Original Article
Repair of congenital heart defects by using the minimal right vertical infra-axillary thoracotomy in children under one year of age

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Abstract: Background: The minimal right vertical infra-axillary thoracotomy approach is one type of incision procedure for congenital heart operations. Objectives: This report describes our experience with this exposure in a limited group of patients under one year of age. Methods: We retrospectively reviewed 44 patients that underwent correction of a congenital heart defect utilizing a standard median sternotomy or a minimal right vertical infra-axillary thoracotomy over one year period. Group 1 consisted of 12 patients that underwent the minimal right vertical infra-axillary thoracotomy while group 2 was made up of 32 patient’s underling a standard median sternotomy. Variable utilized in this comparison included; length of incision, total operative time, cardiopulmonary bypass and cross clamp time, total chest tube output, length of ICU and hospital stay, and duration of mechanical ventilator support. Results: During follow-up period, no deaths were observed in both groups. Both groups had no reoperation for bleeding or residual shunt and had no morbidity. Group 1 patients’ families were very satisfied. Group 1 had a statistically longer bypass time, then Group 2 (P = 0.031). Group 1 had less chest tube drainage (P = 0.069), shorter ventilator times (P = 0.03) and shorter ICU (P = 0.022) and hospital stays (P = 0.03) then compared to Group 2. Conclusions: The intracardiac repair of certain congenital heart defects in children under one year of age can be performed safely and effectively using the right vertical infra-axillary minithoracotomy approach.

Keywords: Minimal right vertical infra-axillary thoracotomy, under one year of age, congenital heart defects

Introduction
The median sternotomy has been considered the gold standard approach for the repair of most congenital heart defect [1]. Although a median sternotomy was considered the routine approach for an open-heart operation, the scar was regarded as unsightly and displeasing and could evoke psychological distress [2], especially in younger, female patients. Ten of thousands of individuals have undergone standard sternotomy with excellent cosmetic results, especially with children. Both ministernotomy (partial inferior sternotomy) [3-7] and limited anterolateral thoracotomy [3, 8-13] are used in paediatric cardiac surgery. The options for surgery using minimally invasive approaches are expanding from the closure of atrial septal defects to the correction of more complex congenital heart defects, such as ventricular septal defects, atrioventricular septal defects and Tetralogy of Fallot [3, 8]. For more than 10 years, the right vertical infra-axillary minithoracotomy approach in paediatric cardiac surgery has been of interest due to its advantages in both Cosmesis and postoperative comfort.

Minimal Right vertical infra-axillary thoracotomy has been used successfully in our clinic for the closure of atrial septal defects [14]. In recent years, this procedure has been used to repair ventricular septal defects in selected patients. In the study, we compare the use of the minimal right vertical infra-axillary thoracotomy to our standard Median sternotomy in the repair of congenital cardiac defects in children under one year of age.

Materials and methods
We retrospectively reviewed 44 patients undergoing correction of a congenital heart defect...
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Patient selection criteria included age, weight and type of heart defects. Our minimum and maximum age limits for both groups were between four months and one year of age. The minimum weight limit was 4 kg for both groups. The selection criteria for both patient groups under one year of age with congenital heart defects were the presence of perimembranous ventricular septal defect, secundum atrial septal defects and partial atrioventricular septal defects. The minimal right vertical infra-axillary thoracotomy and standard median sternotomy procedures were performed in both males and females. Excluded from the study of minimal right vertical infra-axillary thoracotomy and standard median sternotomy were patients who had subpulmonic-inlet, muscular trabecular or multiple ventricular septal defects, a complete atrioventricular septal defect, a complex congenital heart defect, persistent left superior caval vein, right ventricular outflow tract obstruction or pulmonary stenosis, a body mass index of >30 kg/m$^2$ or <20 kg/m$^2$, or those whose families stated a preference for standard median sternotomy.

A perimembranous ventricular septal defect was present in twenty-seven patients (Group 1: n = 8, Group 2: n = 19). A secundum atrial septal defect was present in nine patients (Group 1: n = 3, Group 2: n = 6) and a partial atrioventricular septal defect was present in 8 patients (Group 1: n = 1, Group 2: n = 7). The selected patients had no other concomitant pathologies. A postoperative transthoracic echocardiography was used to detect any residual defects following repair.

### Anesthetic technique

The same anesthetic technique was used in all patients. After an intravenous ketamine bolus (2 mg/kg) was administered anesthesia induction, vecuronium bromide (0.1 mg/kg) was administered as a muscle relaxant. After providing the muscle relaxation tracheal intubation was performed. Anesthesia maintenance was provided using sevoflurane (0.5-2%).

### Surgical procedure

The right vertical infra-axillary thoracotomy approach: The surgical technique for the right

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**Table 1.** Demographic Data and Patient Diagnoses

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1 (n = 12)</th>
<th>Group 2 (n = 32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (months)</td>
<td>7.8 ± 2.1</td>
<td>6.9 ± 3.4</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>5.6 ± 1.3</td>
<td>6.2 ± 2.1</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7 (58.33%)</td>
<td>19 (59.38%)</td>
</tr>
<tr>
<td>Female</td>
<td>5 (41.66%)</td>
<td>13 (40.63%)</td>
</tr>
<tr>
<td>Type of Defects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perimembranous VSD</td>
<td>8 (66.66%)</td>
<td>19 (59.38%)</td>
</tr>
<tr>
<td>Secundum ASD</td>
<td>3 (25%)</td>
<td>6 (18.75%)</td>
</tr>
<tr>
<td>Partial AVSD</td>
<td>1 (8.33%)</td>
<td>7 (21.88%)</td>
</tr>
</tbody>
</table>

Data are presented as mean for continuous variables SD, median (minimum-maximum) and ratios are given as percentage values.

ASD = atrial septal defect. AVSD = atrioventricular septal defect.

Group 1 = Right vertical infra-axillary thoracotomy; Group 2 = Standard median sternotomy; SD = Standard deviation.

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Figure 1. A perioperative view showing the incision of a minimal right vertical infra-axillary thoracotomy.

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Either by a right vertical thoracotomy or a standard median sternotomy over one year period. Informed consent was obtained from the patients’ parents and Institutional Review Board approval was obtained for the study.

We compared patients that underwent minimal right vertical infra-axillary thoracotomy (group 1, n = 12) to standard median sternotomy (group 2, n = 32). The cardiac defects included perimembranous ventricular septal defects (27 patients), ostium secundum atrial septal defects (9 patients) and partial atrioventricular septal defects (8 patients). The patient demographics (age, weight and sex) and diagnostic data are given in Table 1.
vertical infra-axillary thoracotomy has been previously described [15-17]. Following the induction of general anesthesia, the patient was placed in the left lateral decubitus position with the right side elevated 45°-60° and the right arm was wrapped and suspended over the head. The skin incision started from the second intercostal space in the mid-axillary line and continued until the fifth intercostal space (Figure 1). The right thoracic cavity was entered via the 4th intercostal space. The right lung was retracted posteriorly using a wet sponge and a malleable retractor. The pericardium was opened 2 cm anterior to the phrenic nerve. It was then pulled using sling sutures from the superior, middle and inferior parts to provide a good exposure of the aorta and the caval veins. After the pericardium was opened, 3 mg/kg of heparin was administered. The aorta was retracted into the field utilizing a vascular clamp and a single calculation stitch was utilized to stabilize the arterial cannula. Following cannulation of the ascending aorta, purse strings were applied to the superior and inferior Caval veins. The superior caval vein cannula was applied via the thoracotomy incision. A 1 cm incision was made in the seventh intercostal space along the pre-axillary line for the inferior caval vein cannulation to achieve better exposure and facilitate chest drainage after surgery (Figure 2). After bicaval cannulations were applied, the cardiopulmonary bypass was initiated. Under a mildly hypothermic (28-32°C) cardiopulmonary bypass (CPB), the ascending aorta was cross-clamped and cardioplegia was achieved by infusing a cold crystalloid cardioplegic solution into the ascending aorta root. A right atriotomy was performed and closure of the septal defect was accomplished either primarily (all secundum ASDs) or by utilizing a patch of bovine pericardium. The procedures for ventricular septal defect, atrial septal defect and atrioventricular septal defect closure were similar to those used in the median sternotomy. All perimembranous ventricular septal defects were closed through a right atriotomy across the tricuspid valve, without tricuspid valve detachment. Patients with partial AV canal defect underwent primary closure of the mitral cleft and patch closure of the primum ASD. The patients’ pericardia were partially closed to allow pericardial drainage to the thoracic cavity.

**Statistical methods**

The SPSS for Windows version 12.0 pocket program (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis, while quantitative data were given as a mean, standard deviation and qualitative values were expressed as percentages. In the comparison of normal variables between the two groups, we used the independent sample t test, while the Chi-square test was used in the comparison of categorical variables between the groups. All tests were mutual and P<0.05 was considered statistically significant.

**Results**

The demographic data (age, body weight, gender and type of defects) are given in [Table 1](#). The mean age was 7.6 ± 2.1 months in Group 1 and 6.9 ± 3.4 in Group 2. The mean body weight was 5.6 ± 1.3 kg for Group 1 and 6.2 ± 2.1 for Group 2 (P = 0.92).

There were no perioperative complications in either group. Surgical exposure was adequate in all patients. In Group 1 patients, there was no intraoperative extension of the incision or a conversion to a standard approach.

The intraoperative and postoperative results of both groups are listed in [Table 2](#). The mean cardiopulmonary bypass time was longer in Group 1 than in Group 2 and statistically significant (P = 0.031). There were no significant differences in the mean aortic cross-clamp time or in the mean operation time.

In Group 1, the mean ventilation time was 5.1 ± 2.6 hours, ICU stay was 1.5 ± 0.75 days and postoperative hospital stay was 6.4 ± 2.3 days, while in Group 2, they were 9.3 ± 5.7 hours, 2.3 ± 0.54 days and 8.5 ± 1.7 days respectively.
The mean postoperative drainage was 53.35 ± 40.10 ml in Group 1 and 61.10 ± 42.28 ml in Group 2 (P = 0.069). The mean ventilation time (P = 0.028), ICU stay (P = 0.022) and hospital stays (P = 0.03) were statistically different between the two groups.

Patients were followed during postoperative and midterm period (Group 1: 4.2 ± 3.4 months, Group 2: 4.5 ± 3.6 months) with laboratory, electrocardiography, X-Ray and echocardiography. During postoperative follow-up there was no death, no atrioventricular block, no reoperations for bleeding and no other morbidity.

The Group 1 patients’ incisions were healing with excellent results and the parents of all of the patients were highly satisfied with the cosmetic results. There were no thoracic asymmetries, no complaints of hypoaesthetic or anesthetic areas and no signs of unusual posture in those patients who had undergone a minimal right vertical infra-axillary thoracotomy.

Discussion

Median sternotomy has been the standard approach used to correct non-complex congenital heart defects and it has achieved excellent results [15-17 18]. However, deep sternal wound infection, which contributes to significant morbidity, mortality and increased medical cost, is a rare but worrisome complication with this approach and remains a major challenge to cardiac surgeons [19, 20]. Besides, more significant is the fact that the mid-sternotomy scar is a timeless reminder of a ‘heart disease’ for the patients and may evoke psychological distress [2].

In recent years, minimally invasive approaches have gained widespread application and acceptance in adult cardiac surgery due to improved cosmetic results. In addition, reduced surgical trauma may be associated with decreased postoperative pain and discomfort, both of which facilitate faster recovery and a reduction in costs [21]. Several incision alternatives to standard median sternotomy were developed to achieve the same quality of repair with cosmetically superior results. However, all of these incisions have their shortcomings, including a sternotomy scar of mini-sternotomy, breast and pectoral muscle mal-development after anterolateral and posterolateral thoracotomies, [22] and the potential risk of leg ischemia or a later narrowing of the cannulation site [23]. We have performed the minimal right vertical infra-axillary thoracotomy procedure with success in patients older than two years of age to repair atrial septal defects [14]. Additionally, we have received positive feedback from the patients’ parents regarding satisfaction with cosmetic appearance, physical activity and sensation results. For these reasons, we decided to implement this procedure in patients under the age of one.

**Table 2. Results**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1 (n = 12)</th>
<th>Group 2 (n = 32)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incision length (cm)</td>
<td>4.8 ± 2.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Operation time (hours)</td>
<td>3.12 ± 0.77</td>
<td>2.53 ± 0.48</td>
<td>0.086</td>
</tr>
<tr>
<td>CPB time (mins)</td>
<td>56.4 ± 24.7</td>
<td>32.7 ± 22.4</td>
<td>0.031</td>
</tr>
<tr>
<td>ACC time (mins)</td>
<td>31.8 ± 17.4</td>
<td>28.4 ± 19.5</td>
<td>0.241</td>
</tr>
<tr>
<td>Ventilation time (n = 7) (hours)</td>
<td>5.1 ± 2.6</td>
<td>9.3 ± 5.7</td>
<td>0.028</td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>1.5 ± 0.75</td>
<td>2.3 ± 0.54</td>
<td>0.022</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>6.4 ± 2.3</td>
<td>8.5 ± 1.7</td>
<td>0.03</td>
</tr>
<tr>
<td>Amount of chest tube drainage (mL)</td>
<td>53.35 ± 40.10</td>
<td>61.10 ± 42.28</td>
<td>0.069</td>
</tr>
<tr>
<td>Follow-up (months)</td>
<td>4.2 ± 3.4</td>
<td>4.5 ± 3.6</td>
<td>0.119</td>
</tr>
</tbody>
</table>

SD = standard deviation. Continuous variables are presented as mean ± SD. *Independent samples described using t test and Chi-square test. Statistical significance is described as P<0.05.
Qiang Wang and his colleagues [24] published a study regarding their minimal right vertical infra-axillary thoracotomy operations on 274 ventricular septal defect patients. Their graphical evaluation showed that the number of patients under the age of one was eighteen. The small number of patients in our study was due to age; the number of simple cardiac defect operations is less than that of complex cardiac defects in children under one year of age. We believed that we could repair congenital heart defects in patients under one year old via a minimal right vertical infra-axillary thoracotomy and therefore we began performing minimal right vertical infra-axillary thoracotomy procedures in patients under one year of age with simple congenital heart defects. We selected patients with a simple heart defect between the ages of four months and one year who had a suitable body weight. Because low and high body weights can be problems regarding appropriate cannulation and good exposure of the thoracic cavity, we put limitations on an acceptable body mass index range (20-30 kg/m²).

The cosmetic advantage of a minimal right vertical infra-axillary thoracotomy is the short incision, which is often hidden below the armpit (Figure 3). As shown in Figure 3, to avoid the distortion of breast tissue, the incision was made on the infra-axillary line to avoid inhibition of further growth of both the breast tissue and the pectoralis muscle. In addition, the incision site is in the area of the chest wall with the least muscle coverage and it is far from the costochondral junction, thereby not interfering with the development of the chest wall. No asymmetry of the chest or breast was seen in our patients during follow-up. Notably, close observation of breast tissue development is necessary during the follow-up.

Whether minimally invasive procedures in paediatric cardiac surgery will lead to an improved recovery and shorter hospital stays-as has been claimed for adults-is still a point of discussion [4, 5, 8, 25]. In a prospective study of 35 children, Laussen and his colleagues [25] were unable to demonstrate a faster recovery time when comparing patients with a complete sternotomy and a minimally invasive approach for atrial septal defect repair. There were no significant differences in pain scores, ICU stay and total length of hospital stay between the groups. In contrast, Luo and his colleagues [4] reported a significantly shorter hospital stay for patients with mini-sternotomy. However, they did not observe any decrease in postoperative recovery time. In our experience, the length of ventilation time, ICU stay and hospital stay was statistically significant between the two groups. In particular, the decrease in the duration of the hospital stay in this age group was satisfactory, while no peri-procedural or post-procedural complications were observed. This approach seems advantageous in this patient population because it shortens the duration of hospitalization and provides significant cosmetic benefits. However, the low body weight and surface areas of these patients oblige us to make small incisions, making the procedure more difficult because they force us to perform cannulation and surgery in very small areas. Despite these difficulties, we think that the minimal right vertical infra-axillary thoracotomy procedure may be a useful approach for patients younger than one year old who are undergoing congenital heart defect operations.

The minimal right vertical infra-axillary thoracotomy is a minimally invasive approach which provides adequate exposure without compromising the safety or precision of a repair in selected patients under one year old. Complete cannulation for cardiopulmonary bypass can be performed using this approach and the cosmetic results are excellent (Figure 3). In our opinion, simple congenital heart defect patients under the age of one can safely undergo a minimal right vertical infra-axillary thoracotomy. When implementing a minimal right vertical infra-axillary thoracotomy on a child under the age of one, cardiac examination must be carried out in detail. Echocardiographic and angiographies evaluations must be carried out carefully to avoid the need for additional incisions.

Conclusion

Minimalist approaches have gained importance in congenital heart surgery over the last 10 years because they decrease the duration of hospitalization, provide cosmetic advantages and are more cost efficient. Observing muscle, nerve and vessel damage in other minimalist methods led us to perform a minimal right vertical infra-axillary thoracotomy incision. We observed favorable outcomes from this approach in patients under one year of age. The
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limitations and difficulties of a minimal right vertical infra-axillary thoracotomy in patients of this young age are related to their having low or high body weight. Patients in these categories are difficult to cannulate and thoracic exposure for the surgery is poor. We believe that corrective surgery via this approach may be performed on individuals in this patient population who have simple congenital defects and no other pathologies revealed during echocardiographic and angiographic evaluations.

Disclosure of conflict of interest

None.

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References

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