



Atrial septal defect closure via right mini-thoracotomy: Our single center experience

Sağ minitorakotomi ile atriyal septal defekt kapatılması: Tek merkez deneyimimiz

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ABSTRACT

Background: In this article, we report our experience with repair of atrial septal defects through central cannulation and a right mini-thoracotomy.

Methods: A total of 148 patients (93 females, 55 males; mean age 15.7 years; range 1.5 to 50 years) underwent atrial septal defect closure via right mini-thoracotomy between January 2013 and June 2016. Right mini-thoracotomy incision localization was determined according to patients' age and gender. Central aortic and bicaval cannulation was performed in all the patients. The mean length of the skin incision was 5±1 cm in the patients under 13 years of age and 6±1.5 cm in the patients over 13 years of age and 7.5 cm in adolescents. Atrial septal defects were successfully closed through a right mini-thoracotomy in all patients (3 tricuspid regurgitation, 17 partial anomalous pulmonary venous connection, and, 2 Scimitar syndrome).

Results: Mortality was seen in none of the patients. No intraoperative urgent sternotomy or femoral cannulation was required. The mean cardiopulmonary bypass time was 38±8.2 min, while the mean aortic cross-clamp time was 16±3.8 min and the mean time of surgery was 124±11.3 min. The mean intensive care unit stay was 22 hours and duration of hospital stay was 4 to 6 days. Hemodynamically non-significant residual atrial septal defects were detected on echocardiography in four patients (3.25%).

Conclusion: We consider that right mini-thoracotomy with submammary skin incision for the correction of atrial septal defects is a safe and effective technique with improved cosmetic results.

Keywords: Atrial septal defect; congenital heart disease; cosmesis; minimally invasive.

ÖZ

Amaç: Bu yazıda santral kanülasyon ve sağ minitorakotomi ile atriyal septal defekt tamiri deneyimimiz sunuldu.

Çalışma planı: Ocak 2013 - Haziran 2016 tarihleri arasında, toplam 148 hastada (93 kadın, 55 erkek; ort. yaş 15.7 yıl; dağılım 1.5-50 yıl) atriyal septal defektler sağ minitorakotomi ile kapatıldı. Sağ minitorakotomi insizyon yerine hastaların yaşı ve cinsiyetine göre karar verildi. Tüm hastalarda santral aortik ve bikaval kanülasyon uygulandı. Cilt insizyonu 13 yaş altı çocuklarda 5±1 cm, 13 yaş üstü çocuklarda 6±1.5 cm ve yetişkinlerde 7.5 cm uzunluğunda idi. Atriyal septal defektler tüm hastalarda sağ minitorakotomi ile başarıyla kapatıldı (3 triküspid yetmezliği, 17 parsiyel anormal pulmoner venöz dönüş anomali ve 2 Scimitar sendromu).

Bulgular: Hiçbir hastada mortalite izlenmedi. Ameliyat sırasında acil sternotomi veya femoral kanülasyon ihtiyacı olmadı. Ortalama kardiyopulmoner baypas süresi 38±8.2 dk. iken, ortalama aortik kros-klamp süresi 16±3.8 dk. ve ortalama ameliyat süresi 124±11.3 dk. idi. Ortalama yoğun bakımda kalış süresi 22 saat ve hastane kalış süresi 4 ila 6 gün idi. Dört hastada (%3.25) ekokardiyografide hemodinamik olarak hemodinamik açıdan önemsiz rezidüel atriyal septal defekt saptandı.

Sonuç: Atriyal septal defektlerin düzeltilmesinde submammaryan insizyon ile birlikte sağ minitorakotominin iyi estetik sonuçlar ile birlikte güvenli ve etkili bir teknik olduğu düşünülmektedir.

Anahtar sözcükler: Atriyal septal defekt; doğuştan kalp hastalığı; estetik; minimal invaziv.

Minimally invasive cardiac surgery has been used for the surgical treatment of many cardiac pathologies. It has been developed to improve cosmetic outcomes without affecting the clinical results. With the introduction of these advances, cosmetic and functional satisfaction with surgical outcomes have become more important.^[1] To date, many different

techniques have been described for cosmetic concerns such as full sternotomy with limited skin incision,^[2] right anterolateral thoracotomy,^[3,4] posterolateral thoracotomy,^[5] robotic procedures,^[6] a trans-xiphoid approach without a sternotomy^[7] or different port-access cardiac surgery.^[8] Although cannulation of the femoral artery is the preferred method, ascending

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aortic cannulation is more advantageous due to the safety and cosmesis.

In the literature, there are several reports about right mini-thoracotomy and central cannulation technique.^[9] In the present study, we report our early-midterm results of the largest patient population in the literature for the atrial septal defect (ASD) closure with the only central cannulation technique through the right mini-thoracotomy incision.

PATIENTS AND METHODS

Atrial septal defect repair was performed in a total of 148 patients (93 females, 55 males; mean age 15.7 years; range 1.5 to 50 years) through right mini-thoracotomy in our hospital in which the annual cardiac operation rate is over 1,500 and only one surgical team practices congenital surgeries between January 2013 and June 2016. All patients were considered for the percutaneous approach, although it was unable to be used due to the lack of borders in the foramen or failing the percutaneous closure technique. A total of 126 patients had pure secundum ASD, and two patients had Scimitar syndrome. Three patients also had tricuspid regurgitation (TR) and 17 patients had a partial anomalous pulmonary venous connection (PAPVC) with a high venous ASD.

The study protocol was approved by the Türkiye Yüksek İhtisas Training and Research Hospital Ethics Committee. A written informed consent was obtained from each patient/parent. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patients who had an additional congenital disease, such as ventricular septal defect, pulmonary stenosis or atrioventricular septal defect were excluded. An echocardiographic examination and cardiac catheterization were performed to confirm the diagnosis. Thirteen patients were catheterized due to the poor evaluation of partial anomalous venous return on echocardiography and five patients with an enlarged right ventricle were catheterized to calculate the Qp/Qs precisely.

Before surgery, the surgical policy to use minimally invasive cardiac surgical techniques for the closure of ASD was approved by relevant hospital authorities. Anesthesia was carried out in a conventional manner. A transesophageal echocardiographic examination (TEE) was performed in all patients using the probe placed following the endotracheal intubation. Single lumen endotracheal intubation was performed in all patients in the supine position with a longitudinal pad

under the right shoulder, with the right arm lower than the body. The right mini-thoracotomy skin incision area and length were determined by age and gender. The procedure was performed through an incision in the sixth intercostal space for females under 13 years of age (53 patients, 35.81%) (Figure 1). For females over the age of 13 (38 patients, 25.67%) (Figure 2), the incision was applied just below the inframammary groove. In male patients, the incision was applied 2-3 cm below the nipple (55 patients, 37.16%) (Figure 3). The layer under the pectoralis major muscle was dissected, mammary gland tissue was untouched, and the pleural cavity was entered through the third or fourth intercostal space. If the aorta or inferior vena cava was distant for cannulation, upper or lower costal space was cut close to the sternum.

The mean length of the skin incision was 5 ± 1 cm in the patients under 13 years of age and 6 ± 1.5 cm in the patients over 13 years of age. The pericardium was opened on the right side just above the phrenic nerve, and the right atrial appendage was retracted with a simple suture to obtain better exposure of the ascending aorta. After heparinization and purse-string sutures, aortic and bicaval cannulas were placed carefully. A straight, guided aortic cannula was used for aortic cannulation, a single lumen straight venous cannula was used for superior vena cava cannulation, and a curved venous cannula was used for inferior vena cava cannulation. Central aortic and bicaval cannulation were used in all patients. After cross-clamping, standard crystalloid cardioplegia was used. Del Nido solution was used for the remaining



Figure 1. The incision for the girls under 13 years of age.



Figure 2. The incision for the girls over 13 years of age.

30 patients. During total bypass, the right atrium was entered through a conventional incision and direct, or fresh-pericardial patch closure (PAPVC and Scimitar syndrome, 19 patients 12.83%) was performed using over-and-over sutures with superficial suction through the defect. Before complete closure of the ASD, the air in the left atrium was evacuated carefully by rotation of the operating table in all directions and expansion of both lungs. Transesophageal echocardiography was performed in all patients in the de-airing phase. The aortic cross-clamp was removed. Sinus rhythm recovered spontaneously, and cardioversion was not necessary for the majority of the patients. After termination of extracorporeal circulation (ECC), TEE was re-applied in all patients.

During the postoperative period, a detailed physical examination was performed routinely on a daily basis until discharge. A follow-up transthoracic echocardiographic examination was carried out at the fifth postoperative day and first, third, sixth, and 12 months. In addition, time to return to daily activities was recorded. A special focus was paid to female patients for breast anesthesia, hypoesthesia, pain, and development.

RESULTS

Demographic characteristics and postoperative data of the patients are shown in Table 1.

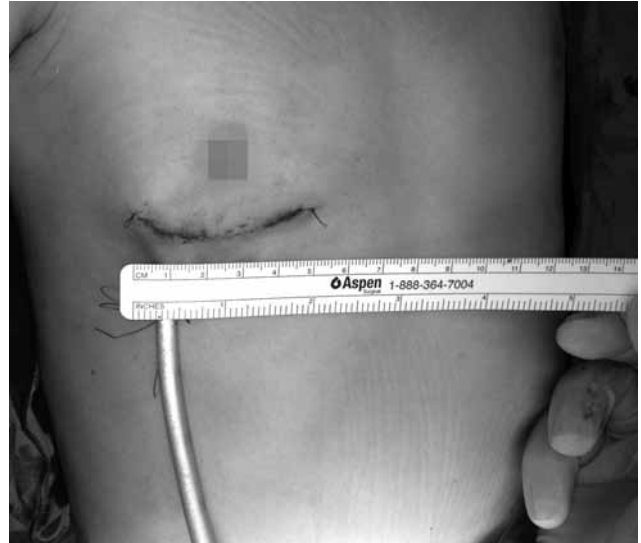


Figure 3. The incision for the male patients.

At baseline, the mean pulmonary-to-systemic flow ratio was 2.6 ± 0.4 (range, 1.5-3.2), and the mean pulmonary artery pressure was 23 ± 4 mmHg (range, 16-27 mmHg). None of the patients had intra- or postoperative complications. The mean duration of ECC was 38 ± 8.2 min. The mean cross-clamp time was 16 ± 3.8 min. The duration of ECC and aortic cross-clamp time for the first 30 patients were longer than that of the remaining 50 patients with the longest time in the patients with Scimitar syndrome (Table 2). The mean operation time was 124 ± 11.3 min. Defibrillation was required in 23 patients after de-clamping of the aorta; however, in the patients who received the Del Nido solution, defibrillation was not needed. Intermittent atrial fibrillation occurred in one patient after decannulation of the aorta. The other patients remained in sinus rhythm, and no cardiac or neurological complications developed.

Aortic tear and massive bleeding occurred in two patients at the decannulation phase. However, both were managed by placing No 4 and 5 Hegar-dilators into the cavity of the aorta and, then, the opening was sutured.

The mean length of stay in the intensive care unit was 22 (range 20 to 24) hours, while the mean duration of stay in the hospital was 4.2 (range 4 to 6) days. There were no cases of reoperation for surgical bleeding or cardiac tamponade. A total of 129 isolated ostium secundum type defects, 17 sinus venosus type defects associated with the PAPVC and two Scimitar syndrome were repaired. Concomitant mild-to-severe TR was repaired in three patients. Hemodynamically

Table 1. Demographic characteristics and postoperative data of patients

	n	%	Mean	Range
Age (year)			15.7	1.5-50
<9	68	45.94		
9-13	13	8.78		
>13	67	45.27		
Gender				
Male	55	37.16		
Female	93	62.83		
Mild-serious TR with ASD	3	2.02		
PAPVC with ASD	17	11.48		
Scimitar syndrome	2	1.35		
Extubation time (min)			130	10-160
Intensive care unit stays (hours)			22	20-24
Hospital stay (days)			4.5	4-5
Drainage (mL)			105	10-200
Returning to daily activity (week)			2.2	2-3

TR: Tricuspid regurgitation; ASD: Atrial septal defect; PAPVC: Partial anomalous pulmonary venous connection.

non-significant residual ASDs were seen in four patients (2.7%) on postoperative transthoracic echocardiography.

The mean follow-up duration was 22.3 months (range, 42 to 2 months) for all patients and time to return to daily activities was 2.2 (range 2 to 3) weeks. All patients were found to be in the New York Heart Association (NYHA) functional Class I. One patient had pleural effusion, and three patients had pericardial effusion as documented by echocardiography at the first follow-up visit, and they were categorized as the NYHA functional Class II. Two patients were treated medically with diuretics and non-steroidal anti-inflammatory drugs and complete recovery was achieved. Pericardiocentesis with a needle was required in one patient (Table 3). The right internal mammary artery (RIMA) injury occurred in 13 female patients. One of them had severe sternal pain, and computed tomography revealed a sternal fracture.

Considering the fact that the pubertal age for the female patients ranges between 9 and 13 years in the

Turkish population,^[10] particular attention was given to the girls for breast development between these ages. In the study, there were 13 female patients between the ages of 9 and 13 (8.78%). In four patients, the breast development did not start at the time of surgery. Five patients' breasts exhibited minimal growth, and four patients' breasts almost achieved adult size at the time of surgery (Table 4). After surgery, these patients were examined carefully with respect to breast development. Growth retardation related to the surgical technique on the breast was not found (Figure 4). All patients were satisfied with the cosmetic healing of the mini-skin incisions.

DISCUSSION

Right mini-thoracotomy is one of the frequently used incisions for the closure of ASDs in young female patients. This approach provides excellent exposure and cosmetic outcomes for female patients. Baharestani et al.^[9] reported 75 patients undergoing successful mini-thoracotomy with central cannulation technique. The cosmetic results of these alternative

Table 2. Operation times

Development of procedure times	Cross-clamp time	CPB time	Mean operation time
	Mean±SD	Mean±SD	Mean±SD
First 30 cases	19±4.8	45±6.2	165±15.1
Last 50 cases	12.3±3.1	31±5.2	102±8.5
Mean values	16±3.8	38±8.2	124±11.3

CPB: Cardiopulmonary bypass; SD: Standard deviation.

Table 3. Postoperative complications/right internal mammary artery

Complications	n
Atrial fibrillation	1
Defibrillation	23
Multiple defibrillation	6
Neurological complications	0
Mediastinitis	0
Wound dehiscence requiring suture	1
Pleural effusion requiring medical treatment	1
Pericardial effusion requiring pericardiocentesis	1
Pericardial effusion requiring medical treatment	2
RIMA injury	13
Sternum fracture	1

RIMA: Right internal mammary artery.

approaches were found to be satisfactory. Also, Doll et al.^[11] reported their five-year experience with right mini-thoracotomy and femoral cannulation technique with 122 patients. Besogul et al.^[12] reported their minimally invasive experience in different cardiac pathologies in 79 patients. Mishra et al.^[13] compared two patient groups (470 transcatheter closure and 170 minimally invasive port access via femoral arteries closure). Our study seems to include the largest patient population for ASD closure with central cannulation through right mini-thoracotomy incision.

Cosmetic results are paramount for pediatric patients undergoing cardiac surgery; however, main concerns remain regarding the optimal method of the corrective surgery for the cardiac anomaly and prevention of postoperative complications. Different approaches have been used over the years to correct



Figure 4. A postoperative second-year view of a girl who was 12 years old at the time of surgery.

Table 4. Pre- and postoperative breast development(+) minimal hypoesthesia on the incision/(++), minimal-to-mild hypoesthesia on the incision and around the incision/(+++), and distinct hypoesthesia around the incision

Patients no	Age (year)	Breast development while surgery	Postoperative follow-up time (month)	Current status of breast	Postoperative asymmetry	Hypoesthesia on the lower part of breast	Hypoesthesia around the incision
1	9	No	13	No	-	-	+
2	9	No	13	No	-	-	+
3	9	No	4	No	-	-	+++
4	9	No	2	Minimally grow	-	-	+++
5	10	Minimally grow	31	Greater than before	-	-	+
6	10	Minimally grow	32	Greater than before	-	-	+
7	11	Minimally grow	23	Greater than before	-	-	+
8	11	Minimally grow	31	Almost adult size	-	-	+
9	11	Minimally grow	18	Greater than before	-	-	+
10	12	Almost adult size	5	Almost adult size	-	-	+++
11	12	Almost adult size	23	Completely grow	-	-	+
12	13	Almost adult size	31	Completely grow	-	-	+
13	13	Almost adult size	10	Almost adult size	-	-	++

congenital heart defects in the pediatric population.^[14] A surgeon's main concerns are adequate exposure, safe application of cardiopulmonary bypass through a central site, effective myocardial protection, and de-airing before the resumption of cardiac ejection.^[15] Although several alternative incision techniques are currently available, our study group showed that access to the heart could be safely achieved by right mini-thoracotomy, incorporating traditional cannulation techniques with a more limited exposure of the heart. In our experience with 148 patients, there were no intraoperative mortality, neurological deficits, or other complications. The incision length was significantly shorter, and all patients were satisfied with the cosmetic healing. All these findings indicate that this technique is a safe and effective procedure.

Femoral and jugular accesses for cardiopulmonary bypass are widely used in minimally invasive and robotic surgeries;^[16] however, there are several complications related to the use of peripheral cannulation. Bedeir et al.^[17] reported that there was an increased risk of stroke in 57 patients in the femoral cannulation group. Also, aortic dissection,^[1] limb ischemia due to low vessel diameter, seroma, pseudoaneurysm, chylothorax or Horner syndrome may be seen due to jugular vein cannulation.^[18-20] Additionally, the length of skin incision in the femoral-cannulated cardiac procedures was longer than central cannulation techniques. Except for the first two patients, all procedures were performed using a single incision in our study, and we observed no complications associated with the femoral cannulation in these patients.

On the other hand, sternotomy is the most common technique for ASD closure, but has some disadvantages. Sternal dehiscence, sternal wound infections and mediastinitis are highly fatal complications related to sternotomy.^[21] Sternal wound complications also carry significant economic burden.^[22] However, minimally invasive procedures are safe, effective, and more cost-effective than median sternotomy.^[23] Cohnet al.^[24] reported a more rapid return to daily activities in their minimally invasive versus full sternotomy comparison study. Similarly, when we used the sternotomy technique, patients under the age of 13 returned to school and resumed daily activities within about 1 to 1.5 months; however, when the thoracotomy method was applied, recovery time was more rapid and return to daily activities was shorter (2.2 weeks).

Furthermore, one of the difficulties faced in the surgery is to identify the skin incision area for prepubertal female patients as the breast tissue localization cannot be easily accessed. Breast

maldevelopment after an inframammary incision and paresthesia around the breast have been documented in the literature.^[25] To avoid this problem, we performed the skin incision on the sixth intercostal space or just below the breast fold. The mammary gland tissue was left intact. Our mid-term follow-up results showed no breast sensitivity and numbness in the lower part of the breast, and asymmetry or breast maldevelopment. Patient satisfaction, particularly with regard to the cosmetic results for women, was higher, and recovery was faster, compared to the sternotomy approach.

However, one of the disadvantages of alternative approaches is the limited position of the heart in de-airing phase.^[15] Therefore, particular attention must be paid to the de-airing phase. Nonetheless, de-airing can be solved by rotation of the operating table in all directions and expansion of both lungs and the use of TEE. In the present study, we employed these techniques for de-airing in all patients, and there were no complications related to ineffective de-airing.

Malignant arrhythmias following de-clamping are other problems during mini-thoracotomy. It is difficult to defibrillate due to the small incisions and position of the heart. To avoid this problem, we used small defibrillation pads. Only six patients required multiple defibrillations (4.87%).

Aortic cannulation and decannulation are other issues to be considered. If the aortic cannula is placed too far from the surgical exposure site, decannulation can be catastrophic. In addition, in case of urgent conversion to sternotomy, mortality and morbidity can increase. In our series, no conversion to sternotomy was necessary. If the aorta and vena cavae are distant from the surgeon, costotomy should be performed near the sternum. Otherwise, it may be difficult to intervene during aortic or caval complications. Similarly, we experienced this problem in two patients. During decannulation of the aorta, aortic tear, and massive bleeding occurred. The bleeding was managed with a suitable size steel plug, and the aorta was sutured with 3/0 polypropylene. Other complications regarding right thoracotomy are conversion to sternotomy, re-thoracotomy, phrenic nerve palsy, wound infection, and thoracic wall hernia;^[26] however, we only experienced the wound infection in one patient. Although the RIMA injury is uncommon via thoracotomy, we experienced this complication in 13 adult female patients with large breasts. Also, a sternal fracture occurred in one of these patients. Based on our assessment, the cause of these two complications is the selected site of the skin incision. In these patients, the skin incisions were small and closed

to the anterior site of the chest. The complications were observed most likely due to the small incision and extreme retraction of the incision. After these complications, we decided to enlarge the skin incision to the mild posterior. The beginning of the incision did not pass the nipple line, and in the remaining 100 patients, we did not experience the RIMA injury or sternal fracture.

Furthermore, prolonged operation time can be a limiting factor for the surgeons in minimally invasive and robotic procedures. Zhe *et al.*^[27] reported that totally thoracoscopic procedures had longer aortic cross-clamp time than surgical repair; however, if the surgical experience was expanded, the total time of the operation would be shortened. In our series, the mean cross-clamp time, cardiopulmonary bypass time, and operation time were $19\pm 4.8/12.3\pm 3.1$ min., $45\pm 6.2/31\pm 5.2$ min., and $165\pm 15.1/102\pm 8.5$ min, respectively in the first 30 patients and the remaining 70 patients.

The main limitation of this study is the lack of long-term follow-up results. In addition, the number of female patients between the ages of 9 and 13 could be increased to observe this technique's special advantages in young female patients. We recommend further studies comparing our technique with other surgical techniques to expand the value of the study.

In conclusion, this study presents the largest series of pediatric patients for whom atrial septal defect closure via right mini-thoracotomy by central cannulation was performed. Based on our study results, we consider that our procedure is safe and effective with improved cosmetic results which also confers many advantages such as less trauma, less bleeding, fewer wound infections, less pain, faster recovery, and shorter hospital stay. However, further studies are required to confirm these findings.

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