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. 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 was examined, and an algorithm using less invasive management was proposed.

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.
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

| 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           | Sternotomyelitis 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   | 75 F           | CABG                        | 1 W and 3 W                      | 2               | Both Rt. pectoralis major  |
| 23   | 5 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   | 5 F            | CABG                        | 3 M                              | 1               | Right Omentum transplant |
| 27   | 75 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   | 59 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 |

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

**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...
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, CAGB 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

![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.]
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.](image-url)
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,

**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    | Soft                  | (−)                  | Rare                 |
| (mediastinitis)|                       | (+)                  | (−)                  |
| Osteomyelitis  |                       | Positive             |                       |
| Culture        | Negative              |                       |                       |
| 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 reported 252 reconstruction methods, and our reported cases.

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**Our algorithm**

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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