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**ARAŞTIRMA / RESEARCH**

# Delayed sternal closure after arterial switch operations: a single center experience

## Arteryel switch operasyonları sonrası gecikmiş sternal kapanma: tek merkez deneyimi

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**Abstract**

**Purpose:** Delayed sternal closure after arterial switch operation is a therapeutic option in the treatment of the hemorrhage, tamponade and edema. The purpose of this study is to evaluate the relationship between delayed sternal closure and mediastinitis after arterial switch operation.

**Material and Methods:** Between January 2011 and November 2016, 43 consecutive patients undergoing arterial switch surgery and delayed sternal closure due to major arterial transposition or Taussig-Bing anomaly were examined retrospectively. The patients' operations were performed by the same surgeon. Indications for delayed sternal closure, sternal closure time, pre- and post-cardiopulmonary bypass, and metabolic status, mortality, and infection parameters were recorded.

**Results:** The mean sternal closure time was 2.7 days. The mortality rate was 2.32 % (n=1). 5 (11.63%) patients required prolonged antibiotic use due to postoperative infection. There was gram negative microorganism predominance. There were no patients with postoperative mediastinitis. Postoperative infection rate statistically not increased with cardiopulmonary bypass time, sternal closure time and intensive care unit stay time. On the other hand, the mortality was seen only one patient. This patients' diagnosis was taussing bing anomaly with single coronary ostia and postoperatively patient needed extracorporeal membrane oxygenation in Intensive care unit.

**Conclusions:** Use of delayed sternal closure is an important management strategy after arterial switch operations. In our study, the prolonged sternal closure time is not associated with increased rate of postoperative mediastinit.

**Key words:** Delayed sternal closure, arterial switch operation, mediastinitis.

**Öz**

**Amaç:** Arteryel switch ameliyatından sonra gecikmiş sternal kapanma hemoraji, tamponad ve ödem tedavisinde terapötik bir seçenektir. Bu çalışmanın amacı, arteryel switch operasyonu sonrası gecikmiş sternal kapanma ile mediastinit ilişkisini değerlendirmektir.

**Gereç ve Yöntem:** Ocak 2011 ile Kasım 2016 arasında, Büyük arter transpozisyonu veya Taussig-Bing anomalisi nedeniyle Arteryel switch ameliyatı yapılan ve gecikmiş sternal kapatma uygulanan ardışık 43 hasta retrospektif olarak incelendi. Hastaların aynı cerrah tarafından uygulandı. Gecikmiş sternal kapanma endikasyonu, sternal kapatılma zamanı, kardiyopulmoner bypass öncesi ve sonrası ve metabolik durum, mortalite, enfeksiyon parametreleri kaydedildi.

**Bulgular:** Ortalama sternal kapanma süresi 2.7 gün idi. Ölüm oranı 2.32% (n=1) idi. Postoperatif enfeksiyon nedeniyle 5 (11.63%) hastada antibiyotik kullanımı uzun sürdü. Gram negatif mikroorganizma baskınlığı vardı. Postoperatif mediastinitli hasta yoktu. Ameliyat sonrası enfeksiyon hızı istatistiksel olarak kardiyopulmoner baypas zamanı, sternal kapatma zamanı ve yoğun bakım ünitesinde kalış süresi ile birlikte artmadı. Öte yandan, mortalite sadece bir hastada görülmüştür. Bu hastaların tanıları bing anomalisini tek koroner ostia ile, postoperatif dönemde ise yoğun bakım ünitesinde ekstrakorporeal membran oksijenasyonuna ihtiyaç duydu.

**Sonuç:** Arterial anahtar işlemlerinden sonra gecikmiş sternal kapatmanın kullanılması önemli bir yönetim stratejisidir. Çalışmamızda, sternum kapanma süresinin uzaması postoperatif enfeksiyon ve mediastinit oranı ile ilişkili bulunmamıştır.

**Anahtar kelimeler**: Gecikmiş sternal kapatma, arteriel switch ameliyatı, mediastinit.

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## INTRODUCTION

Open chest management and delayed sternal closure (DSC) after cardiac surgery is a therapeutic option in the treatment of the severely impaired heart especially in pediatric cardiac surgery. In the early days of cardiac surgery, primary closure of the sternum at the end of the operation was mandatory because of the concern of mediastinal infection. DSC is now accepted as a therapeutic tool in the management of hemodynamically unstable patients where cardiac compression by sternal closure is not tolerated. Sternal closure has been shown to result in a significant decrease in cardiac output and diastolic filling, despite the preserved velocity of fiber shortening, even in patients with good cardiac performance[1]. This procedure, with optimal inotropic and ventilatory assistance, can provide the necessary interim support vital for ultimate survival.

The application of the technique varies among different centers to the degree that while a few centers delay the sternal closure routinely either in all neonates or for certain pathologies, whereas others do not apply the technique. We present our results with the technique of DSC over a 5-year period to examine the outcome with special regard to relations with mediastinitis.

## MATERIALS AND METHODS

### Patients

This study was conducted in conformity with the internationally accepted 1975 Helsinki Declaration as revised in 2002, the Turkish Health Ministry's 'Regulations on Drug Research' No 2148, dated 29 January 1993 and published in the Official Gazette and regulations published later. Ethical approval was obtained from the Cukurova University Ethics Committee. Prior to the procedure, patient parents were provided detailed and clear information on the nature of the intervention and potential complications and written informed consent was obtained from all patient parents. We retrospectively reviewed records of 43 Transposion of Great arteries (TGA) and Taussing bing anomaly whose arterial switch operation were performed between July 2011 and September 2016. 43 operations were performed with median sternotomy. All the patients underwent DSC were enrolled in the study. DSC was used after elective median sternotomy in all of the patients (Figure 1). The patients' cardiac pathologies are listed in Table 1. Cardiopulmonary bypass time (CPBT), Cross clamp time (CCT), intraoperative characteristic are given in Table 2.


**Figure 1. An image of open sterna. Open sterna protected with sponge and steril drape.**

Pediatric ICU mortality, wound infections, lung infections and bloodstream infections were recorded. The patients who had been treated for sterile wound infection (SWI), mediastinitis and other infections were noted. SWI was defined as inflammatory changes and non-purulent drainage on the sternal incision confirmed with clear cultures. Mediastinitis was defined as the presence of pus in the retrosternal space and isolation of organisms from retrosternal cultures obtained at revision operations or debridement. The patients with SWI, mediastinitis and other infections along with the organisms detected from cultures were summarized in Table 3. Delayed sternal closure (DSC) is defined as delaying the sternal closure either as a principal method or after arterial switch operations. The main reason for leaving the sterna open at the end of the procedures was avoid sternal pressure to the pulmonary artery and heart.

All patients were operated on having a cardiopulmonary bypass (CPB) with aortic cross-clamping. The CPB was performed with a basic flow of 2.8 l/min per m2. Myocardial preservation was performed by the anterograde blood cardioplegic solution. We used normothermic blood cardioplegia with warm induction and reperfusion. The average interval between the cardioplegia doses was about 15 min.

**Table 1. Patient characteristics**

| | Mean/n | %/Range |
|---|---|---|
| Age at operation (days) | 22.67 ±75.75 | 3-450 |
| Male | 29 | 67.44% |
| Female | 15 | 32.56% |
| Weight (kg) | 3248±487.95 | 2000-4200 |
| Previous Interventions | | |
| Pulmonary banding | 1 | 2.32% |
| Atrial septectomy | 13 | 30.23% |
| Modified Bt shunt | 0 | |
| TGA pathology | | |
| TGA+ASD+VSD | 18 | 41.86% |
| Taussing-Bing | 4 | 9.30% |
| TGA+ASD | 16 | 37.21% |

TGA: Transposition of great arteries , BT: Blalock–Taussig, VSD: Ventricular septal defect, ASD: Atrial septal defect

**Table 2. Intraoperative characteristics of patients**

| | Patient/Mean | %/Range |
|---|---|---|
| CPB time(min) | 146.22±59.75 | 91-328 |
| Cross Clemp time(min) | 87.15±33.16 | 45-133 |
| VSD closure | 18 | 41.86% |
| ASD closure | 34 | 79.06% |
| Debanding of PA | 1 | 2.32% |

CPB: Cardiopulmonary bypass; VSD: Ventricular septal defect, ASD: Atrial septal defect, PA: Pulmonary artery

**Table 3. Postoperative infection data**

| Patient # | Diagnosis | Site of infection | Organism detected | Result |
|---|---|---|---|---|
| 1. | TGA+VSD | Blood | Staphylococcus Aureus | Alive |
| 2. | Taussing Bing | Blood | Klebsiella Pneumonia | Exitus |
| 3. | TGA+ASD | Blood | Staf̈lococ Aureus | Alive |
| 4. | TGA+ASD+VSD | Blood | Acinotobacter Baumanii | Alive |
| 5. | TGA+VSD | Trachea | Acinetobacter Baumanii | Alive |
| 6. | TGA+VSD | Trachea | Candida | Alive |

TGA: Transposition of great arteries , BT: Blalock–Taussig, VSD: Ventricular septal defect, ASD: Atrial septal defect

**Table 4. Postoperative infections**

| Type | n | % |
|---|---|---|
| Sternal wound infection | 1 | 2.32% |
| Mediastinitis | 0 | 0 |
| Sternal dehiscence | 0 | 0 |
| Refixation required | 1 | 2.32% |

For DSC procedure, sterna were left open and skin was brought close to primary suturation with 2/0 polyglactin suture, an incision was closed with sponge and covered with a sterile wound cover. The dressing was changed in ICU in a totally aseptic manner every day. The patient is evaluated for sternal closure on a daily basis. If a stable hemodynamic condition; a negative total fluid balance and an improvement of the respiratory dynamics and arterial blood gases; and decrease in the blood lactate level in the last 48 hours were maintained, then the patient was taken to OR for closure trial. The trial of closure was identical to the intraoperative trial. Before each trial, two mediastinal swabs for culture were taken. In the case of a successful trial, the sternum was closed with steel wires and the deep subcutaneous tissue also with absorbable suture. The skin was then closed with continued suture. In the interim, we administer diuretics and apply lower tidal volume. The number of cases in whom we achieved to close the sterna primarily with this manipulation has increased lately. Our routine antibiotic prophylaxis was cephazoline 50 mg/kg at the induction of anesthesia and 50

mg/kg on the bypass, then switching to vancomycin 40–60 mg/ kg/day and imipenem 100–150 mg/kg/day, the dosages were adjusted according to the renal functions in case of DSC until the removal of drains. The antibiotic regimen was then changed according to the cultures.

### Statistical analysis

The data were compared with a two-tailed paired t-test. Comparisons between groups of unequal populations were achieved with use of a two-tailed unpaired t-test assuming unequal variances or the Wilcoxon rank sum test, or with both tests. Univariate analysis and multivariate logistic regression were used to determine predictors for DSC. A value of $p<0.05$ was considered significant. Analysis was performed using SPSS 16.0 (SPSS Inc, Chicago, IL).

## RESULTS

There were 43 patients who were enrolled in the study. 14 (32.56%) patients were female and 29 (67.44%) patients were male. The mean age was 22,67 ±75.75 days (3 to 450). The mean body weight was 3248±487.95grams (2000 to 7700). There were no reoperations and no history of previous sternotomy. There was only one patient with preoperative infection. The mean cardiopulmonary bypass time (CPBT) was 146.22±59.75 minutes (91-328) and the mean cross clamp time (CCT) was 87.15±33.16 minutes (45 to 133). 1 (2.32%) patients had ECMO in the postoperative term. 42 (97.67%) patients were weaned from ventilator support. The mean duration of ventilation was 5.7 ± 18 days (3 to 24). The mean length of stay in the intensive care unit was 17.8 ± 40.3 days (6 to 31) and the mean hospital stay time was 16,7 ± 43.8 days (12 to 57). The mean sternal closure time was 2.7 ± 2.3 days (34 hours to 6 days). The hospital mortality rate was 2.32% (n = 1).

Six (13.95%) patients required prolonged antibiotic use due to postoperative infection. The most common microorganism detected was Stafilococ Aureus (33.3%) and Acinetobacter baumani (33.3%) (Table 3). Gram negative microorganisms were detected more than gram positive organisms. One (2.32%) patient had minor wound dehiscence and sterile mediastinal discharge (sterile wound infection), which subsequently healed by secondary intention, however there were no patients with postoperative mediastinitis (Table 4).

## DISCUSSION

Open sternotomy and DSC is a surgical technique that has been used in children to facilitate postoperative recovery. Cardiac compression, which may occur at the time of sternal closure, can lead to decreased cardiac output and hemodynamic instability. Riahi and colleagues were the first to point out the problem of postoperative cardiomediastinal disproportion in 1975[2]. Surgical manipulation of the heart leading to swelling in the pericardium and/or the pericardiomediastinal space, bleeding at the end of CPB, significant increase in heart size with severe ventricular dysfunction, reperfusion related myocardial edema and relentless arrhythmias are all severe complications of cardiac operations that preclude the sternum to be closed[3-5]. They are often associated with a prolonged perfusion time and poor myocardial preservation[3]. Treatment by DSC provides time for recovery of myocardium and for treating the bleeding complications.

The potential for benefit from DSC is greater in small children, because of a larger cardiac size relative to the thoracic cavity. The utility of DSC in children has become evident over the last two decades. While shifting from palliative to earlier corrective surgery, procedures with longer CPB times for younger patients and DSC have become more common. Furnary and colleagues have recently demonstrated after re-opening the sternal incision, up to 59% increase in cardiac index and 18% rise in systemic blood pressure, without significant change in cardiac filling pressures could be obtained[3]. It has been suggested that DSC can be used to prevent the development of low cardiac output state[6]. Some of the pediatric cardiac surgery programs currently use an "elective sternal opening from the operating room" strategy for patients with marginal hemodynamic profiles. In many pediatric institutions it is routine to leave the sternum open prophylactically following long operations or specific procedures such as Norwood I for hypoplastic left heart syndrome[7].

The optimal time for sternal closure remains unclear. In all cases the decision is being made usually by personally based criteria which are highly subjective. There are surgeons who generally leave the sternum open for at least 3 days, and close it any

time from 2 to 14 days postoperatively[7,8]. There are also others who have an aggressive approach to DSC, aiming for closure within 24 hours[9]. We don't have strict criteria for the timing of the sternal closure. We don't want to prolong the closure time over 3 days for infection purposes; however, we usually close the chest when the patient becomes hemodynamically stable. In fact SCT prolonged up to 6 days in one of our patient who was then died to septicemia. The mean SCT in our study was 2.7 days. During these follow up we did not observe mediastinitis. It is a very important fort he cardiac stability.

Many techniques for the maintenance of an open sternum have been described in the literature, including direct closure of the skin, or adaptation of the skin with a latex membrane (Esmark Bandage) sewn to the skin edges or VAC treatment[10]. We prefer to leave open the sterna and suture the skin primarily. It is easy to handle, cheap and helps monitor the bleeding and clot evacuation to avoid tamponade.

Potential risks of delayed sternal closure include sepsis, mediastinitis, bleeding, and late sternal instability. Infectious complications are already well-known contributors to postoperative morbidity and mortality after pediatric open heart surgery[8]. Kagan and colleagues demonstrated that an American Society of Anesthesiologists score of 4 or greater was a risk factor for development of mediastinitis[11]. Tabbutt found mortality as 19%, surgical site infection as 6.7% and mediastinitis as 3.9% in his study of delayed sternal closure in pediatric patients[8].

Shin reported postoperative infection and sterile wound dehiscence rate in DSC patients as 11% and 9%, respectively[12]. These sternal wound infections have been associated with longer postoperative stay[8,13-15]. The group of patients undergoing DSC is believed to have an increased risk for infection because they have predisposing factors such as: prolonged CPB time, low cardiac output, massive transfusion and the need for multiple re-explorations of the chest. A review of the literature reveals that the incidence of wound infection after DSC is generally less than 10%[8]. Some have reported that DSC is not associated with an increase in surgical site infections[6,8,14,16-19], besides some authors claim that wound complications are reduced in DSC technique[20]. Others report DSC as a significant risk factor for bloodstream and surgical site infections[8,13].

In Woodwards' study determining the rate of mediastinitis among the pediatric cardiac centers, 38 (43%) of the 89 centers were enrolled in the study. Woodwards reported 8,774 pediatric congenital procedures with a mean mediastinitis rate of 1.53%. The study concluded that DSC was not associated with increased incidence of mediastinitis. Variations in preoperative measures, antibiotic regimens, and wound care among these centers didn't statistically influence the incidence of mediastinitis[21]. Between July 2007 and September 2011, 1100 pediatric cardiac operations were performed in our center. The total number of mediastinitis cases was 12 (1.09%) in our cohort in which 4 cases initially had undergone delayed sternal closure [4 out of 38 DSC cases (10.5%)].

The difference between the rates of mediastinitis in two different techniques is statistically significant. Prolonged SCT was also shown to be a risk factor for postoperative infection. The infants with open chest are potentially critically ill for a variety of reasons that led to DSC. This may itself be a factor contributing to prolonged ICU stay which we also showed to be strongly related with high rate of postoperative infections in our study. The most common microorganism we isolated from the cultures was gram negative, which is in agreement with the literature[8,13,21]. Like Woodwards and colleagues, we were not detected strong correlation between DSC and mediastinitis in our study. The limitation of this initial report is that there was only a small number of patients in the study cohort and we will require a larger cohort to compare the efficacy and outcome of this technique with other larger studies in our center.

In conclusion, use of DSC is an important management strategy for congenital cardiac surgery, particularly for very young infants who undergo meticulous and long cardiac procedures. Elective DSC does not reduce the morbidity but it confirms the safety and efficacy of the cardiac procedure. The prolonged sternal closure time is not associated with increased rate of postoperative infection rate and mediastinitis; but early closure is strongly advocated.

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