SAS Journal of Surgery (SASJS) **ISSN 2454-5104**
Abbreviated Key Title: SAS J. Surg.

A Unit of Scholars Academic and Scientific Society, India

Delayed Sternal Closure in Cardiac Surgery

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Original Research Article

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Article History
Received: 18.12.2018
Accepted: 28.12.2018
Published: 30.12.2018

DOI:
10.21276/sasjs.2018.4.12.4

Abstract: Open chest (OC) with subsequent delayed sternal closure (DSC) has been described as a theraputic option in the treatment of severely impaired heart including hemodynamic instability, marked myocardial edema, respiratory compromise, intractable bleeding, placement of assist devices, and persistent arrhythmias. In this review, we evaluate the investigations on the incidence, survival, and morbidity of open chest management (OCM) patients who subsequently required DSC. The Medline and Embase databases were searched in December 2018 using relevant key words, limited to human studies in the English language. Cohort studies of open chest management with delayed sternal closure were identified. 191 studies screened by text, abstract and full paper, 29 of which were eventually deemed relevant to this review. DSC has become a valuable tool in the management of patients with postcardiotomy instability and mediastinal edema, with a current incidence of 1.2% to 4.2% in the adult cardiac surgical literature. As this technique was implemented, certain advantages became apparent, including the ability to relieve cardiac compression postoperatively, provide rapid access to control postoperative complications such as hemorrhage and arrhythmia, and to allow easy access to evacuate blood and/or clot formation in the mediastinum to prevent tamponade It can end in reasonable mortality and morbidity rate if used appropriately. Transient consequences following DSC including decrease in stroke volume, cardiac output, arterial blood pressure and also impaired lung compliance and blood oxygenation should be considered in management of the patients. Surgeons should be aware of its proper use and also physiologic changes and management of the patients when the sternum is left open.

Keywords: Open chest management, delayed sternal closure, Survival, Sternal Infection, Mortality.

INTRODUCTION

Prolonged open sternotomy can relieve cardiac compression and provide rapid access to control hemorrhage and arrhythmias; sternal closure can be carried out after the patient's hemodynamic status has been stabilized [5, 6].

Open chest (OC) with subsequent delayed sternal closure (DSC) has been described as a theraputic option and a useful method in the treatment of severely impaired heart [5, 9, 10, 19], uncontrollable hemorrhage [13, 21], intractable arrhythmias [10, 14], reperfusion myocardial edema [5, 17] or when either ventricular assist devices [10] or transthoracic intra-aortic balloon pumps (IABP) [18, 21] are required after cardiac surgery. There has always been a serious concern about the increased rate of post-operative infection and mortality in this situation.

In this review, we summarize the literature regarding the outcome and timing of delayed sternal closure in open chest management after cardiac operations.

METHODS

Search strategy, selection criteria, and data abstraction

We searched for studies describing incidence, survival and predictor of poor outcome after delayed sternal closure in open chest management patients of cardiac operations excluding pediatric DSC.

The following keywords were entered into Medline (OVID) and Embase: [Delayed sternal closure or sternal closure or open chest management or coronary artery bypass grafting CABG] and [outcome OR mortality OR morbidity OR survival OR death]. The search was limited to English-language human studies. The final search (December 20, 2018) yielded 234 articles.

Articles were screened by text, abstract, and then full text. Reference lists were hand searched to identify additional relevant studies. Specifically, we only included studies that

- Verified all cases of open chest management,

- Included consecutive patients with delayed sternal closure as eligible rather than select samples (to minimize selection bias),
- Reported mortality,
- Perioperative complications,
- Included sufficient information to judge the validity of the statistical methods.
- Eleven articles were selected for inclusion based on this strategy.

HISTORY

Primary DSC after surgery was first reported by Riahi *et al*. [23] in a pediatric population [23]. He indicated that primary sternal closure results in hemodynamic instability and may not be possible in some cases for a few days. Ott *et al*. [21] also reported primary DSC to prevent postoperative bleeding or cardiac compression [2]. Gielchinsky *et al*. [11] reported this technique in 29 adults [11]. Since the first report of Riahi *et al*. several small and large scale studies in different cardiac surgery centers in numerous regions of the world have been performed, which resulted in valuable but still controversial findings. As this technique was implemented, certain advantages became apparent, including the ability to relieve cardiac compression postoperatively, provide rapid access to control postoperative complications such as hemorrhage and arrhythmia, and to allow easy access to evacuate blood and/or clot formation in the mediastinum to prevent tamponade [3].

PREVALENCE

DSC has become a valuable tool in the management of patients with postcardiotomy instability and mediastinal edema, with a current incidence of 1.2% to 4.2% in the adult cardiac surgical literature [7]. Several previous investigations have reported the prevalence of DSC to be 1.5% in adults [26]. This wide variety of figures is mainly due to the differences in therapeutic strategies, experiences and tendencies of the surgeons, and diversity of pathologies in different study groups.

Hashemzadeh *et al*. [12] from a major cardiac surgery center in Tabriz, Iran reported that out of 2485 cardiac operations between June 2006 and January 2008, DSC strategy was adopted for 3.3% of patients [12]. Siavash Saadat *et al*. [28] from a Medical school in New Jersey, USA reported that out of 1261 cardiac operations between January 2012 to June 2013, DSC strategy was adopted for 3.25% of patients.

DSC is more prevalent in complex operations of adults (e.g. combined coronary bypass and valvular surgery) in comparison with closed heart surgeries and isolated coronary bypass operations.

INDICATIONS

According to several previous studies it can be concluded that DSC is indicated in the following conditions: hemodynamic instability, myocardial edema, cardiac dilatation, intractable bleeding, coagulopathies, dysrhythmias, respiratory compromise, and placement of a circulatory assist device [15]. Yasa *et al*. [27] reported that DSC is a secure and straightforward technique for treating bleeding, arrhythmia and myocardial edema following on pump cardiac surgery [27].

After failure of all attempts to achieve hemodynamic stability and a trial of chest closure, OCM is left the only option. Reasons for planned DSC include bleeding, hemodynamic instability and other cardiac abnormalities. Another indication of DSC in adults is non-surgical bleeding or uncontrolled bleeding which is only responsive to packing [7, 25].

Additional indications, that influence the surgeon's decision to leave the chest open includes bleeding/coagulopathy; cardiac edema, and arrhythmias. It is expected that as cardiac surgeons become more expert in the technique of DSC, the incidence of its application following on pump cardiac surgery may increase.

TIME OF DELAYED STERNAL CLOSURE

Sternal closure is frequently possible after 1-2 days in adults. It is important to notice that the most suitable time frame for DSC in the critical care units depends on the patients' conditions, but it is usually within the first 24 to 72 hours of the recovery phase [22]. In some clinical circumstances, such as mediastinitis or implantation of a mechanical support device through the open sternum, the sternum must remain open for longer than 72 hours.

The decision and timing of sternal closure depends at the discretion of the attending surgeon, influenced by improvements in hemodynamics, edema, and cardiac function.

At the presence of following conditions, sternal closure can be tried [2, 25]

- Hemodynamic stability in the last 24 hours (minimal dependence on intra-aortic balloon pump (IABP) and inotropic support below 2µg of epinephrine(per minute) or equivalent doses of other inotropic agents
- Negative fluid balance
- Appropriate coagulation state
- Improvement of respiratory situation and normal arterial gases

OPERATIVE TECHNIQUE

Complete debridement of the dead tissue and refreshment of the incision margins are necessary [27].

During prolonged open chest management, the skin could be closed by heavy merselin stitches and covered with sterile dressing. The dressing should be changed daily using strict sterile method with povidone-iodine [27]. Mc Elhinney *et al*. [20] explained the application of a Silastic sheet (Dow Corning, Midland, Michigan) cut into the shape of the open mediastinal cavity, attached to the external skin via sutures, and covered with an occlusive sterile dressing[20]. Patients routinely underwent transesophageal echocardiography to assess ventricular function before and after closure.

Sternum closure can be performed in ICU with full sterility and transferring the patient to operating room is not necessary [26]. However some surgeons prefer to do the sternum closure in operation rooms [27]. It is of importance to notice that not only the technique of sternotomy closure but also the material and size of sutures can influence the incidence of mediastinitis.

Re-opening and irrigation is not necessary during the time when sternum is open provided that appropriate coverage (skin or Gortex) is applied, otherwise, daily re-opening and irrigation of the incision is necessary; however, this issue is still controversial. Estrera *et al*. [8] recommended that DSC after complex aortic surgeries should be followed by mediastinal exploration every 24—48 h until complete duration of DS [8]. Estrera *et al*. suggested the performance of mediastinal exploration in the operating room or in the ICU with sterile irrigation of mediastinal contents [8].

COMPLICATIONS

The most common concern of the surgeons in using DSC is increase of infection rate. Some investigations reported lower rate of mediastinal infection with DSC (between 1 and 4%) and they concluded that no significant increase in the rate of mediastinitis has been observed when compared to primary closure [9]. Other studies have reported the infection risk to be 0-20% [6, 26, 10].

There were no incidences of superficial sternal infection or mediastinitis in the DSC cohort, while infection occurred in (0.25%) patients after conventional closure. Infection occuers after normal wire closure of the sternum.

Contradictory results of previous investigations could not be able to clarify the exact effect of DSC on outcomes of surgeries including survival to hospital discharge and morbidities such as postoperative infection [1, 24]. These studies due to small sample population and also lack of relevant control group did not elucidate the clear association between DSC and considered side effects.

The causes of this variety of results can be

- Age variety and different indications of DSC
- Different strategies of different centers regarding the coverage of mediastinal viscera during the time when sternum is open
- Variety of infection definitions (superficial, deep, mediastinitis, asymptomatic positive culture)

Mediastinal covering and time of sternal opening have not been completely assessed in association with infection; nevertheless, they both seem to be influential in occurrence of infection. Special attentions in this regard are highly recommended to prevent infectious morbidity and mortality of the open wounds following cardiac surgeries which are susceptible to acquire hospital infections.

Furthermore, the rates of deep sternal infection and mediastinitis have been shown to be the same in patients undergoing primary sternal closure and DSC in a study performed by Christenson *et al.* [7].

Conclusively, there have been little data indicating higher deep infection in patients undergoing DSC; however, superficial infections might be more prevalent. Other complications of DSC include respiratory failure, renal failure, cerebro-vascular accidents, myocardial infarction, cardiac failure and gastrointestinal complications (hepatic failure, intestinal ischemia, etc). Hashemzadeh *et al.* [12] reported that the most common causes of death included low cardiac output (67.2%) and multiorgan failure (26.2%) [12]. New onset of acute renal failure reported the predictive risk factor of in hospital mortality [12].

MORTALITY

Evaluation of mortality rate in different studies might not be accurate enough as some studies have reported total mortality, while others have reported the mortality during the time that sternum was still open.

Siavash Saadat *et al*. [12] reported the mortality 34.2% whereas 31.7% mortality was reported by Curtis A. Anderson *et al*. [24]. Cause of death included multisystem organ failure, low cardiac output, cardiac arrest, stroke, and sepsis.

These studies have reported mortality from 0% [3, 4] to 60% [5] but the mean mortality rate was 15-25% in different studies (11, 27, 43-46). Thirty three to fifty percent of the mortality occurred in the period after sternal closure [26, 20].

In-hospital mortality of DSC following complex aortic surgery hase been reported about 17% [8]. Mortality rate is higher in cases of secondary DSC (reopening the chest after closure in operating room or ICU) in comparison with primary DSC (more than twice)[25,26].

A study carried out by Furnary *et al*. [10] listed the risk factors of mortality in 6000 patients as follow (50):

- Application of more than 4µg/minute epinephrine or equivalent doses of other inotrops
- Cerebrovascular accidents after surgery
- Creatinine>3mg/dl
- Severe ventricular arrhythmia (The last 2 increase the mortality up to 50%)

Other risk factors of mortality based on other studies are [7]

- IABP (increase of mortality rate up to 3 times)
- Malnutrition
- Prolonged mechanical ventilation and need for tracheostomy
- reoperation due to bleeding (increase in mortality rate up to 3.4 times)
- VAD (increase of mortality rate up to 3.8 times)

This finding emphasizes the importance of correct decision making at the time of sternal closure during operation. Furthermore, the surgeons have to put aside their tendency not to re-open sternum in ICU and awaiting severe hemodynamic changes to make this decision. However, these findings should not persuade the surgeons to overuse this technique.

Systematic review of published data

Characteristics of the 11 studies in which the outcome and timing of delayed sternal closure in open chest management patients had previously been published are presented in the table-1.

Table-1

References	Number	Duration of study	OCM Cases	Incidence of DSC	Age	Mortality	Timing of DSC	Complications
Siavash Saadat *et al*. [28]	1261	17 month	CABG- 7 (17.1%), MVR- 2 (4.88%), AVR + CABG- 2 (4.88%), MVR + CABG- 28 (68.3%)	41 (3.25%)	73± 13 Male- 33 (80.5%) Female- 8 (19.5%)	14 (34.2%)		Stroke- 2 (4.88%), Atrial Fibrillation- 6 (14.6%), Renal Failure- 16 (39%)
Curtis A. Anderson *et al*. [2]	5177	3 years	CABG- 16 (0.7%), Valve- 15 (1.6%), Valve + CABG- 47 (5.6%)	87	65 years male – 49 (56%)	21 (24%)	3.7days	Deep Sternal Infection- 4, Stroke- 8, Dialysis- 13
Haydar Yasa *et al*. [27]	2698	7 years	CABG- 15 (0.85%), Valve- 12 (2.6%), Valve + CABG- 2 (2.2%)	46	57 yeare Male- 31 Female- 15	12 (27%)	3.48 days	Infection- 3 (6.6%), Renal Failure -5 (11%)
J. T. Christenson *et al*. [7]	3373	6 years	CABG- 108 (3.7%), Valve- 6 (2.6%), Valve + CABG- 15 (12.4%)	142	62.3 year Male- 94, Female 48	45 (31.7%)	2.1 days	Infection- 2 (1.6%), Renal Failure 45 (31.7%)
Udo Boeken *et al*. [29]	6041	5 years	CABG- 57 (1.4%),	212	72.6 years Male 70%	59 (28%)	NA	Infection- 9(4.8%), Renal Failure 47(22.2%),
Anthony P. Furnary *et al.* [10]	6030	4 years	NA	75	66 years Male – 59, Female- 48	25 (33%)	3.4 days	Sternal Infection 4 (5%),
Hashemzadeh *et al*. [12]	2485	2 years	NA	81		16 (18.6%)	2.35±1.73	Superficial sternal wound infection- 1 (1.2%), mediastinitis- 4 (4.9%), sternal dehiscence- 2 (2.4%)
Estrera AL *et al*. [8]	1011	16 years	NA	12 (1.2%)	56 years Male- 8 (67%)	2 (16.7%)	3 days	
Shalabi *et al.* [26]	1950	5 years	CABG- 13, Valve replacement – 10, CABG and valve replacement – 12	40 (2%)	58 years Male- 28 Female - 12	4 (10%)	22 ± 0.3 hours	respiratory distress syndrome- 2, superficial wound infections- 8,
Fanning WJ *et al.* [9]	3014	NA	NA	60 (2%)	NA	Operative mortality was 47 % but was not unexpected based on the number of urgent/emergent procedures but does not appear to be related to the technique of DSC.	1.6 ± 0.7 days	sternal wound infection 1 (1.7%)

CONCLUSION

The concept for open chest management (OCM) with the intent for delayed sternal closure was first utilized in 1975. As this technique was implemented, certain advantages became apparent, including the ability to relieve cardiac compression postoperatively, provide rapid access to control postoperative complications such as hemorrhage and arrhythmia, and to allow easy access to evacuate blood and/or clot formation in the mediastinum to prevent tamponade [3]. However, fears of mediastinal infection from prolonged open sternotomy have led many to refrain from the utilization of open chest management.

It can end in reasonable mortality and morbidity rate if used appropriately. Transient consequences following DSC including decrease in stroke volume, cardiac output, arterial blood pressure and also impaired lung compliance and blood oxygenation should be considered in management of the patients. Surgeons should be aware of its proper use and also physiologic changes and management of the patients when the sternum is left open. According to several previous investigations it can be concluded that a wide variation in practice of DSC by institutions exist. Different strategies in post-operative care of the children and adults in different centers necessitate prospective multicenter trials to draw more conclusive results. These trials may need to stratify or randomize the cases and apply standardized supervision protocols across institutions.

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