Analysis of Different Aspects of Delayed Sternal Closure in Pediatrics and Adults: A Review

Mahmood reza Sarzaeem M.D** Mohammad Jebelli M.D*
Asadallah Amidshahi M.D *, Mohammad hosein Mandegar M.D*

Abstract:

Introduction: Delayed sternal closure (DSC) has been shown to be useful following cardiac surgeries in case of indications including hemodynamic instability, noticeable myocardial edema, respiratory compromise, stubborn bleeding, placement of extra-corporeal support device,and persistent arrhythmias. In this review, we summarize the investigations on this topic to analyze the controversial aspects of DSC in pediatrics and adults.

Methods: Med-Line systematic review of the relevant literatures, which hase been published through 1970-2010, was performed.

Results: A total of 191 studies were identified, 62 of which were eventually deemed relevant
to this review. According to proper indications, DSC has been used in several types of cardiac surgeries in pediatric (newborns, infants and children) and adult cardiac surgeries in recent 35 years. The outcomes concerning survival and complications seem to be acceptable.

Conclusion: DSC is more frequent in pediatric cardiac surgery rather than adult cardiac surgery. DSC is an effective and safe strategy in patients with appropriate indications. Surgeons should be aware of its suitable use and also physiologic alterations and management of the patients when the sternum is still open. Several previous investigations showed wide variations in methods of DSC by institutions. Apparent differences in post-operative care of the patients with DSC clarify the demand for planning prospective multicenter trials with available control groups which can result in the implementation of standardized supervision protocols across institutions.

Sternal closure at the end of the surgery is sometimes associated with difficulties and complications. Moreover, in some patients, re-opening of the sternum and secondary delayed sternal closure (DSC) might be necessary during post-operative course in intensive care unit (ICU) or operating room. 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 thus far described different controversial aspects of DSC in pediatric and adult cardiac surgeries.

Methods:

Med-Line (1970-2010) was searched using the subsequent keyword "DSC", pediatric DSC and adult DSC. Searches were not restricted by language or study format. A total of 191 studies were iden-

*Department of Cardiovascular Surgery, Shariati Hospital, Cardiac Transplantation & Surgery Research Center(CTRC),Tehran University of Medical sciences(TUMS)
**Corresponding author, Department of Cardiovascular Surgery, Shariati Hospital, Cardiac Transplantation & Surgery Research Center(CTRC),Tehran University of Medical sciences(TUMS)
SARZAEEM_MR@yahoo.com

tified. Reference lists of the identified papers were also screened to recognize additional relevant publications. Overall, a total of 61 observational and comparison studies were considered relevant to this review and were summarized. Applications and consequences of DSC in all types of cardiac surgeries and also in all age ranges (newborns, infants, children and adults) were focused in this review.

History:

Primary DSC after surgery was first reported by Riahi et al (1975) in a pediatric population (1). 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; (1978) also reported primary DSC to prevent postoperative bleeding or cardiac compression (2). Gielchinsky et al; (1981) reported this technique in 29 adults (3). 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.

Prevalence:

Occurrence of DSC in different centers has been reported to range from 0.29% to 30% (4, 5). Several previous investigations have reported the prevalence of DSC to be 4.5% in children and 1.5% in adults (4-10). However the incidence of DSC in the adult cardiac surgery population has been stated up to 4.2% in two investigations (6,7).

Vojtovic et al (2009) revealed that DSC is used in two-fifths of newborns in their institution in Czech (11).

Hashemzadeh et al (2009) 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).

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

Circulatory and Respiratory Physiology in DSC

Patients who have the marginal cardiac index (CI) might experience a remarkable decrease in CI and blood pressure after sternal closure. The study performed by Moggio et al (1986) showed that DSC is beneficial in patients with severe decrease in CI after sternal closure, re-opening of the sternum increased the CI from 1.1 to 1.9 (9). CI significantly increased after 3-11 days and sternal closure became possible in this study. Shalabi et al also reported 59% increase in CI and 18% increase in blood pressure after re-opening of sternum in patients experiencing extraordinary CI fall after sternal closure (10).

These changes actually happen in all patients undergoing sternotomy; however, they are more significant in patients with decreased cardiac output. In a study carried out by McElhinney et al (2000), primary sternal closure in patients under 1 year old resulted in 5 mmHg increase in pulmonary artery pressure, 3mmHg increase in left atrial pressure and 2.5mmHg increase in right atrial pressure (13). Reuter et al (2005) also reported that CI decreased from 2.9 to 2.3 after primary sternal closure in patients with normal cardiac output prior to operation (14). Left ventricular end-diastolic volume decreased as much as 14% after sternal closure (14). In conclusion, cardiac physiology is different in open and closed sternal situations and sternal closure in cases with impaired systolic function can cause intolerable alterations of blood pressure and cardiac output, and endanger the life.

It is worthwhile to mention that cardiac response to the increase of intravascular volume is the same in open and closed sternal situations, thus changes of pulse pressure and systolic blood pressure can be accurately applied to determine the cardiac response to increase of intravascular volume. Moreover, it has been shown that the effects of Positive End Expiratory Pressure (PEEP) on systolic blood pressure are not influenced by sternal closure (14). PEEP effects on blood pressure are mostly due to increase in small pulmonary vessels resulted by longer dilation of alveoli, and less often because of changes in respiratory pump (14).

The effects of sternal closure on respiratory system are remarkable too. Sternal closure in a normal paitent without underlying pulmonary disorder results in 1.2mmHg increase of mean airway pressure and 2mmHg increase of maximum inspiratory pressure (13). Sternal closure in normal surgical patients also causes 17% decrease in expired tidal volume, 29% decrease in CO2 elimination , 19% decrease in pul-

monary compliance and increased endotracheal tube leak (15). The influence of sternal closure on increase of pulmonary vessels resistance is significant and can significantly decrease arterial saturation in patients who have shunt dependent circulation, specifically (5).

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 (16).

The most common DSC indication in corrective surgery of congenital cardiac anomalies is hemodynamic changes at the time of sternal closure (5). These changes are the result of edema or dilation of cardiac chambers (17). Shunts might become bi-directional at the time of sternal closure in cyanotic diseases and result in decreased O2 saturation which is probably due to the increase of airway pressure and pulmonary vessel resistance. This problem can be dealt with by DSC (5). Another indication of DSC in children and adults is non-surgical bleeding or uncontrolled bleeding which is only responsive to packing (7,10,17). Application of extra-anatomic homograft can also result in hemodynamic changes at the time of sternal closure (17).

Recurrent ventricular arrhythmias and need for high positive pressure to maintain normal O2 saturation are other indications of DSC (17). The latter mostly occurs in children because of pulmonary edema caused by cardiopulmonary bypass (CPB). Larger cardiac size relative to the thoracic cavity in the children may increase the benefits from DSC in children compared to the adults. Wernovsky et al (2007), in a large review from 52 centers treating over 1000 neonates with hypoplastic left heart syndrome per year, reported that the efficiency of DSC in children has become obvious over the last two decades (18).

Alexi-Meskishvili et al (1995) following an investigation of 113 infants and children with congenital heart defects confirmed that indications of DSC in children are similar to those described in adults, including myocardial edema, depressed myocardial function, inadequate intraoperative hemostasis, dysrhythmias, and access for external cardiac support systems (19). Riphagen et al (2005) expressed that inadequate hemostasis was the most common indication of DSC in children who underwent cardiac surgeries in a single center study over a 3-year period (20).

Yasa et al (2010) reported that DSC is a secure and straightforward technique for treating bleeding, arrhythmia and myocardial edema following on pump cardiac surgery (21). 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.

DSC in heart transplantation is an accepted method with favorable results. Takayama et al (2004) investigated 410 heart transplants from 1985 through 2004 and reported that open chest management followed by DSC is effective and safe in selected patients who have hemodynamic instability after orthotopic heart transplantation (22).

Risk Factors

Samir et al (2002) evaluated 119 children after surgery using DSC in 2002. They showed that weight, gender, inotropic support, PGE2 administration and mechanical ventilation did not affect the final decision, while CPB time above 185 minutes, cross-clamp time above 98 minutes, mixed venous O2 saturation below 51% after termination of CPB, age of below 7 days and cardiac disease type [e.g. aortic interruption and total anomalous pulmonary venous connection] were the main risk factors of DSC (17). In this study, all children who had CPB time above 196 minutes, cross-clamp time above 108 minutes or mixed venous O2 saturation below 47% experienced instability at the time of sternal closure and were treated using DSC. However, another study did not verify the role of cross-clamp time in making the final decision (23).The latter has mentioned ventricular fibrillation at the time of CPB termination as a main risk factor of DSC.

Postoperative hyperglycemia which is a probable risk factor for the development of mediastinitis in infants and children following cardiac surgeries, is a factor which might be another risk factor of DSC (24). Generally exact independent predictive risk factors of DSC have not been indicated in available studies. Prospective investigations in both children and adults are necessary which may elucidate the important risk factors of DSC.

Time of sternal closure

Sternal closure is frequently possible after 1-2 days in adults,

while children may need more time. 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 (25). Riphagen et al (2005) investigated the retrospective chart review of all bypass surgeries performed in a single center over a 3-year period in UK, and concluded that DSC was performed at a median of 21 hours (range, 18-40 hours) after surgery in 60 children patients with median age of 5 year old (25).

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. Different ranges of the duration of open chest management (from 2 to 14 days) postoperatively (12, 26, 27) revealed that the most probable time seems to be dependent on patient condition and surgeon decisions.

Ziemer (1992) reported the mean sternal closure time to be 3 days (5), while this value was reported as long as 5.5 days by Moggio et al (1986) (9). Other studies have reported a range of 2-5 days for sternal closure (28).

Samir et al (2002) suggests that sternal closure should not be tried prior to 3rd post-operative day in children (17); however right decision might be better made considering the condition of each individual case (6).

At the presence of following conditions, sternal closure can be tried (6,17):

1. 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
2. Negative fluid balance
3. Appropriate coagulation state
4. Improvement of respiratory situation and normal arterial gases

Following conditions after trial of sternal closure indicate failure and warrant re-opening of sternum (17,23):

1. Fall in heart rate, arterial O2 saturation or mixed venous O2 saturation
2. Increase of heart rate, central venous pressure (>2mmHg), left atrial pressure (>2mmHg), airway pressure or pulmonary artery pressure
3. Acidosis

Risk factors of elongated sternal opening time are (29-31):

1. Coagulopathy and continuous bleeding
2. Cardiomegaly with or without dysrhtythmia
3. Extra-cardiac devices [e.g. ventricular assist devices (VADs) or extra-anatomic conduit]
4. Pulmonary edema and the decrease of pulmonary compliance

Operative technique

During the time when sternum is open, mediastinal viscera should be provided with coverage (30, 32). Many surgeons prefer to repair the skin and leave sternum open; however, this method seems not to provide the chest with enough space and Gortex patch (PTFE) is a better option for incision site repair (9,17).

Pleura should not be opened in cases of DSC, because in addition to the increase of infection risk, opening the pleura does not provide us with further space as lungs are edematous due to right and left ventricular insufficiency. Moreover, appropriate draining tubes have to be inserted in pericardial space with negative pressure of -20cmHg connected to suction (9).

At the time of sternal closure, culture samples have to be obtained and then normal saline with or without povidon iodine has to be used for irrigation (8,33). Complete debridement of the dead tissue and refreshment of the incision margins are necessary (21).

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 (21). McElhinney et al (2000) 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 (13).

Sternum closure can be performed in ICU with full sterility and transferring the patient to operating room is not necessary (10). However some surgeons prefer to do the sternum closure in operation rooms (21). 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 (2010) recommended that DSC after complex aortic surgeries should be followed by mediastinal exploration every 24—48 h until complete duration of DS (34). Estrera et al suggested the performance of mediastinal exploration in the operating room or in the ICU with sterile irrigation of mediastinal contents (34).

The vacuum-assisted closure system (VAC) is a noninvasive active therapy which results in better healing in difficult wounds that are refractory to conventional therapies and could be used in complicated wounds of DSC (35-37). VAC system is based on the application of negative pressure by controlled suction to the wound surface. Several studies confirmed the effectiveness of the VAC system on microcirculation and the promotion of granulation tissue proliferation (35-38). Baillot et al (2010) in a 15-year review of 23,499 sternotomies reported the lower mortality of VAC method in comparison with the conventional methods of open chest wound management (39). So, VAC is a way to improve the outcome of DSC.

Mortality Rate

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. On the other hand, age range of the patients was from 1 day to 80 years in different studies and it was even 1 day to 19 years in studies of congenital cardiac diseases. These studies have reported mortality from 0% (40, 41) to 60% (42) 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 (10, 13). In-hospital mortality of DSC following complex aortic surgery hase been reported about 17% (34). Yasa et al (2010) reported that 30 day mortality of the 46 patients, ranging in age from 2 to 73 years, who underwent DSC was 23.9% (7 patients died before closure and the remaining 4 after closure) (21).

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) (10, 17). 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. A study by Owens et al (2001) showed that application of DSC in all patients undergoing arterial switch did not yield a better outcome in comparison with selective use of DSC and did not reduce mortality (47).

Johnson et al (2010) examined in-hospital mortality of the newborns with median age of 6 days (4–9 days) reported from 45 centers who underwent DSC after stage 1 palliation for hypoplastic left heart syndrome. He concluded that in centers with high, moderate and low incidence of DSC, mortality rates were: 15%, 26% and 23% respectively (48).

Moreover, the cause of DSC significantly affects the mortality. Uncontrolled bleeding is associated with the highest mortality among the indications of DSC (4,7, 49). This finding emphasizes the role of coagulation disorders in mortality .

The most common cause of death is biventricular failure during the time when sternum is open; and renal failure, respiratory failure and sepsis are the most common causes after sternal closure (9) A study carried out by Furnary et al (1992) listed the risk factors of mortality in 6000 patients as follow (50):

1. Application of more than 4µg/minute epinephrine or equivalent doses of other inotrops
2. Cerebrovascular accidents after surgery
3. Creatinine>3mg/dl
4. Severe ventricular arrhythmia

(The last 2 increase the mortality up to 50%)

Other risk factors of mortality based on other studies are (6, 7, 9):

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

Complications

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 (19, 20, 51-58). 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 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 (43). Other studies have reported the infection risk to be 0-20% (4, 10, 13). The causes of this variety of results can be:

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

It is interesting that Jason et al (2010) reported that the surgical centers with more frequent use of DSC have higher postoperative infection rates (48). The methods of wound care and the therapy approaches was not compared in this Jason et al investigation, but it seems that the higher rate of nosocomial infection could be an effective factor in outcome of DSC. 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.

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. There are also studies indicating that infection may be more prevalent in younger patients and patients who undergo DSC due to uncontrolled bleeding (47, 49). Asymptomatic positive sternal culture is observed in 36-100% of the patients and gram negative bacilli are the most prevalent growing germs; however, clinical infection is rare (5,8,9). Owens et al (2001) (47) showed that deep sternal infection rate was equal in patients who underwent primary sterna closure and DSC after arterial switch for transposition of great vessels. 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 (1996) (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, cerebrovascular accidents, myocardial infarction, cardiac failure and gastrointestinal complications (hepatic failure, intestinal ischemia, etc.). Hashemzadeh et al (2008) 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).???

The most common complication in post-operative course was respiratory failure which was reported up to 50% in some studies (9). However, the studies of Owens et al (2001) and Christenson et al (1996) did not show a higher rate of respiratory failure and longer mechanical ventilation in patients undergoing DSC (7, 47). Vojtovic et al (2009) showed that DSC may cause an important transitory decrease in stroke volume, cardiac output and arterial blood pressure (11).

Nevertheless, overall rate of complications is higher in patients undergoing DSC and roughly 30-50% of these patients experience at least 1 major complication after surgery (4,6,9) Hospitalization period and ICU stay are also significantly longer in these patients (7).

The summary of characteristics and major findings of selected investigations in regard of DSC in pediatrics and adults can be observed in Tables 1 and 2.

Conclusion

DSC is a surgical strategy that has been used in children and adults during the past 35 years in cardiac surgery centers. DSC is an effective technique in patients with severe reduction in cardiac output, respiratory failure, uncontrolled bleeding, arrhythmia, myocardial edema following on pump cardiac surgery and some very ill patients. It can end in reasonable mortality and morbidity rate if used appropriately. DSC is more common in infants and children heart surgeries than adults. 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 physi-

ologic 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.

Table 1: Review on Selected articles on pediatrics DSC

Author	Year	Sample Size	Important findings
Shore et al (46)	1982	n=9 (with average age of 27 months)	*Mortality rate :22%*
Ziemer et al (5)	1992	n =42 (age at operation ranged from 1 day to 15 years, mean: 2 years and 1 month).	*Mortality rate: 33.3% in newborns younger than 30 and totally 40.4% mortality in patients younger than 10 year old.*
Alexi-Meskishvili et al (19)	1993	n =113 [including 43 newborns (38%), 36 infants (32%) and 34 children (30%) between the ages of 1 and 14 years].	Overall mortality was 36.2%
Hakimi et al (44)	1994	n = 55 (with average age of <30 days)	Mortality rate: 20% 2.4% superficial surgical site infection
Iyer et al (59)	1997	n = 150 (age at operation was 229 ± 51 days)	*Survival rate: 88%* *The sternum was left open for 3.86 ± 0.29 days.* *Fifteen patients had minor wound infections requiring antibiotics.*
Tabbutt et al (27)	1997	n =178	Overall mortality :19% Myocardial distention or chest wall edema (n = 47) was a common indication Sternal closure was achieved in 89% of patients at a mean of 3.4 ±1.8 days after opening
McElhinney et al (13)	2000	n = 128 *(age <1 y/o)*	Mortality rate:11.4% During sternal closure: significant increases were noted in pulmonary arterial, left atrial and right atrial pressures. In addition, mean airway pressure and peak inspiratory pressure increased. Sternal wound infection occurred in one patient.
Main et al (15)	2001	n = 17	*Respiratory function may be compromised after DSC, requiring ventilator changes at the time of closure*
Samir et al (17)	2002	n =119 (neonates)	*Interruption of the aortic arch or total anomalous pulmonary venous drainage was most important predictive risk factor of use of DSC*

Table 1: Review on Selected articles on pediatrics DSC (Continued):

Author	Year	Sample Size	Important findings
Riphagen et al (20)	*2005*	*n =60 (with median age 5 days old)*	*Median time of sterna closure: 21 hours (18 to 40 hours)* The most common indication was inadequate hemostasis Overall mortality was 19.7% *Median duration of ventilation and intensive care stay among survivors: 3.8 days (2.4 to 6.3 days) and 4.8 days (3.7 to 7.9 days), respectively.*
Johnson et al (48)	2010	n =1283 (in 45 centers which in 74% of cases DSC was performed; median age at surgery was 6 days (4–9 days), and median weight at surgery was 3.2 kg; 59% were male)	Centers with high and middle DSC use had prolonged length of stay and more infection In centers with high, middle, low DSC use mortality rate were: 15%, 26% and 23% respectively.
Pye et al (25)	*2010*	*A review on nursing considerations for children undergoing DSC after surgery for congenital heart disease*	*Use of open sternotomy and DSC will continue to be an important management strategy for some time, particularly with the trend toward earlier age for surgical repair or staged palliation.*

Table 2: Review on Selected articles on Adult DSC

Author	Year	Sample Size	Important findings
Ott et al (2)	1978	n =4 *(3 adult patients and 1 infant patient)*	*Reviewed the use of DSC for cases of cardiac compression or risk of cardiac tamponade due to excessive bleeding*
Ugorji et al (60)	1980	n =28 *(mean age: 60.4 ± 3 years; Transascending aortic intraaortic balloon insertion was done for the patients)*	*DSC was accomplished within 48 to 96 hours.*
Gielchinsky et al (3)	1981	n =29	*The indications were enlarged heart with tamponade when the mediastinum was closed, poor lung compliance, hemodynamic instability due to intractable arrhythmias or coagulopathy, and presence of a mediastinal assist device.* Of the 29 patients treated, 19 were long-term survivors and only 1 patient had a minor superficial wound infection.
El Abdel Hafez et al (61)	1983	n =50 (with complex heart disease)	Three cases of infection were recorded
Murphy (32)	1985	-Method description	*A method is described for DSC that employs a temporary impermeable rubber patch sutured to the presternal fascia.*
Josa et al (62)	1986	n=15	*DSC was indicated for severe bleeding in 10 patients, heart compression in four patients, and severe postbypass arrhythmias in one patient* Thirteen of the 15 patients were long-term survivors, none of them had wound infections

Table 2: Review on Selected articles on adult DSC (Continued 1):

Author	Year	Sample Size	Important findings
Milgater et al (63)	1986	n =13	*DSC was performed 36-120 hours later on 10 of the patients, when their condition had stabilized.* *Nine patients are long term survivors.* *None of these patients has developed mediastinitis, wound infection, osteomyelitis or instability of the sternum.*
Fanning et al (43)	1987	n =57	*DSC was performed at a mean of 2.8 days* *Thirty-eight patients survived to leave the hospital.* *Superficial wound infection (3 patients), sternal osteomyelitis (1 patient), and fatal mediastinal infection (1 patient).*
Mestres et al (31)	1991	n =25	*DSC was performed at a mean of 2.64 days* The indications were extreme cardiac dilatation and uncontrollable mediastinal hemorrhage Survival rate:72% No mediastinal or fatal infection developed and only 1 patient had late superficial wound infection
Furnary et al (50)	1992	n =75	*DSC was performed at a mean of* 3.4 +/- 0.3 days*days* *Survival rate:67%* Baseline cardiac index improved and remained stable through DSC and late follow-up Sternal infection:5%
Tobe et al (64)	1994	n = 4	DSC was performed 48-72 hours later *The only recognized complication was an abscess formation around the bleeding area, which was successfully treated with systemic antibiotics* In two of these patients, hemodynamic instability was continued because of right ventricular outflow tract obstruction by compression of the packs which were left over the bleeding area.
Donatelli et al (65)	1995	n =8	Three patients died in hospital: 1 case of multiorgan failure; 1 cases of refractory low cardiac output syndrome; and 1 case of respiratory distress syndrome.
Christenson et al (7)	1996	n =123	DSC was performed at 2.0 ± 1.4 days (range 0.5-8 days). Survival rate: 78.9% Mortality was related to indications for open chest: low cardiac output: 38.6%, hemodynamic collapse on closure 0%, diffuse bleeding 33.3% and arrhythmias 27.3%. Superficial sternal wound infection occurred in 1.6% patients after DSC, mediastinitis in 1 (0.8%) and sternal dehiscence in 3 (2.4%) patients, which does not differ from a control population that had primary sternal closure.

Table 2: Review on Selected articles on Adult DSC (Continued 2):

Author	Year	Sample Size	Important findings
Freeman et al (66)	1997	n = 45	Sternal wound infection : 1.7% 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. DSC appears to be a simple and safe method for treating low cardiac output syndrome following CABG
Shalabi et al (10)	2002	n = 40	Mortality rate: 10% The sternum was closed in 36 patients on an average of 22 ± 0.3 hours (range, 8 to 48 hours) postoperatively. Wound infections: 8 patients
Estrera et al (34)	2008	n = 12	In-hospital mortality : 16.7% Mean time to closure was 3 days (range 1-9 days) No patients developed mediastinitis or aortic graft infection during postoperative follow-up (mean:60 months)
Hashemzadeh et al (12)	2008	n = 81	Survival rate: 81.4% who discharged from the hospital at a mean of 15.6+/-8.4 days. The most common causes of death included low cardiac output (67.2%) and multiorgan failure (26.2%). Superficial sternal wound infection :1.2%, mediastinitis :4.9%, sternal dehiscence : 2.4% New onset of acute renal failure and the presence of intraaortic balloon pump were predictive of in-hospital death.
Yasa et al (21)	2010	n = 46 *[31 men and 15 women, ranging in age from 2 to 73 years (mean 57.0+/-7.6 years)].*	Bleeding (n=21), hemodynamic instability (n=16), arrest (n=5), and arrhythmia (n=4) were the reasons of DSC. DSC was performed at 3.48±0.35 days. Mortality within 30 days was 23.9% Complications were mediastinitis (n=2), minor wound infection (n=3) and renal failure (n=5).

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