Outcome of Delayed Sternal Closure 
After Cardiac Operations

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Background: Open chest management and delayed sternal closure has been described as a useful method in treatment of severely impaired contractility, uncontrollable hemorrhage, intractable arrhythmias, reperfusion myocardial edema or when either ventricular assist devices or transthoracic intra-aortic balloon pump.

Patient and methods: From January 2010 to December 2010, thirty patients (1.25%) left the operating room with open chest after cardiac operations. Delayed sternal closure was performed after hemodynamic improvement. Analysis of indications, mortality and postoperative complications were done.

Results: Open chest with delayed sternal closure was used in 30 patients (1.25%) out of 2387 patients. There were 20 men and 10 women, with an average age of 50.9±8.6 years. In 16 patients, primary sternal closure was not possible as a consequence of postoperative low cardiac output, and in 14 patients due to bleeding/coagulopathy. Emergency operations (46.7%) and aortic dissection surgery (20%) were more frequent. Delayed sternal closure was done after 14.3±9.9 hours. Extubation was done after 46.4±34.7 hours. Eighteen patients were weaned from inotropic support and discharged from the intensive care unit an average of 3.8±1.9 days. One patient had mediastinitis and required sternal refixation.

Conclusion: Delayed sternal closure can be beneficial when all attempts to optimize cardiac function and hemostasis have failed.

KEY WORDS: Delayed sternal closure (DSC), open chest management (OCM).

Open chest management (OCM) and delayed sternal closure (DSC) for cardiac surgical patients was described in the late 1970s. It has been described as a useful method in the treatment of severely impaired heart[1,2,3], uncontrollable hemorrhage [4], intractable arrhythmias [2, 5], reperfusion myocardial edema or when either ventricular assist devices [2] or transthoracic intra-aortic balloon pumps (IABP) [6] are required after cardiac surgery. In these instances, OCM may relieve cardiac compression and provide rapid access for the control of hemorrhage or arrhythmias. Delayed sternal closure can subsequently be carried out after the patient’s condition has improved.

A concern that prolonged open sternotomy would result in infectious complications caused early hesitancy to use this technique. With evidence for low sternal morbidity, and a growing population of patients with complex cardiac disease, DSC will be an increasingly important management option for the cardiac surgeon. OCM with a delayed closure has become a routinely used tool, with a current incidence of 1.2–4.2% in the adult cardiac surgical literature [7]. We have tried to identify the risks and benefits of this technique and variables associated with the outcome.

Patients and methods

From January 2010 to December 2010, 2387 cardiac operations were performed in adults in our department. Standard anesthesia, cardiopulmonary bypass (CPB) and surgical techniques were employed. Thirty patients (1.25%) left the operating room
with open chest. We wanted to analyze indications, mortality and postoperative complications.

Preoperative characteristics of these patients include a mean age of 50.9 ± 8.6 years, 20 patients were males (66.7%), emergent or urgent operations in 14 patients (46.7%), and redo cardiac operation in 5 patients (16.7%). Operations included coronary artery bypass grafting (10), valve surgery (10), aortic dissection (6), combined coronary artery bypass grafting and valve replacement (3) and repair of postinfarct ventricular septal defect (1) of the series. Our patient population has a much larger proportion of high risk patients.

Standard anesthesia, cardiopulmonary bypass, and surgical techniques were employed. For myocardial protection, cold crystalloid hyperkalemic cardioplegia was infused into the aortic root (or directly into the coronary ostia in cases of aortic valve surgery) in addition to topical hypothermia with ice slush or antegrade warm blood cardioplegia in most coronary artery bypass grafting surgery. The sternum was left open in 30 patients (1.25%). In cases of DSC, broad spectrum intravenous antibiotics were continued until the removal of the mediastinal drains.

Indications

OCM was performed if all attempts to achieve hemodynamic stability were unsuccessful. Measures taken to stabilize the patient included optimization of preload and afterload, isotropic support and IABP. Ventricular function was routinely determined by transesophageal echocardiography. Hemodynamic instability was the major indication for OCM in all patients. In some patients, this instability manifested after a trial chest closure, but not all patients underwent trial closure. Additional indications that influenced the surgeon’s decision to leave the chest open included bleeding/coagulopathy, cardiac edema, and arrhythmias with hemodynamic compromise. Sixteen patients became hemodynamically unstable upon attempted sternal closure despite maximum isotropic support and in ten patients intra aortic balloon counterpulsation (IABP) was used. Forty patients had massive coagulopathic postoperative bleeding, which prevented safe closure of the sternum. The wounds were packed with sterile laparotomy pads, and frequent dressing changes were done while coagulation factors were replaced. In the intensive care unit (ICU), all patients were ventilated and sedated until the time of chest closure.

Methods of mediastinal isolation

We used sterile laparotomy packing with Steri-Drape and dressing changes were routinely performed every 8 hours. Povidone-iodine (Betadine) preparation of the entire chest wall was done. Full sterile technique was used to inspect the cardiac activity and apply new dressings. A sternal retractor was left in place in cases of extreme myocardial edema or hemodynamic instability. The wound was then covered with Steri-Drape plastic film.

Delayed sternal closure

Timing for delayed closure was determined by periodic inspection of the heart, dressing soaking and need for frequent new dressings, evaluation of the level of pharmacological support, and determination of the response to temporary reapproximation of the sternum. Wound closure was done in the operating room. Sternum was closed and the subcutaneous tissue and skin were reapproximated. Sternal, neurologic, renal, respiratory, coagulation, and infectious morbidity were recorded. Sternal morbidity was defined as deep sternal infection, dehiscence, or nonunion.

Results

Open chest with delayed sternal closure was used in 30 patients (1.25%) out of 2387 patients. There were 20 men and 10 women, with an average age of 50.9 ± 8.6 years. The incidence of open chest and delayed sternal closure according to type of operation is depicted in table 1.

<table>
<thead>
<tr>
<th>Type of surgery</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG</td>
<td>10</td>
</tr>
<tr>
<td>Redo MVR</td>
<td>4</td>
</tr>
<tr>
<td>DVR</td>
<td>3</td>
</tr>
<tr>
<td>DVR+TR</td>
<td>2</td>
</tr>
<tr>
<td>Redo TV surgery</td>
<td>1</td>
</tr>
<tr>
<td>CABG+ MR</td>
<td>3</td>
</tr>
<tr>
<td>Aortic dissection surgery</td>
<td>6</td>
</tr>
<tr>
<td>VSD closure</td>
<td>1</td>
</tr>
</tbody>
</table>


Table 1. Types of surgery

In 16 patients, primary sternal closure was not possible as a consequence of postoperative low cardiac output (LCO), and in 14 patients due to bleeding/coagulopathy. Postoperative LCO was defined as systolic blood pressure < 90 mmHg inspite of requiring combined maximum pharmacologic isotropic support (dopamine, dobutamine, epinephrine and amrinone) administered intravenously with or without additional IABP. Emergency operations (46.7%) and aortic dissection surgery (20%) were more frequent in patients treated with OCM and DSC.

A sternal retractor was employed for additional hemodynamic stability in some of the patients. Open sternotomy
provided easy accessibility to the myocardium and rapid access for resuscitation in patients who experienced cardiac arrest. Just before DSC all the patients whom required IABP were still on IABP support, but less inotropic support was needed as compared with when open chest was established. Delayed sternal closure was done after 14.3 ± 9.9 hours. Seven patients deteriorated after the first delayed closure and had the sternum reopened an average of 1 day after the first DSC, but only three of these patients survived. Extravagation was done after 46.4 ± 34.7 hours. Eighteen patients were weaned from inotropic support and discharged from the intensive care unit an average of 3.8 ± 1.9 days (range, 2 to 11 days). Hospital stay was 10.9 ± 8 days. Perioperative patient results are shown in Table (2).

### Survival

Eighteen patients (60%) from this series were discharged from the hospital in good condition at 16.1 ± 6.1 days postoperatively. The overall survival rate after delayed sternal closure was 60%. Survival rate according to the cause of open chest was 50% for hemodynamic instability and 28.5% for intractable bleeding. DSC in patients with IABP support was more likely to be successful. The mortality rate in patients with IABP was 40% (2/5) compared with 54.5% (6/11) when IABP was not required. Table (3) shows mean of different variables according to outcome.

#### Table 2. Perioperative results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (X̄)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>50.9</td>
<td>± 8.6</td>
</tr>
<tr>
<td>OCM (hrs)</td>
<td>14.3</td>
<td>± 9.9</td>
</tr>
<tr>
<td>ICU (d)</td>
<td>3.8</td>
<td>± 1.9</td>
</tr>
<tr>
<td>Vent. (hrs)</td>
<td>46.4</td>
<td>± 34.7</td>
</tr>
<tr>
<td>AC (min)</td>
<td>83.4</td>
<td>± 25.4</td>
</tr>
<tr>
<td>TBT (min)</td>
<td>138</td>
<td>± 45.8</td>
</tr>
<tr>
<td>H. stay (d)</td>
<td>10.9</td>
<td>± 8</td>
</tr>
</tbody>
</table>

OCM: open chest management, ICU: intensive care unit, vent.: ventilation, AC: aortic cross clamp time, TBT: total bypass time, H.: hospital, yrs.: years, hrs.: hours, d.: days, min.: minutes.

#### Table 3. Means (X̄) ± SD of different variables according to outcome

<table>
<thead>
<tr>
<th>Variable</th>
<th>Died n(12)</th>
<th>Home n(18)</th>
<th>Total</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age(yrs)</td>
<td>48.2±9.4</td>
<td>52.6±7.8</td>
<td>1.34</td>
<td>&gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>OCM(hrs)</td>
<td>16.8±14.1</td>
<td>12.5±5.7</td>
<td>1.01</td>
<td>&gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>ICU(d)</td>
<td>3.2±1.7</td>
<td>3.9±2.1</td>
<td>0.43</td>
<td>&gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>Vent.(hrs)</td>
<td>56.4±44.3</td>
<td>39.8±25.7</td>
<td>1.17</td>
<td>&gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>AC(min)</td>
<td>89.7±29.4</td>
<td>79.3±22.2</td>
<td>1.04</td>
<td>&gt; 0.05</td>
<td></td>
</tr>
<tr>
<td>TBT(min)</td>
<td>160±55.1</td>
<td>123±32.3</td>
<td>2.08</td>
<td>&lt; 0.05</td>
<td></td>
</tr>
<tr>
<td>Hstay(d)</td>
<td>3.2±1.7</td>
<td>16.1±6.1</td>
<td>8.49</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
</tbody>
</table>

OCM: open chest management, ICU: intensive care unit, vent.: ventilation, AC: aortic cross clamp time, TBT: total bypass time, H.: hospital, yrs.: years, hrs.: hours, d.: days, min.: minutes.

#### Table 4. Different variables according to outcome among the study group

One patient of this group of patients had mediastinitis and required sternal re fixation. Delayed sternal closure was carried out in 30 patients at a mean of 14.3 ± 9.9 hrs. The causes of deaths were: multisystem organ failure in 7 patients, low cardiac output in 2 patients and cardiac arrest in 3 patients. The incidences of major postoperative complications are presented in Table (4).

Discussion

Closure of the chest at the end of the operation was negotiable in earlier cardiac surgery because of the fear of mediastinal infection. Several reports have described prolonged OCM and subsequent DSC as a life-saving procedure in patients with uncontrollable hemorrhage, myocardial edema, low cardiac output and arrhythmias postoperatively [1, 2].

Rhiai and colleagues [8] were the first to bring the problem of tight mediastinum (cardio-mediastinal disproportion) to attention in 1975. They used upward traction on the closed chest, which then might be weaned as the patient improved. Mediastinitis and sternal morbidity have been less frequent than anticipated since the initial description of OCM in the late 1970s [3, 5, 7]. Open chest management has now gained acceptance as a technique in the management of hemodynamically unstable patients where cardiac compression by sternal closure is not tolerated. Patients may further benefit because of ready access to the mediastinum for clot evacuation and electrical cardioversion. In this study we have evaluated our outcome using OCM in patients with hemodynamic instability and bleeding after cardiac operations.

Sternal closure has been shown to result in a significant decrease in cardiac output and diastolic filling, despite preserved velocity of blood transfusion, even in patients with good cardiac performance [9]. These effects are magnified in the presence of poor ventricular compliance secondary to ischemia, reperfusion, and edema. Furnary and associates [2] have demonstrated that LCO can be improved by opening of the sternum. After the sternal incision had been re-opened, there was a 59% increase in cardiac index and 18% rise in systemic blood pressure, without significant change in cardiac filling pressures [2, 7].

Severe bleeding after cardiopulmonary bypass and excessive blood transfusion, and marked increase in heart size, resulting in severe ventricular dysfunction and arrhythmias are often associated with a prolonged perfusion time and poor myocardial preservation [4]. DSC in these cases allows time for recovery of the heart and for the bleeding to stop, while totally isolating the myocardial structures from the outside environment. In addition, it provides easy access to the mediastinum for evacuation of blood clots, thus preventing cardiac tamponade [10].

Patients who required open sternotomy were a higher risk group than the general population of patients undergoing heart operations as stated by Furnary and colleagues. This is reflected by the high percentages of emergency (46.7%) and aortic dissection (20%) operations in our patients. Most were in a severely compromised condition after the operation. These patients have increased frequency of systemic complications including renal failure, respiratory failure, disseminated intravascular coagulation, gastrointestinal bleeding, neurologic sequelae, and death. The use of open sternotomy in these critical situations may be beneficial [2].

The overall incidence (1.25%) of open sternotomy after open heart operations in our study concurs with that of three large series [1, 2, 3]. But it was lower than that of Boeken and colleagues (3.5%) [11]. The overall incidence (4.2%) of OCM after cardiac operations described by Christenson and associates is slightly higher than ours and his earlier reported series (1.7%). The high proportion of high risk patients (redos, diffuse coronary artery disease and extremely poor preoperative left ventricular function) in their patient population may explain the relatively high incidence of OCM and DSC in this series [7].

Multiple factors have to be examined when determining the timing of DSC [11, 12]. Tran-esophageal echocardiography is used in the operating room for any unstable patient to give continuous information about ventricular function and response to different therapeutic maneuvers. Further considerations regarding timing of closure include isotrope requirements, degree of fluid mobilization, and level of dependency on IABP therapy. Although the decision of when to close is made individually, patients who are successfully closed are generally on low epinephrine and in negative fluid balance.

Our results indicate that successful closure is more likely to be achieved after 14 hours while Furnary and colleagues took 48 hours to do so which allowed for extra time to achieve negative water balance. The prolonged bypass times, initial markedly positive mean water balance, and subsequent diuresis in surviving patients suggest that myocardial edema is an important underlying factor [2]. Many reports described a variety of methods to isolate the mediastinum from the external environment. These included an array of synthetic materials [3, 5, 9], skin closure, skin zipper [12], and open packing with foam tape [4]. We found sterile packing and Steri-Drape isolation of the mediastinum to be preferable. This method is easy to apply, provides rapid access to the myocardium, permits continued use of a sternal retractor. It is of note that the duration of OCM did not have a significant impact on subsequent sternal morbidity.

Sternal infection rates for patients undergoing routine cardiac operations are in the range of 1% to 2%. It is our policy to keep patients on broad-spectrum antibiotics while the chest is open. It is therefore interesting to note that, in our series, the incidence of wound infections, mediastinitis and sternal dehiscence after OCM and DSC was not significantly different from a control population that had primary sternal closure. The incidence of mediastinal infection after routine
cardiac operations is reported to be greater than 1.5%. Low incidence of sternal morbidity after DSC has also been reported by others[1,2,4]. The group of patients undergoing DSC are particularly at risk for infection because they have predisposing factors such as: prolonged CPB time, LCO, excessive bleeding, and the need for multiple re-explorations of the chest [11].

Hospital survival in our series of 30 patients was 60% which compares well with Anderson and associates earlier reports which have ranged from 48% to 66% while it was less than that of his later series which was 76% [13].

In summary, DSC is an important management procedure in patients with postoperative LCO with severe hemodynamic instability and excessive bleeding. This procedure can be performed in patients with a relatively low incidence of sternal morbidity.

References