Delayed sternal closure: an effective procedure for life-saving in open-heart surgery

Açık kalp cerrahisinde hayat kurtarmada etkili bir işlem: Sternumun geç kapatılması

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ABSTRACT

Objective: To determine the incidence, short term survival and safety of delayed sternal closure following open-heart operation due to myocardial edema, non-surgical bleeding and malignant arrhythmia.

Methods: We retrospectively reviewed our medical records to identify the patients who underwent delayed sternal closure following open-heart operation and recorded morbidity, mortality postoperative complications of these patients. Among 2698 patients who underwent on-pump cardiac surgery, the sternum was left open in 46 (1.7%) patients, 31 men and 15 women, ranging in age from 2 to 73 years (mean 57.0±7.6 years). In 39 patients sternum was left opened following the initial operation and in 7 patients sternum was re-opened due to bleeding or hemodynamic instability after initial surgery. Statistical analysis was accomplished using Chi-square test, Mann Whitney U test and analysis of variances for repeated measurements.

Results: The operative procedures were classified as elective in 24 (52.8%), emergency in 10 (22%), urgent in 7 (15.4%), and redo cardiac operations in 5 patients (11%). Bleeding (n=21), hemodynamic instability (n=16), arrest (n=5), and arrhythmia (n=4) were the reasons of delayed sternal closure. The patients had an open sternum for 3.48±0.35 days. Time to discharge was 21.5±1.6 days after operation and 17.6±1.6 days after sternal closure. Mortality within 30 days was 23.9% (7 patients died before closure and the remaining 4 after closure). Complications were mediastinitis (n=2), minor wound infection (n=3) and renal failure (n=5).

Conclusion: Delayed sternal closure is a safe and simple method for treating bleeding, arrhythmia and myocardial edema following on pump cardiac surgery. It is anticipated that as cardiac surgeons become more familiar with the technique of delayed sternal closure, the frequency of its use following on pump cardiac surgery may increase. *(Anadolu Kardiyol Derg 2010; 10: 163-7)*

Key words: Sternum, on-pump cardiac surgery, delayed closure, cardiac surgery procedures

ÖZET

Amaç: Açık kalp cerrahisinden sonra gelişen miyokardiyal ödem, cerrahi olmayan kanama, kardiyak arest ve malign aritmili hastalarda, sternumun açık bırakılmasının güvenli ve efektif olup olmadığını araştırmaktı.

Yöntemler: Açık kalp cerrahisi uygulanan ve sternumu açık bırakılan olgular retrospektif olarak araştırıldı. Mortalite, morbidite ve postoperatif komplikasyonları incelendi. Toplam 2698 hasta açık kalp cerrahisi ile ameliyata alındı. Bunların arasında 46 (%1.7) hastanın sternumu açık bırakıldı. Hastaların 31'i erkek, 15 kadın idi. Yaş aralığı 2-73 (ortalama 57.0±7.6 yıl) yıl idi. Hastaların 39'unda cerrahiden sonra sternum kapatılmadan açık bırakıldı. Yedi hastada ise kanama, hemodinamik bozukluk nedeni ile revizyona alınan hastalar idi. İstatistiksel analizde Ki-kare testi, Mann Whitney U testi ve tekrarlayan ölçümler için ANOVA testi kullanıldı.

Bulgular: Ameliyata alınan hastaların 24'ü elektif, 10'nu erken, 7 acil cerrahi ayrıca, 5'ide redo vakalardan oluşuyordu. Yirmi bir olguda kanama, 16 olguda hemodinamik bozukluk, 5 olguda kardiyak arest, 4 olguda da malign aritmi nedeni ile sternum açık bırakıldı. Ortalama 3.84±0.35 gün içinde sternum kapatıldı. Operasyondan 21.5±1.6 gün, sternum kapatılmasından 17.6±1.6 gün sonra hastalar taburcu edildiler. Otuz günlük hastane içi mortalite 11 hasta da gelişti (%23.9). Yedi olgu sternum kapatılmadan önce, 4 hastada ise sternum kapatıldıktan sonra gelişti. İki hasta da mediastinit, 3 hastada minör yara enfeksiyonları ve 5 hastada akut böbrek yetmezliği gelişti.

Sonuç: Açık kalp cerrahisinden sonra gelişen miyokardiyal ödem, cerrahi olmayan kanama, kardiyak arest ve malign aritmilerde sternumun açık bırakılması basit ve güvenilir bir teknik olarak gözükmektedir. Açık kalp cerrahisinden sonra bu tekniğin kullanım sıklığının artmasının uygun olacağını düşünüyoruz. *(Anadolu Kardiyol Derg 2010; 10: 163-7)*

Anahtar kelimeler: Sternum, on-pump kardiyak cerrahi, gecikmiş kapatma, kardiyak cerrahi işlemleri

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Introduction

The concept of the delayed sternal closure (DSC) after adult cardiac surgery was described in 1975 when Riahi and associates reported the use of external traction of the sternum to minimize postoperative tamponade conditions (1, 2). Myocardial edema, poor hemodynamic indices, primary pulmonary problems, arrhythmias, unsatisfactory hemostasis and cardiac assist devices may prevent primary sternal closure after open-heart operations (3). Sternal closure in these situations may cause additional myocardial compression. Compression of the heart by its surrounding structures can limit the end-diastolic volume of the ventricles and in turn lead to decrease in cardiac output (4).

Since the initial description, DSC has become a valuable tool in the management of patients with postcardiotomy instability and mediastinal edema with a current incidence (5).

Here we report our experience of 46 patients with simple technique of the DSC following open-heart operations over a period of 7 years with the aim of identifying the risks and assessing the outcomes of this technique.

Methods

Patients

Overall, 2698 patients underwent open-heart surgery at our hospital between March 2001 and January 2009. We retrospectively reviewed our medical records to identify the patients who underwent DSC following open-heart operation and recorded morbidity, mortality postoperative complications of these patients. The sternum was left open in 46 (1.7%) patients, 31 men and 15 women, ranging in age from 2 to 73 years (mean-57.0±7.6 years). In 39 patients sternum was left opened following the initial operation and in 7 patients sternum was re-opened due to bleeding or hemodynamic instability after initial surgery. Indications for DSC are given in Table 1. The operative procedure were classified as elective in 24 (52.8%), emergency in 10 (22%), urgent in 7 (15.4%), redo cardiac operations in 5 patients (11%). The primary operative procedures and intraoperative variables are summarized in Tables 2 and 3. Mild ventricular dysfunction was present with a mean ejection fraction of 45.3±15.2% an average mean pulmonary artery (PA) pressure of 45.0±25.5 mmHg (n=37).

Surgical procedure

Standard anesthesia, cardiopulmonary bypass and surgical techniques were employed. For myocardial protection, we preferred blood cardioplegia with normothermia and antegrade-retrograde cardioplegia. All patients received prophylactic antibiotics with combination of cephalosporin and aminoglycosides at induction of anesthesia and thereafter for one week postoperatively. Intraaortic balloon pump (IABP) insertion, preload and after load optimization were the methods to stabilize the patients. IABP were inserted in 20 patients (44%), those who did not have bleeding.

Table 1. Indications for DSC after 2698 cardiac operations

Etiology	number of the patients	%
Bleeding	21	0.77
Hemodynamic instability	16	0.59
Cardiac arrest	5	0.18
Arrhythmia	4	0.14
Total	46	1.7

Data are presented as numbers/percentages
DSC - Delayed sternal closure

Table 2. The distribution of open cardiac surgery and DSC procedures according to the diagnosis

Surgical procedure	No. of patients	DSC, n(%)
CABG	1746	15 (0.85)
CABG+ valve surgery	91	2 (2.2)
CABG + Carotid and peripheral vascular surgery	23	1 (4.3)
CABG + arrhythmia surgery	9	-
CABG + Post MI VSD repair	7	1 (14.3)
Valve surgery	453	12 (2.6)
Valve + arrhythmia surgery	12	-
Aortic dissection and aneurysms	104	10 (9.6)
Redo CABG	21	1 (4.3)
Redo dissection	5	1 (20)
Redo valve surgery	13	1 (7.6)
Congenital cardiac surgery	207	2 (0.9)
Other	15	-
Total	2698	46 (1.17)

Data are presented as numbers/percentages
CABG - coronary artery bypass surgery, DSC - delayed sternal closure, MI - myocardial infarction, VSD - ventricular septal defect

Table 3. Characteristics of patients with and without DSC

Variables	DSC (-)	DSC (+)	*p
Patient age at time of operation, years	55.0±6.4 (1-84)	57.0±7.6 (2-73)	NS
Bypass time, min	64 (27- 212)	147 (40-674)	<0.05
Aortic cross-clamp time, min	52 (18-187)	87 (68-349)	<0.05
Postoperative days until extubation	2 (1-17)	7 (5-102)	<0.05
Postoperative days until hospital discharge	5 (4-102)	16 (15-116)	<0.05

Data are presented as median (min-max) and mean±SD (min-max) values
*Mann Whitney U test
DSC - delayed sternal closure, NS - not significant

DSC was carried out due to hemodynamic instability, major bleeding, cardiopulmonary arrest and uncontrolled arrhythmia. Major bleeding was defined as bleeding ≥150cc/hour with an

unidentified surgical origin site of bleeding. Major bleeding was the reason of DSC in 13 patients because of difficult or unsatisfactory hemostasis, combined with a risk of tamponade if the sternum were closed primarily. The reason of the bleeding was aortic dissection or aneurysm in 7 patients (54%).

During prolonged sternotomy, the skin was closed by heavy merselin stitches and covered with sterile dressing. The dressing was changed daily using a strictly sterile technique with povidone-iodine. The timing of sternal closure was determined by the level of pharmacological support, correction of coagulation defects, improved hemodynamic parameters, especially when starting weaning from the intra-aortic balloon pump and response to temporary re-approximation of the sternum as a test before deciding to close it. Sternal closure was routinely performed in the operation room. Debridement of all nonviable tissue and meticulous cleaning with serum physiologic solution and then Betadine solution were performed. Multiple bacterial cultures were taken from the chest wound. Two mediastinal as well as the pleural drains were kept in place when necessary. The sternum was rewired before closure of subcutaneous tissue and skin.

Statistical analysis

Statistical analysis was done with SPSS 10.0 statistical software program (SPSS Inc, Chicago, IL). Statistical analysis was performed using analysis of variances for repeated measurements, Mann Whitney U test for continuous variables and Chi-square test for nominal variables, respectively. Significance of differences was defined as a p value less than 0.05.

Results

The 46 patients who underwent DSC after cardiac operations from March 2001 through January 2009 represent 1.7% of all cases in which cardiac surgery.

Hemodynamic data and inotropic agents

Hemodynamic data are shown in Table 4. Both the central venous pressure and the mean PA pressure decreased from the time of operation to the period before chest closure consistent with fluid mobilization ($p<0.05$). The cardiac index changed in an inverse fashion to the filling pressures; however, these changes were not significant.

Postoperative course

The patients had an open sternum for 3.48±0.35 days; with a range of 1 to 33 days. Eight patients (17.6%) were extubated within 24 hours of sternal closure. The overall duration of ventilation was 6.2±0.9 days (range, 2 to 102 days) after sternal closure. Time to discharge was 21.5±1.6 days after operation and 17.6±1.6 days after sternal closure.

Mortality

Our operative mortality for DSC patients, defined as death within 30 days or during the same hospitalization, was 27% (n=12). Of the 12 non-survivors, 7 patients died before closure and the remaining 5 after closure. Causes of death were multisystem organ failure (n=4), low cardiac output (n=3), cardiac arrest (n=3), stroke (n=1), and sepsis (n=1). Mortality within 30 days in patients those who did not require DSC was 3.6%.

Morbidity

Two patients (4.4%) required re-exploration for mediastinitis. Methicillin-resistant *Staphylococcus aureus* was detected in blood samples and mediastinal fluid samples of first patient and he died due to sepsis 27 days postoperatively. The sternum of second patient with mediastinitis was not closed by wiring and left to secondary heeling. This patient recovered from mediastinitis was referred to plastic surgery 3 months postoperatively. Three patients (6.6%) had minor subcutaneous wound infections after closure. These were treated with antibiotics and debridement was performed. Seven patients (15.4%) required tracheotomy before being weaned off the ventilator. Extracorporeal membrane oxygenation was performed in 6 patients (13.2%). Two of the 6 patients requiring extra corporal membrane oxygenation died 2 and 3 days postoperatively. Five patients (11%) had developed renal failure. Three of the five patients developed chronic renal failure and required hemodialysis.

Pulmonary problems occurred in 7 (15.4%) of the patients and included suboptimal ventilation requiring high inflation pressures (n=4), atelectasis (n=3) and intrapulmonary hemorrhage (n=1).

Discussion

Our study demonstrated that operative mortality for 46 DSC patients, defined as death within 30 days or during the same hospitalization, was 27%. Of the 12 non-survivors, 7 patients died before closure and the remaining 5 after closure in this study. Causes of death were multisystem organ failure, low cardiac output, cardiac arrest, stroke and sepsis. Mortality within 30 days in patients those who did not require DSC was 3.6%.

Recently several reports have appeared in the literature describing prolonged open chest and subsequent DSC as a life-

Table 4. Hemodynamic data

Time period	HR, beats/min	Mean BP, mm Hg	CVP, mm Hg	Mean PAP, mm Hg	CI, L/min/m^2
Early post-op	96.4±18.9	80.8±15.7	14.7±4.6	46±6.7	2.4±0.64
Before closure	88.5±20.2	92.5±14.6	11.3±2.4	35±4.3	2.8±0.48
Early after closure	87.7±18.4	90.3±12.7	10.8±3.0*	35±4.5*	2.8±0.44

Data are shown as mean ±SD
*ANOVA for repeated measurements, $p<0.05$
BP - blood pressure, CI - cardiac index; CVP - central venous pressure; HR - heart rate; PAP - pulmonary artery pressure

saving procedure in patients with uncontrollable hemorrhage, myocardial edema, low cardiac output and arrhythmias postoperatively (3).

Various methods of DSC have been used, including maintaining the sternum open with a self-retaining retractor (6), mediastinal packing (7), Steridrape (3M Health Care, St.Paul, MN) film coverage (8), silicone membrane (9) and primary skin closure (10, 11). Closure of the skin alone using silicone elastomer sheeting also has proved useful in neonates (9). Gielchinsky et al. (4) reported the first series of 29 adult patients with DSC in 1981. In the same year, Gangahar et al reported relief of tamponade conditions after postoperative sternal reopening in an infant (12, 13).

Mechanical restriction of ventricular relaxation can occur in the absence of intrapericardial blood or clot and contribute to low cardiac output (1). Capillary leak syndrome and an increase in lung water also can contribute to cardiac compromise. DSC can prevent the limitation of diastolic filling in the heart imposed by pulmonary problems such as severely congested or overinflated lungs (14-16). We preferred to leave sternum open in patients with bleeding due to high risk of tamponade and the results were satisfactory in these patients. DSC is an effective method to prevent tamponade in such patients.

Large series in adult patients have reported the incidence of wound infection after heart operations at 1.5-1.8 % (17-19). The choice and duration of antibiotic prophylaxis may influence the risk for surgical site infection in patients with DSC. Pollock et al. (20) used gentamycine until sternums were closed with mediastinitis developing in 10.3% (3/29). Another series used triple antibiotic coverage with cefotaxime, piperacilline and teicoplanin (glycopeptide) until 3 days after sternal closure and reported a 0.9% (1/113) incidence of mediastinitis (21, 22). Hakimi et al. (23) used a first-generation cephalosporin until sternal closure followed by penicillinase-resistant and an aminoglycoside and reported no cases (0/55). We used cephazolin (50 to 75 mg/kg per day) or vancomycin (40 to 60 mg (kg per day) and gentamycine (5 to 7.5 mg/kg per day) until sternal closure with additional coverage if culture-positive infection developed at other sites. We observed mediastinitis in 2 (4.4%) and minor wound infection in 3 patients (6.6%). Our results confirm the prior studies that report low infection rates in patients with DSC.

We did not closed sternum by wiring in a patient with mediastinitis and left him to secondary heeling. There is little data about secondary heeling for mediastinitis following cardiac surgery. Trouillet et al. (24) reported 19 critically ill adults with acute mediastinitis after cardiac surgery who were treated with granulated sugar, either directly (11 patients) or after failure of continuous irrigation (8 patients). Although 5 of 19 (26%) patients died before discharge, none was because of wound complications. After initial debridement of the wound; 11 underwent secondary surgical closure of the wound and in 3 the wound healed by granulation tissue formation alone. No recurrence of sternal infection has occurred after a mean follow-up of 8.2 months (range 3 to 17). In our patient secondary heeling was effective and he was still alive 2 years postoperatively. However, more reports are needed to demonstrate the efficacy of secondary heeling for mediastinitis in patients sternum left open.

Patients who required DSC had a higher mortality rate than the patients not requiring the procedure ($p<0.05$). Patients who required DSC constituted a higher risk group than the patients not requiring DSC. They had more urgent or emergent operation procedures, more severe bleeding and increased frequency of renal failure and pulmonary failure.

DSC rate was higher among patients who underwent complex cardiac surgery in our study. Its rate was higher in patients who underwent surgery due to post myocardial infarction, ventricular septal rupture and aortic dissection, redo or combined cardiac surgery ($p<0.5$). Mortality rates in our patients were similar to previously reported (5, 7, 21, 22).

Study limitations

The aim of the study was to demonstrate DSC effects of low cardiac output, bleeding, arrhythmia and myocardial edema following on pump cardiac surgery under optimized monitoring conditions. Of course, patients after uncomplicated cardiac surgery will not present major postoperative problems. Therefore, these patients were optimal in demonstrating clearly hemodynamic and physiologic alterations. These could assume that the need for inotropic agents, time to discharge time, mortality, aortic cross clamp time, extubation time, would be higher in DSC patients than in those patients without DSC. For future investigations, it is recommended that the demonstrated hemodynamic and fluid mobilizing effects be reproduced in severe and critically patients who present with manifest low cardiac output, bleeding, arrhythmia and myocardial edema following on pump cardiac surgery.

Conclusion

Delayed sternal closure is a safe and simple method for treating bleeding, arrhythmia, and myocardial edema following on pump cardiac surgery. It is effective in resolving the majority of patients without the addition of any significant morbidity and mortality. It is anticipated that as cardiac surgeons become more familiar with the technique of DSC, the frequency of its use following on pump cardiac surgery may increase.

Conflict of interest: None declared

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