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Delayed sternal closure following open heart surgery in children

Açık kalp cerrahisi sonrası çocuklarda geç sternum kapatılması

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Background: In this article, we reviewed the clinical results of patients in which delayed sternum closing was performed following neonatal open-heart surgery.

Methods: Between April 2008 and April 2011, delayed sternum closure was performed for 142 of 1416 pediatric open-heart operations. Mortality and wound infection rates as well as duration of mechanical ventilation were assessed in this patient group with a mean body weight of 3.55 kg and mean age of 33 days.

Results: In-hospital mortality rate was found to be 31.6% (n=45) of a total of 142 patients whose sternum remained open. The mean time to close sternum was 44 hours in 97 survivors. Only one patient developed mediastinitis, while four patients (4% of survivors) developed superficial wound infection. The mean length of stay on mechanical ventilation was 102 hours.

Conclusion: Although delayed sternum closure is not a new application, it deserves a special attention because of the increasing incidence of neonatal open heart surgery and thanks to its unique advantages.

Key words: Cardiac surgery; intensive care; pediatrics.

Amaç: Bu çalışmada neonatal açık kalp cerrahisi sonrası geç sternum kapatılması uygulanan hastaların klinik sonuçları değerlendirildi.

Çalışma planı: Kliniğimizde Nisan 2008 - Nisan 2011 tarihleri arasında yapılan 1416 pediatrik açık kalp cerrahisi ameliyatından 142'sinde geç sternum kapatılması uygulandı. Ortalama vücut ağırlığı 3.55 kg ve ortalama yaşları 33 gün olan bu hasta grubunun mortalite ve yara yeri enfeksiyon oranlarının yanı sıra mekanik ventilasyon süreleri değerlendirildi.

Bulgular: Sternumu açık bırakılan 142 hastada hastane içi ölüm oranı %31.6 (n=45) olarak bulundu. Sağ kalan 97 hastada ortalama sternum açık kalma süresi 44 saat olarak hesaplandı. Yalnızca bir hastada mediastinit görüldü ve dört hastada (%4 sağ kalan hastalarda) yüzeyel yara yeri enfeksiyonu gelişti. Ortalama mekanik ventilasyonda kalma süresi, 102 saat olarak bulundu.

Sonuç: Geç sternum kapatılması yeni bir uygulama olmasa da, neonatal açık kalp cerrahisinin sıklığının günümüzde artmış olması ve bu uygulamanın sağladığı benzersiz avantajlar nedeniyle üzerinde durulması gereken bir tekniktir.

Anahtar sözcükler: Kardiyak cerrahi; yoğun bakım; pediatri.

Cardiac tamponade is a notorious complication of open heart surgery. A limited ventricular filling with a surrounding blood clot is the usual scenario. However, myocardial swelling and increased lung water may mimic the same clinical picture without bleeding, especially in small children who have a larger cardiac size relative to their thoracic cavity. This phenomenon, known as atypical tamponade,[1] can be overcome by delaying sternal closure until edema regresses. Extracorporeal membrane oxygenation (ECMO) and similar mechanical circulatory support systems are other indications for delayed sternal closure (DSC) since peripheral vessel cannulation is not feasible for small children. Even though DSC is applied in many hospitals practicing congenital heart surgery, surgical techniques, instruments, and the timing of the closure may differ among institutions. We would like to share our experience regarding DSC for pediatric patients who underwent open heart surgery.

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PATIENTS AND METHODS

We operated on 1416 patients with various congenital cardiac defects between April 2008 and April 2011. Among these open heart operations, 142 patients (10%) required DSC in the postoperative period. The mean age and body weight of these patients was 33 days (5-210 days), and the body weight was 3.55 kg (2.1-9 kg). The majority were infants undergoing an arterial switch operation for transposition of the great arteries (TGA) (n=112; 78.8%). The remainder of the patients were listed as truncus arteriosus (n=9; 6.3%), total anomalous pulmonary venous connection (n=5; 3.5%), and miscellaneous (n=16; 16%), (Şekil 1).

The decision for DSC was made electively in most cases as a precaution for atypical tamponade (n=118; 83%). A sudden increase in left atrium pressure and urgent reopening following attempted closure were rare occurrences because of this liberal approach (n=5; 3.5%). Other indications were bleeding (n=17; 11.9%) and ECMO or left ventricular assist devices (LVAD) access (n=2; 1.4%), (Şekil 2). Patients who were not able to survive the first 12 hours following surgery were accounted for as perioperative exitus and were not included in the study.

The length of hospital stay, duration of mechanical ventilation, mortality rate, and percentage of nosocomial infection were analyzed.

Surgical technique and intensive care unit (ICU) management

Our technique is similar to the one published by Iyer et al.[2] Likewise, we used a polyvinyl chloride tube that was readily available from the ¼ inch or ⅜ inch tubing of the bypass circuit for stenting sternal halves. However, we preferred to use the plastic sheath of an isotonic fluid bag instead of a silicon membrane to cover the wound. Separate incisions were made for the pacing wires and chest drainage tubes, but ECMO cannulas were inserted through the sternotomy incision in cases where it was indicated. The left atrial pressure line was standard in all cases. A peritoneal dialysis catheter was not routinely inserted in the operating room, contrary to our earlier protocol.

The antibiotic therapy regimen was similar to standard cases except for the addition of vancomycin in DSC patients. Sedation was achieved with fentanyl infusion and intermittent doses of lorazepam, if required. Neuromuscular blockade was routine so as to provide optimal mechanical ventilation. Ventilator settings were adjusted to pressure-regulated mode with moderate positive end-expiratory pressure (PEEP) values. Loop diuretics were commenced upon the patient's arrival at the ICU to obtain a negative fluid balance. Total fluid intake was restricted to 50 ml/kg/day for all patients since they all weighed less than 10 kg. Enoximone and adrenalin were first line inotropes, and their doses were titrated according to left atrial and systemic pressure values. Total parenteral nutrition was started on the second day in the ICU. The blood acid-base balance was adjusted with serial arterial blood gas (ABG) analyses, with particular attention being paid to the serum lactate levels. The decision for closure was made when patients became hemodynamically stable with moderate doses of inotrope support.

We preferred to close the sternum in the ICU because mobilization may impose unnecessary risks, such as the accidental removal of lines, in some patients. An additional dose of cefuroxime was given before closure. The surgical field was prepared and covered in the usual fashion. Wound edges were debrided with povidone-iodine (Betadine®) solution to enhance wound healing, and the thoracic

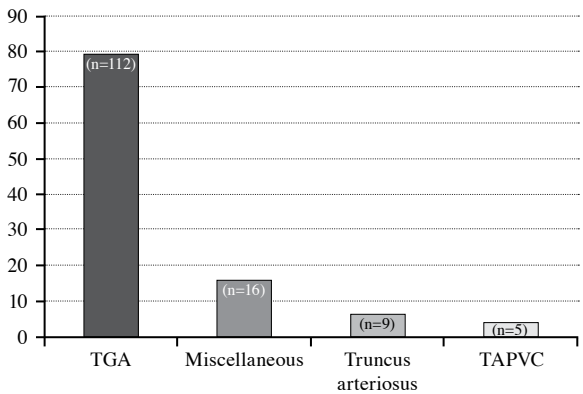

Figure 1. Diagnosis of patients who required delayed sternal closure. TGA: Transposition of great arteries; TAPVC: Total anomalous pulmonary venous connection.

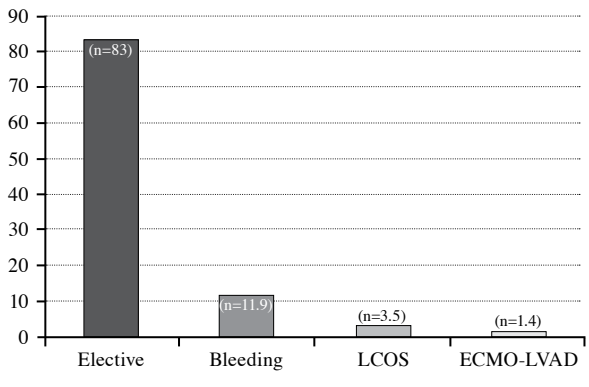

Figure 2. Indications for delayed sternal closure. ECMO: Extracorporeal membrane oxygenation; LVAD: Left ventricular assist device; LCOS: Low cardiac output syndrome.

cavity was irrigated with a mixture of warm saline, weak povidone, and iodine. The sternal edges were approximated, and left atrium pressure was monitored for any rapid increase. If the patient maintained hemodynamic stability, the trial period was ended, and the left atrial pressure line was removed. Bleeding was closely scrutinized until spontaneous hemostasis was achieved. Fortunately, no suture to the pulmonary vein was needed. Anatomic layers were then closed in a manner similar to intraoperative closure.

RESULTS

The mean duration for delayed closure was 44 hours. There were 45 deaths (31.6%), with 27 of those being patients with TGA. Thirteen patients died of sepsis accompanied by multi-organ failure. We postulate that sepsis developed secondary to low cardiac output and prolonged mechanical ventilation. Sixty-eight patients (70% of the 97 survivors) were extubated within 48 hours following sternal closure, and the overall duration for mechanical ventilation was 102 hours. No patients required reopening due to cardiac arrest. The overall hospital stay was nine days after sternal closure. There were four cases (4% of the 97 survivors) of superficial wound infection, and they were all treated with antibiotics. There was only one case of mediastinitis with sternal dehiscence. Blood and wound swab culture tests of this patient found *Klebsiella pneumoniae*. The patient was treated with antibiotics and mechanical irrigation. Finally, after two operations for sternum revision, wound healing was achieved.

DISCUSSION

The benefits of DSC after cardiac surgery have so far received approval.[3] Although an increasing volume of younger patients undergoing open heart surgery has made this application more valuable in the last two decades, the first clinical case was published back in 1975.[4]

The same indications for DSC application in adults are also applicable in children. These can be summarized as inadequate hemostasis that is likely to cause tamponade upon closure, the need for ECMO access or similar life support systems, and pulmonary problems. However, atypical tamponade, which is described as 'a state clinically indistinguishable from cardiac tamponade occurring after operation for congenital heart disease in the absence of intrapericardial blood or clot' is unique to pediatric cases.[1] The tendency of this phenomenon in neonates is the result of a large cardiac size relative to the thoracic cavity. The need for higher pressures to inflate edematous lungs further restricts the movements of the swollen myocardium, which is already disproportionate to the thoracic cavity. Delayed sternal closure has been the sole technique to address these problems in the early postoperative period since mechanical ventilation with therapeutic PEEP values is also rendered possible when the sternum is left open.

Many authors have previously emphasized the importance of fluid balance in neonatal open heart surgery.[5] Limitations of pump prime volumes, blood products, shorter tubing sets, and different ultrafiltration strategies have been key factors regarding this issue.[6,7] Likewise, the maintenance of negative fluid balance in the ICU is an indispensable asset of fluid management therapy which is especially crucial for DSC patients. We start loop diuretics immediately upon arrival from the operating room and insert a peritoneal dialysis catheter liberally if diuretic drugs fail to provide adequate diuresis. Fluid intake is restricted to 50 ml/kg/day. Mechanical ventilator settings are also optimized with the help of complete neuromuscular blockade.

Continuous monitoring of left atrium pressure in the ICU is vital for neonates who have undergone open heart surgery.[8,9] We insert a 3-Fr catheter directly into the left superior pulmonary vein for continuous invasive monitorization. Fortunately, no bleeding has yet been seen from the pulmonary vein, but it may nevertheless drastically impair a patient's hemodynamic status. Therefore, in addition to all the advantages of DSC that have been mentioned above, we would like to reiterate the importance of removing the left atrial pressure line under direct vision as a safety measure. Ceyran et al.[10] proposed a safer alternative in which they used a 5-Fr triple-lumen polyethylene catheter placed into the left atrium trans-septally. According to their description, the tip of the internal jugular vein catheter needs to be inserted manually into the left atrium cavity through the foramen ovale. This technique may be preferable if DSC is not applied.

There are slight differences between DSC methods, such as stenting the sternum followed by skin closure or leaving the wound completely open but covering it only with a silicone membrane. Chu et al.[11] published two cases in which they used a fibular homograft for single-stage sternal closure. They claimed that their technique is feasible since it avoids a second operation and such main disadvantages of DSC as prolonged ICU stay and nosocomial infection. We may prefer this expensive technique in the future if a patient is not stabilized after 72 hours despite maximal inotrope support. Sternal traction devices and autologous rib grafts are other alternatives, but

they are unsurprisingly not suitable for this group of patients because of the miniature nature of the tissues. Our technique is an economic alternative because we use a short segment of a tubing set for stenting and the plastic sheath of an isotonic fluid bag for covering the wound, all of which are readily available on the operating table.

We prefer to undertake the operation for DSC in the ICU. Our main purpose for doing so is to avoid unnecessary risks that may be caused by mobilizing the patient. There was only one patient with mediastinitis accompanied by sternal dehiscence in our retrospective study. Microbiological tests revealed Klebsiella pneumonia, a pathogen also isolated from the majority of our patients who had suffered from bacterial sepsis previously. This patient was treated with antibiotics and mechanical irrigation of the thoracic cavity. We had to operate on him twice to achieve an infection-free stable sternum. There were four cases of superficial wound infection that were similarly treated with antibiotics. Their wound swab culture results were also reported as *Klebsiella pneumoniae*. All of these four patients were discharged without any further operation for the sternum. Since there was only one case of mediastinitis and four cases of wound infections, we conclude that it is safe to perform this operation in the ICU with regard to the risk of infection due to contamination. Shin et al.[12] published their results with a similar group of patients. Their mortality rates were similar, but superficial wound infection rates were higher (20.6%). Although our mortality rate seems to be high, our actual overall mortality rate was 10.7% of the 1416 patients. We would like to emphasize that this group of patients who required DSC had the highest risk for mortality because of their age, body weight, and type of surgical procedure. Finally, we recommend DSC, especially for patients with low body weight who require open heart surgery for complex cardiac anomalies.

Declaration of conflicting interests

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