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Original Article

# Transverse sternal plating in secondary sternal reconstruction: Single-center clinical experience

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***ABSTRACT***

**Objectives:** This study reviews five-years' experience of transverse sternal plating in secondary sternal reconstruction in our clinic.

**Materials and methods:** We retrospectively reviewed our experience with transverse sternal plating using a titanium sternal plate system between January 2015 and December 2019. During this period, a total of 31 sternal plating operations for secondary sternal closure after cardiac surgery were performed.

**Results:** During the five years of the study, 31 patients underwent sternal plating. There were 20 males and 11 females in the group. The average age was 65.4±10.2 years with a body mass index (BMI) of 27.5±2.9 kg/m$^2$. Twenty-six (83.9%) were diabetics, 23 (74.2%) active smokers, 11 (35.5%) had chronic obstructive pulmonary disease (COPD) and two (6.5%) had renal failure.

**Conclusion:** Titanium plate fixation is an effective method to stabilize complicated sternal dehiscence. It is a simple and safe technique without risks. More comprehensive research is required to address the indications, benefits, and complications of sternal plating.

***Keywords:*** Plating, sternal closure, wound closure.

Sternal instability after cardiac surgery occurs infrequently but can be challenging to manage. Mediastinitis and sternal wound dehiscence are devastating and life-threatening complications of median sternotomy incision. Sternal wound complications occur in 0.5 to 3% of patients following median sternotomy.[1] The most common reasons for sternal instability are obesity, chronic obstructive pulmonary disease (COPD), peripheral arterial disease, reoperations, prolonged operation time, prolonged mechanical ventilation, and low cardiac output.[2]

The most common treatment of mechanical sternal instability is operative rewiring. Transverse rib-to-rib stabilization with titanium plates designed for sternal fixation is a recent option. Rigid plate fixation results in more rapid bony healing with decreased rates of nonunion and infection. We evaluated the clinical utility of the transverse plating system in our cardiac surgery practice.

## MATERIALS AND METHODS

We retrospectively reviewed our experience with transverse sternal plating using a titanium sternal plate system (SternaLock Blu, Biomet Microfixation Inc., Florida, USA) between January 2015 and December 2019. A written informed consent was obtained from each patient before their involvement in this study. The study was conducted in accordance with the principles of the Declaration of Helsinki. Patients were considered for plate fixation after the failure of the primary standard wire closure associated with wound dehiscence. For each procedure, informed consent was obtained. Demographic factors, indications for surgery, and risk factors for postoperative complications including mediastinitis and non-union were reviewed. Outcomes assessed include dehiscence, deep and superficial wound infections, sternal instability, and the need for reoperation.

Thirty-one consecutive patients between January 2015 and December 2019 were diagnosed with sternal dehiscence with or

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without infection following median sternotomy. Patients with infections were managed by precise debridement and wound excision in the operating room and then dressed with a vacuum-assisted closure (VAC) device and intravenous antibiotics were prescribed for wound and blood culture microbiological sensitivity. After bacteriological control of the wounds, patients were returned to the operating room for definitive closure using rigid sternal plating.

Follow-up includes all in-hospital complications and following discharge visits. Clinical examination was performed at 1, 6, 12, 24, 36, and 48 months postoperatively.

**Operative procedure** (Figure 1)

Each patient was given general anesthesia with endotracheal intubation. The old sternal wires were removed and the debridement was begun with excision of all wound edges, including skin, subcutaneous tissue, and any necrotic tissue until they were free of the devitalized tissue and down to the bleeding tissue. Hemostasis was obtained. The bone biopsy was sent to microbiology for culture.

Both-sided pectoralis major muscles were elevated with overlying soft tissue from the midline to the level of the mid-clavicular line to create flaps and permit later approximation in the midline. Large reduction forceps were used on both the superior and inferior aspects of the sternum the two sternal halves were brought together.

Different shaped titanium plates (SternaLock Blu, Biomet Microfixation Inc., Florida, USA) were placed. Using a template, the plates were contoured. Using the measurement tool sternal and rib thickness can be assessed preoperatively. It was also important to stay away from the inferior margin of the rib to avoid injuring the intercostal vessels and nerves. Screw lengths varied among patients and ranged from 12 to 18 mm in length, with 14 mm being the most commonly used size. Once the plates were secured in place, the reduction forceps were removed.

Two Jackson-Pratt no: 10 drains were placed one under each muscle flap, through two separate small incisions along the lower edge of the sternotomy wound. The muscles were approximated at the mid-line with interrupted no. 1 Vicryl sutures. Superficial muscle fascia and subcutaneous tissues were closed with 2-0 Vicryl sutures. The skin was closed with 3-0 Vicryl sutures continual technique or 3-0 Prolene sutures with a single suture technique.

Drains were removed when output was consistently less than 25 mL per drain per day. An antibiotic course for 4-6 weeks was completed postoperatively under the direction of the infectious disease service.

**Statistical analysis**

All preoperative patient demographic data together with operative characteristics and postoperative data were imported into Excel worksheets, for organizational purposes. Data were expressed as mean ± SD, median (range), or number (%) using Excel 2019 for Windows (Microsoft Corp., Redmond, WA, USA).

## RESULTS

During the five years of the study, 31 patients underwent sternal plating. Operation numbers

**Figure 1.** Postoperative view of total sternal reconstruction.

**Table 1.** Operation numbers according to years

| Years | Number of cardiac operations | Number of secondary sternal closure | Sternal reoperation rate (%) |
|---|---|---|---|
| 2015 | 1,143 | 10 | 0.87 |
| 2016 | 1,057 | 7 | 0.66 |
| 2017 | 1,084 | 6 | 0.55 |
| 2018 | 963 | 4 | 0.41 |
| 2019 | 812 | 4 | 0.49 |
| Between 2015-2019 | 5,059 | 31 | 0.61 |

according to years are shown in Table 1. There were 20 males and 11 females in the group. The average age was 65.4±10.2 years with a body mass index (BMI) of 27.5±2.9 kg/m$^2$. Twenty-six (83.9%) patients were diabetics, 23 (74.2%) patients were active smokers, 11 (35.5%) patients had COPD and two (6.5%) patients had renal failure. Sternal instability occurs most often following coronary artery bypass graft (CABG) (74.2%), valve surgery (6.4%), or combined procedures (19.3%). Left internal mammary artery (LIMA) was used in all CABG patients. Bilateral internal mammary artery (IMA) was used at 7 (30.4%) patients. A summary of the patient's characteristics is shown in Table 2 and Table 3. Secondary operative characteristics of the patients are shown in Table 4 and Table 5. The decision to proceed with the plating system was

**Table 2.** Patient demographics per years

| | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % |
| Sex | | | | | | | | | | |
| Male | 7 | 70.0 | 4 | 57.1 | 4 | 66.6 | 3 | 75.0 | 2 | 50.0 |
| Female | 3 | 30.0 | 3 | 42.8 | 2 | 33.3 | 1 | 25.0 | 2 | 50.0 |
| First operation | | | | | | | | | | |
| Valve | 1 | 10.0 | 1 | 14.2 | 0 | 0 | 0 | 0.0 | 0 | 0.0 |
| CABG | 7 | 70.0 | 4 | 57.1 | 5 | 83.3 | 4 | 100 | 3 | 75.0 |
| CABG + Valve | 2 | 20.0 | 2 | 28.5 | 1 | 16.6 | 0 | 0 | 1 | 25.0 |
| Infection | | | | | | | | | | |
| Yes | 5 | 50.0 | 4 | 57.1 | 3 | 50.0 | 3 | 75.0 | 4 | 100 |
| No | 5 | 50.0 | 3 | 42.8 | 3 | 50.0 | 1 | 25.0 | 0 | 0 |
| Diyabetes mellitus | | | | | | | | | | |
| Yes insulin + | 5 | 50.0 | 5 | 71.4 | 3 | 50.0 | 1 | 25.0 | 2 | 50.0 |
| Yes oral antidiabetics | 4 | 40.0 | 1 | 14.2 | 1 | 16.6 | 2 | 50.0 | 2 | 50.0 |
| No | 1 | 10.0 | 1 | 14.2 | 2 | 33.3 | 1 | 25.0 | 0 | 0 |
| Smoke | | | | | | | | | | |
| Yes | 7 | 70.0 | 5 | 71.4 | 4 | 66.6 | 4 | 100 | 3 | 75.0 |
| No | 3 | 30.0 | 2 | 28.5 | 2 | 33.3 | 0 | 0 | 1 | 25.0 |
| COPD | | | | | | | | | | |
| Yes | 4 | 40.0 | 2 | 28.5 | 2 | 33.3 | 2 | 50.0 | 1 | 25.0 |
| No | 6 | 60.0 | 5 | 71.5 | 4 | 66.6 | 2 | 50.0 | 3 | 75.0 |
| Chronic renal faliure | | | | | | | | | | |
| Dialysis | 1 | 10.0 | 0 | 0 | 0 | 0.0 | 1 | 25.0 | 0 | 0.0 |
| No | 9 | 90.0 | 7 | 100 | 6 | 100.0 | 3 | 75.0 | 4 | 100.0 |

CABG: Coronary artery bypass graft; COPD: Chronic obstructive pulmonary disease; CRF: Chronic renal failure.

**Table 3.** Patients demographics distribution between 2015-2019 (n=31)

| | Frequency | |
|---|---|---|
| | n | % |
| Sex | | |
| Male | 20 | 64.5 |
| Female | 11 | 35.5 |
| Total | 31 | 100.0 |
| Primary operation | | |
| Valve | 2 | 6.4 |
| CABG | 23 | 74.2 |
| CABG + Valve | 6 | 19.3 |
| Total | 31 | 100.0 |
| Infection | | |
| Yes | 19 | 61.3 |
| No | 12 | 38.7 |
| Total | 31 | 100.0 |
| Diyabetes mellitus | | |
| Yes insulin + | 16 | 51.6 |
| Yes oral antidiabetics | 10 | 32.2 |
| No | 5 | 16.1 |
| Total | 31 | 100.0 |
| Active smoker | | |
| Yes | 23 | 74.2 |
| No | 8 | 25.8 |
| Total | 31 | 100.0 |
| COPD | | |
| Yes | 11 | 35.5 |
| No | 20 | 64.5 |
| Total | 31 | 100.0 |
| Chronic renal faliure | | |
| Yes dialysis | 2 | 6.5 |
| No | 29 | 93.5 |
| Total | 31 | 100.0 |

CABG: Coronary artery bypass graft; COPD: Chronic obstructive pulmonary disease; CRF: Chronic renal failure.

made by clinical assessment of the sternum in the operating room. The partial dehiscence of the sternum was the exclusion criteria. All patients had gross instability at the time of plating. Twelve (38.7%) patients were presented with sternal instability without infection while 19 (61.3%) patients with associated wound infection. The infected wounds were treated with intravenous antibiotics and vacuum-assisted dressing before the closure procedure. These patients' sternums were closed after the eradication of the infection which was verified by negative cultures. The most common pathogens were *coagulase-negative staphylococci* (35%) and *Staphylococcus aureus* (17.5%). Operative cultures of eight (20%) patients showed no growth.

Transverse plating required more extensive mobilization of the pectoral muscle (Figure 1). All patients had an uneventful early postoperative course and were extubated 2.0±1.4 hours after surgery. Postoperatively, all patients had a stable sternum after the surgery. Postoperative wound complications included: One (3.2%) patient developed postoperative seroma after nine days. Two (6.4%) patients developed postoperative superficial wound dehiscence with discharge. They all subsequently healed. Two (6.4%) patients developed recurrent wound infections and healed with negative pressure wound therapy. Both were immunocompromised. In the long-term one patient complained of plate-related pain during breathing, with the subsequent need for plate removal. One multi-morbid patient died on the 31$^{st}$ postoperative day. The cause of death was not related to the sternal plate re-fixation postoperative complications are shown in Table 6.

## DISCUSSION

Since the introduction of median sternotomy as an approach to perform open-heart operations,

**Table 4.** Secondary operation characteristics per year

| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD |
| Age | 66.310±11.540 | 64.090±7.148 | 67.000±11.019 | 63.710±11.715 | 65.500±11.327 |
| Wound reopen after surgery (day) | 20.440±10.321 | 10.820±4.446 | 11.250±4.464 | 10.710±3.147 | 10.830±3.061 |
| Wound closure time (day) | 10.560±4.746 | 9.000±3.098 | 10.000±3.625 | 8.860±2.673 | 9.500±3.082 |
| EF % | 52.310±7.391 | 49.090±6.595 | 43.000±6.633 | 47.140±4.880 | 45.670±4.719 |
| BMI | 27.969±3.577 | 27.991±2.081 | 27.800±2.989 | 26.686±2.569 | 28.567±2.070 |
| Extubation (hour) | 2.250±1.653 | 1.820±1.250 | 1.750±1.389 | 1.290±1.113 | 3.000±1.095 |

SD: Standard deviation; EF: Ejection fraction; BMI: Body mass index.

**Table 5.** Secondary operation characteristics between 2015-2019

| | Mean±SD |
|---|---|
| Age | 65.4±10.2 |
| Wound open after surgery (day) | 14.0±8.0 |
| Wound closure time (day) | 9.7±3.7 |
| Ejection fraction (%) | 48.4±7.1 |
| Body mass index | 27.5±2.9 |
| Extubation time (hour) | 2.0±1.4 |

SD: Standard deviation.

**Table 6.** Postoperative complications

| | n | % |
|---|---|---|
| Seroma | 1 | 3.2 |
| Superficial wound dehiscence | 2 | 6.4 |
| Recurrent infection | 2 | 6.4 |
| Pain (late plate removal) | 1 | 3.2 |

it remains the preferred approach allowing better exposure and easy access to the heart and mediastinal structures. Two well-described complications with this type of incision are sternal dehiscence and wound infection.[3-5]

Mediastinitis and sternal wound dehiscence are devastating and life-threatening complications of median sternotomy incision. Although this complication is rare, morbid outcomes from it are common and mortality rates are high if effective therapy is not instituted quickly.[6] The potential impact on mediastinal structures requires prompt and deliberate management to eliminate infection while maintaining a protective environment for fragile structures such as coronary grafts.[7]

Many techniques have been developed to break the vicious circle of sternal stability and infection. Debridement with the removal of all infected tissue is emphasized no matter what the reconstructive technique is utilized. Negative pressure wound therapy has also been utilized both as a treatment for wound dehiscence and as a temporary measure to help treat the infection before sternal reconstruction.

Robicsek parasternal weave is still the standard technique used for sternal rewiring in many centers.[8] As a supplement to sternal wires, longitudinal plates had been used to fix the sternum together with circumferential wire.[9-11]

The transverse sternal plating system successfully achieved stability in all cases and is valuable in complex sternal reconstructions. Sternal plating is an effective alternative to wire closure in sternum with fractures, chronic and acute instability, or poor bone quality with high-risk patients, without the need for extensive retrosternal dissection.

With increasing life expectancy, reoperations are often and will be more in the future. Baillot et al.[12] suggested that; if the patient is in good condition, reoperation is feasible and sternal reentry can be done safely and with minimal risk even after sternal reconstruction with horizontal titanium plating.

Snyder et al.[13] demonstrated that, compared to standard wire closure, primary sternal plating is associated with a shorter postoperative length of stay and no significant increase in operating time. Although the technique may reduce early wound complications, it appears to have no effect on late wound complications. The transverse sternal plating system successfully achieved stability in all cases and is valuable in complex sternal reconstructions.

Many groups have reported the use of rigid fixation of the sternum to close the complicated median sternotomy.[14] The rate of restoring sternal integrity through the use of plates ranges from 96-98% in patients with complicated median sternotomy. It is important to note that none of our patients required sternectomy.[15] We believe that with precise debridement instead of empiric sternotomy, enough healthy sternal segments can be salvaged in most wounds to enable rigid sternal fixation. Other benefits include an observed reduction in ventilator requirements.[16] In all patients reported here, we achieved immediate postoperative extubation, and no patients required reintubation perioperatively. It is logical to consider that any method that returns chest wall integrity to a physiologic state will be likely to improve lung function status in these patients.

Techniques for rigid sternal fixation as a way to manage the complicated median sternotomy have been previously described in the literature. While we agree that sternal salvage with rigid plating is the best definitive management for these wounds, we prefer to bridge early

debridement to delayed closure using the VAC dressing. After thorough wound debridement, excision, and stabilization with wound VAC dressing we can effectively transform a chronic wound into an acute wound. This allows control of infection, management, and avoidance of bacterial sepsis, and contraction of a healthy granulating wound to achieve the greater success of final reconstruction. Sternal salvage with sternal plating is our preferred method of definitive reconstruction of sternal wounds. We hypothesize this allows earlier extubation, reduced hospital stay, decreased flap use, higher rates of flap survival, improved cosmetic outcome, and lower postreconstruction wound complication rates. The algorithm outlined in this article provides a useful and alternative methodology toward the management of complex sternal wound infection.

If the patient is in good condition, reoperation is feasible and sternal reentry can be done safely and with minimal risk even after sternal reconstruction with horizontal titanium plating.[17]

The main limitation of this study is that it is a single-center study. However, out of a total of 5059 patients, 31 underwent open-heart surgery over a five-year period.

In conclusion, titanium plate fixation is an effective method to stabilize complicated sternal dehiscence. It is a simple and safe technique without risks. Further larger studies are needed to address the indications, benefits, and complications of sternal plating.

**Declaration of conflicting interests**

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