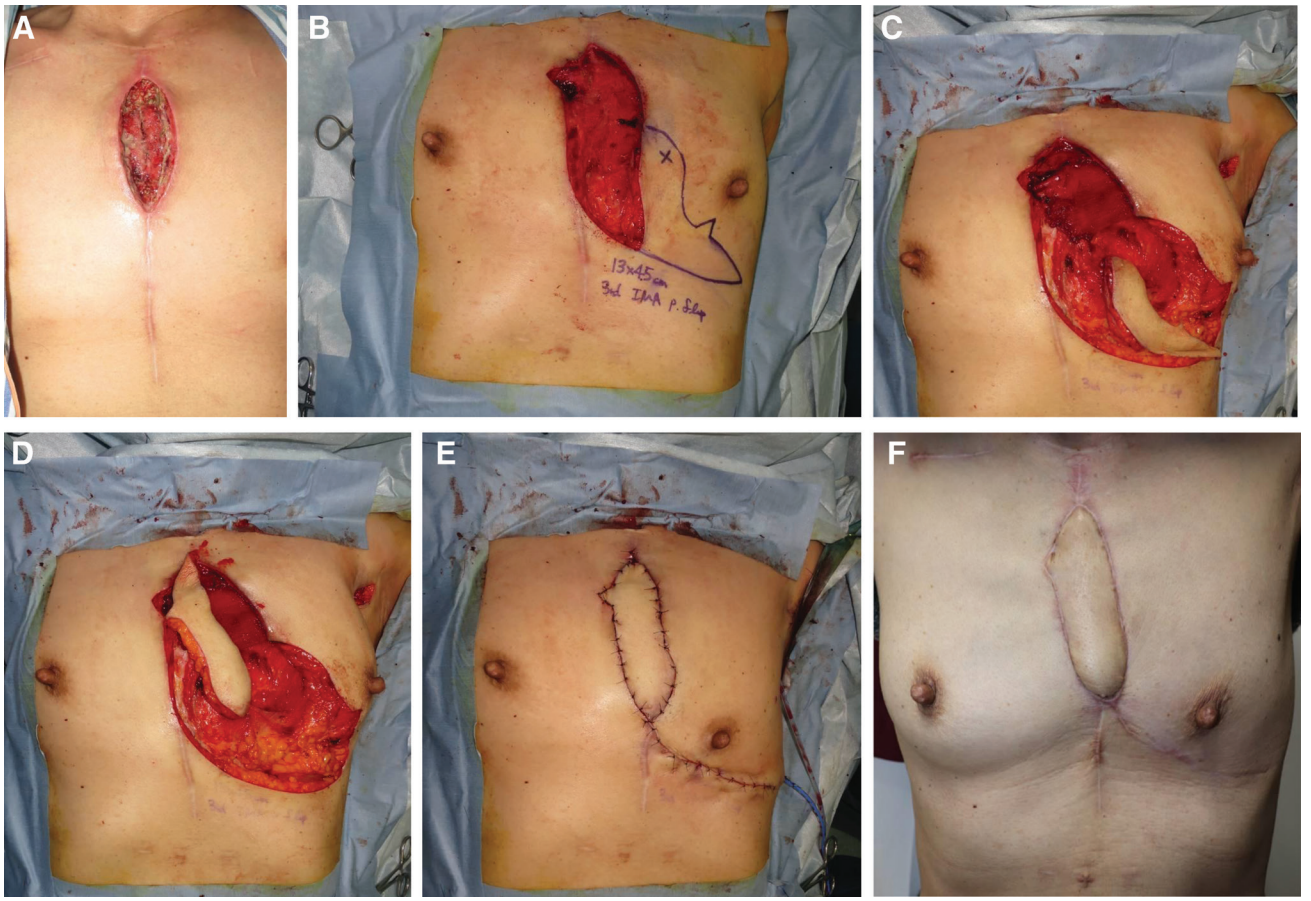

Fig. 3. Case 1: IMA perforator flap. A, The skin defect was 15 × 3 cm, and the sternum was exposed in the wound. B, A perforator pedicled propeller flap (with a 13 × 4.5 cm skin island) using the left internal mammary artery penetrating branch (left third intercostal) and a left pectoralis major musculocutaneous flap were planned. C, The flap was raised. D, The flap was rotated 180 degrees and moved to the defect. E, The flap color was good during the operation, and simple closure was used for the donor site. F, No recurrence was observed at 6 months after surgery.

seen after the last surgery had settled, but there was no increase in granulation at the site of bone exposure. After 4 weeks of NPWTi-d, it was judged that there was no infection, but it was thought that no increase in granulation could be expected, and surgery was performed under general anesthesia.

Reconstruction with a right pectoralis major musculocutaneous flap was planned. At the time of surgery, the sternum was resected to the site with confirmed bleeding. The inside of the wound was washed with saline using SURGLAB (Stryker). The right pectoralis major musculocutaneous flap was designed at the right inframammary fold incision, and the flap was lifted and moved to the median wound. The flap filled the defect completely. Simple closure of the skin was performed. The skin flap was fully engrafted. Although there was a hypertrophic scar in the lower center, there were no complications after surgery, and there were no signs of recurrence half a year after the operation (Fig. 4A–E).

DISCUSSION

Diabetes mellitus, renal dysfunction, chronic obstructive pulmonary disease, CABG using bilateral internal thoracic arteries, smoking, and others are possible risk factors after midline sternotomy that can cause sternomyelitis and mediastinitis. Once they occur, treatment is often refractory and sometimes follows a lethal course.

First, control of infection is necessary, and removal of necrotic tissue and of foreign bodies is indispensable, but in many cases, the patient's condition is poor, and it is difficult to establish the right treatment.

Deep sternal wound infections are invariably accompanied by varying degrees of sternal dehiscence and mediastinitis. Furthermore, even a purely mechanical sternal dehiscence will quickly get secondarily infected unless rewiring is undertaken expeditiously. The negative pressure wound therapy (NPWT) has revolutionized the ward-based management of deep sternal wound infections. Pectoralis, rectus, and latissimus flaps and omental grafts are the commonest forms of sternal reconstruction, although free flaps, intercostal perforator flaps, breast flaps, and allogeneic bone grafts have been used.[4–8]

Therefore, based on this study of the treatment of sternomyelitis/mediastinitis, an algorithm for treatment was developed.

First, with respect to staging of osteomyelitis, the classification of Pairolero and Arnold[9] is a representative one.[3]

A total of 100 cases of sternomyelitis and mediastinitis were *classified as type I to type III* based on the stage of onset, the amount of exudate, the presence or absence of cellulitis, etc, but occurrence was most likely (84 cases) within a few weeks after surgery in stage II. Even in the present cases, *type II* was the most common (27 cases) (Table 2).

It seems that, in cases after CABG, the use of the IMA may tend to induce and exacerbate infection early due to insufficient blood flow in the sternum.

For reconstruction, it has been reported that the pectoralis major musculocutaneous flap is the most commonly used, and good results were reported in 83% of reconstructive cases. [9,10]

Pairolero and Arnold[9] and Pairolero et al[10] *reported 252 reconstruction methods* in their 2 articles. In the present study, the pectoralis major musculocutaneous flap was used for 31 cases (63.2%). In recent years, there has been an increasing trend to use the IMA perforator flap; it was used in 6 cases, and the SEAP flap was used for 2 cases in the present study (Table 3 and Fig. 2).

As a reason for this, local NPWT and NPWTi-d have become the first choice as a treatment method after debridement in recent years, and the infection can be controlled.

In the present study, there were 3 cases on the right and 3 cases on the left of IMA perforator flaps. Regarding this, either the left or right can be selected if both internal mammary arteries remain, but in the case of using the left IMA as a graft at the time of CABG, the right side IMA perforator flap was used. If the IMA is missing, the SEAP flap is useful as a safe alternative. Based on the above, the current standard in reconstructive surgery after sternomyelitis is to eliminate foreign substances such as wires and perform debridement, and if the infection is controlled, the use of the pectoralis major musculocutaneous flap

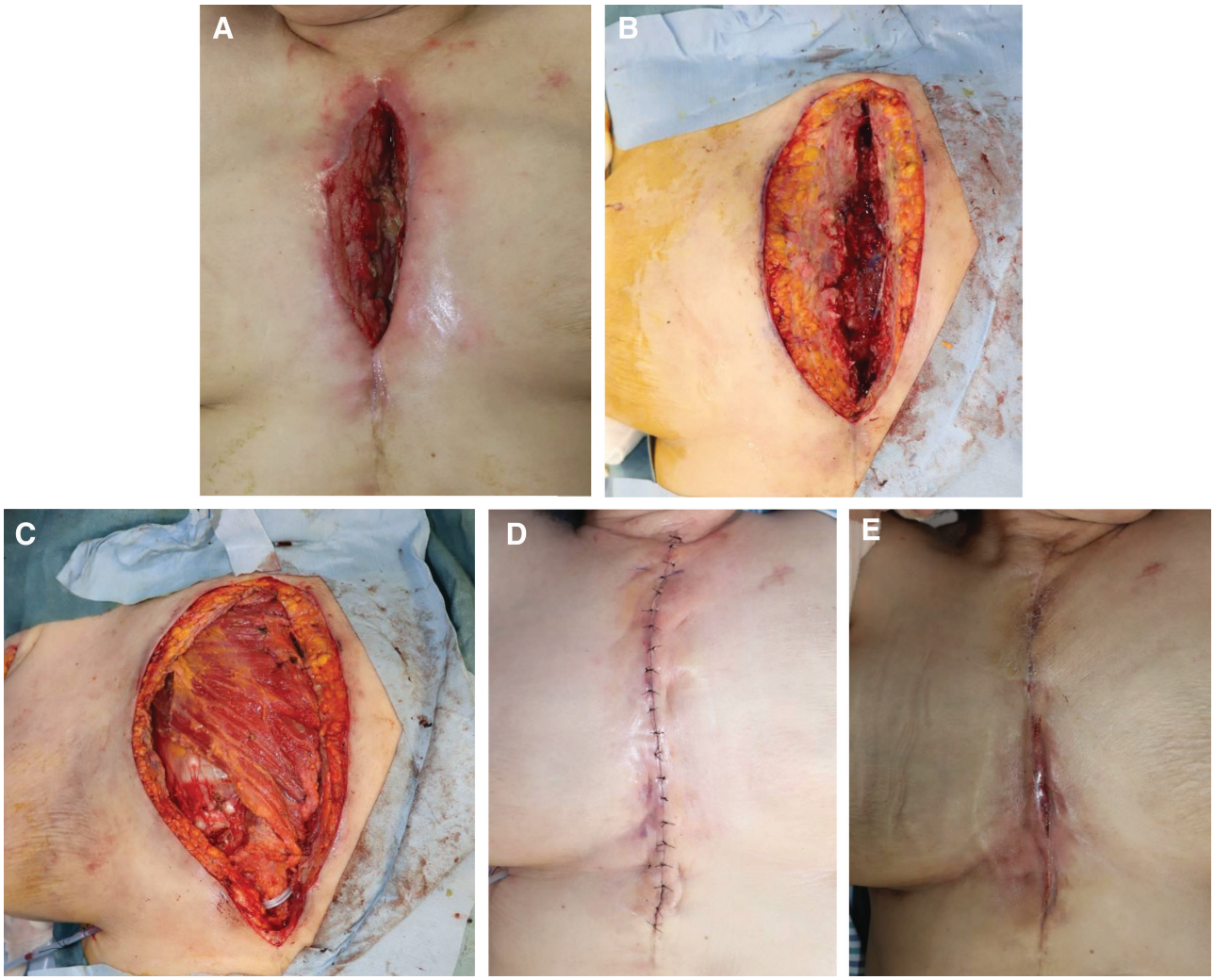

Fig. 4. Case 2: Pectoralis major flap. A, The skin defect was 8 × 3 cm, and bone exposure of the sternum was observed in the wound. B, The sternum was resected to the site with confirmed bleeding. C, The right pectoralis major musculocutaneous flap was designed and raised. D, Simple closure of the skin was performed. E, There was a hypertrophic scar in the lower center, but there were no signs of recurrence half a year after the operation.

Table 2. Classification of Sternomyelitis and Mediastinitis

	Type I	Type II	Type III
Onset	Within a few days	Within several weeks	Several months to several years
Exudate	Bloody	Purulent	Chronic retention
Cellulitis	(−)	(+)	Local
Mediastinum (mediastinitis)	Soft	Purulent	Rare
Osteomyelitis	(−)	(+)	(+)
Culture	Negative	Positive	Positive
Total, n (%)	11 (11.0)	84 (84.0)	5 (5.0)
Present cases, n (%)	3 (0.06)	27 (57.4)	17 (36.1)

A total of 100 cases of sternomyelitis and mediastinitis were classified as type I to type III.

Table 3. Reconstruction Methods

	Total	Present Cases
Pectoralis major musculocutaneous flap	242	31
Latissimus dorsi musculocutaneous flap	3	1
Serratus anterior flap	1	0
Rectus abdominis musculocutaneous flap	3	4
External abdominal oblique muscle flap	2	1
Other flap	1	0
Internal thoracic artery perforator flap	0	7
Omentum transplant	0	3
SEAP flap	0	2
Total	252	49

Pairolero et al[9] reported 252 reconstruction methods, and our reported cases.

muscle flap (and free skin grafting) is standard. *However, because donor sites involve the use of muscles, the procedure is highly invasive to patients.* On the other hand, if the granulation rises with NPWT and NPWTi-d and a good wound bed is prepared, the IMA perforation flap and the SEAP flap are also useful. Their advantages include that they are minimally invasive, involve less donor-site sacrifice, provide anatomically stable perforators, relatively easy elevation, use of internal mammary arteries, although it depends on whether raising flaps from both sides is also possible, etc. Fortunately, no cases of recurrence have yet been seen with this approach. If the IMA is used for cardiac surgery, it is better not to use the flap on that side, but to consider surgery *using the opposite-side IMA or the intercostal artery.*

Based on the above, we have developed an algorithm for the treatment of sternomyelitis and mediastinitis. Debridement including wire removal is performed first, and NPWT is used for 2 weeks to control infection. If we cannot control it or infection recurs, debridement is repeated. Control is then performed, and if there is no dead space and the position of the perforator of the IMA or superior epigastric artery can be confirmed by color Doppler, such as duplex scanning before surgery, the IMA perforator flap and a SEAP flap are used. When there is a large dead space, we consider the use of the pectoralis major musculocutaneous flap/rectus abdominis musculocutaneous flap/omentum transplant (Fig. 5). By using this algorithm, we have had no recurrences of sternomyelitis after reconstructive surgery, good results have been obtained, and it is considered a safe and less invasive treatment at present. Recognizing that sternal osteomyelitis is a complication that can occur after heart surgery, it is important to standardize subsequent treatment, and our treatment algorithm has been proposed for this purpose at this time.

CONCLUSIONS

For the defects that occur after sternomyelitis, reconstructive surgery was performed after infection control,

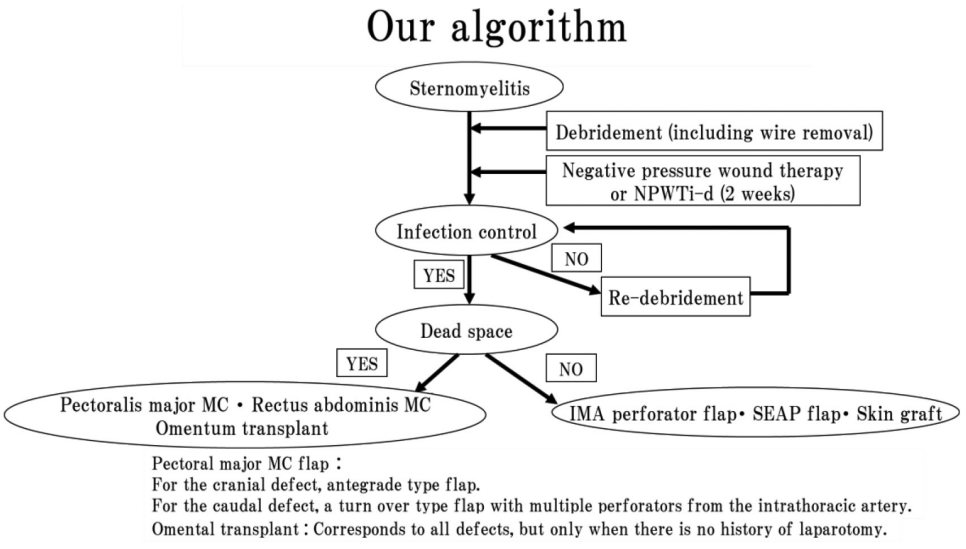

Fig. 5. Our algorithm for tissue defects in the midline of the thorax after sternal osteomyelitis. MC, musculocutaneous.

such as debridement and NPWT, and a treatment algorithm was proposed.

When the dead space is large, the use of a pectoralis major musculocutaneous flap is the first choice, but with the use of NPWT and NPWTi-d management in recent years, by controlling the infection sufficiently and increasing the granulation, the IMA perforator flap and SEAP flap have been effective treatment options; such flaps are reliable and easy to raise and spare donor-site morbidity.

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