Comparison of cardiac function in children after surgical and Amplatzer occluder closure of secundum atrial septal defects

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Abstract

Objective: The aim of the retrospective study was to examine the changes in the left and right ventricular size as well as the systolic and diastolic function of the left ventricle after surgical and transcatheter treatment of atrial septal defects with Amplatzer atrial septal defect occluder (ASDO).

Methods: Two groups of patients were examined using transthoracic cross-sectional echocardiography before and after the treatment of atrial septal defect: Group A — Amplatzer ASD occluder — 38 children and Group S treated surgically — 20 children. The following parameters were assessed: left and right ventricular end-diastolic diameter indexes, ejection fraction, mitral E wave to A wave velocity ratio, deceleration time (DCT), isovolumetric relaxation time (IVRT) and heart rate.

Results: There was a significant decrease in right ventricular and an increase in left ventricular size in both groups during the follow-up observation. The long-term ECHO examination revealed smaller right ventricle (RV) (Group A: RVEDI=1.00±0.20 vs Group S RVEDI: 1.18±0.20 (p=0.001)) and bigger left ventricle (Group A: LVEDI = 1.04±0.08 vs Group S: LVEDI = 0.99±0.07 (p=0.02)) in Group A in comparison to Group S. Children undergoing operation had significantly shorter IVRT (Group A: IVRT = 50.00±9.65 vs Group S: IVRT = 42.5±8.95 (p=0.02)) than patients after ASDO device application.

Conclusions: (1) During the follow-up period, the diastolic function of the left ventricle is better in children with device closure of ASD compared with those patients treated surgically. (2) Postoperative changes of the left and right ventricular size indexes are more favourable in patients after the device closure of ASD compared with children undergoing the surgical procedure.

Keywords: Atrial septal defect; Paediatric cardiac surgery; Amplatzer occluder; Systolic function; Diastolic function

1. Introduction

The first transcatheter closure of an atrial septal defect (ASD) was described by King in 1974 [1]. The first application of self-expandable double disc Amplatzer occluder (ASDO), performed and described by Masura in 1995 [2], was a subsequent continuation of progress in interventional ASD treatment after some other devices had been used.

The introduction of non-operative methods of ASD treatment allows us to compare this method with surgical techniques. There are several publications assessing the results of surgical and non-operative methods of ASD closure. Authors usually compare patients’ age, complications, presence of residual shunts, length of hospital stay and procedure costs [3–6]. However, there is inadequate literature that evaluates the systolic and diastolic function of the left ventricle after the use of Amplatzer occluder in comparison with children treated surgically.

Systolic and diastolic dysfunction among children with congenital heart defects in pre and postoperative periods is a well-known problem, described by a number of investigators [7–13]. These alterations depend on various factors, e.g., relaxation, contractility, compliance and filling of the atria and ventricles [14–16].

The recovery of right ventricle (RV) and right atrium (RA) sizes after surgical and percutaneous ASD closure have also been described [6,12,14,17]. These parameters return to normal values in 90% of surgical patients. However, specifically the systolic function recovers in only 80% of operated children [12]. The return to the normal values depends on the defect size, patient’s age and pulmonary artery pressure [18,19]. At the same time, no significant increase in systolic function has been found among patients operated for ASD [19].

The formation of pericardial adhesions to the heart muscle and thoracic wall is well described [18].
studies have shown that postoperative changes of the heart surroundings lead to decrease in the right ventricular ejection fraction [20]. The influence of cardio-pulmonary bypass and aortic cross clamping during the operative treatment on myocardium can also influence the outcomes of this method. However, there is no data concerning the influence of all post-surgical changes on the systolic and diastolic function of the left ventricle in comparison with patients treated with the use of interventional cardiology techniques.

The aim of the study was to determine whether the systolic and diastolic function of the left ventricle as well as left and right ventricular size differ in children with ASD depending on the method of treatment.

2. Materials and methods

The study was conducted retrospectively and evaluated patients referred to The Academic Centre in Poznan for treatment of secundum ASD. There were two groups of patients with secundum ASD: Group A — children treated with Amplatzer ASO device and Group S — children treated surgically. Patients were not randomised—an unfavourable anatomy such as absence or presence of small interatrial septal rim favoured recommendation for surgical treatment. Children with arrhythmias or more than trivial mitral and aortic regurgitation were excluded from both groups.

Group A consisted of 38 children with body weight over 13 kg (range 13.0—65 kg, mean 26.1 ± 13.3 kg), for whom the follow-up period ranged from 1 to 3.5 years, mean 2.08 ± 0.73 years. Qualification for percutaneous ASD closure was based on transthoracic echocardiography in all patients. The final decision regarding catheter closure was made on the basis of transoesophageal echocardiography (TOE) examination. Amplatzer device size and stretch diameter of ASD are presented in Table 1.

Group S consisted of 20 operated patients with weight ranging from 12.5 to 65.0 kg, mean 33.10 ± 17.6 kg, for whom the follow-up period was 1.7—3.5 years, mean 2.6 ± 0.61 years. The patients were matched with respect to age and body weight at the time of the surgery to patients from Group A.

Pre-treatment values were marked as Group A-1 or S-1. Follow-up values were marked as A-2 or S-2.

The demographic variables of both the groups are presented in Table 1. There were no significant differences between groups in terms of age, body weight, height, heart rate, ventricle size (normalised to age), Qp:Qs ratio and follow-up time.

Group S was operated in general anaesthesia and in normothermia with use of ECC (membrane oxygenator) and cold crystalloid cardioplegia. ECC time, cross-clamping time and hospital stay after surgery are presented in Table 1. There were no complications after surgical treatment of any patient.

All defects were closed with continuous monofilament polipropylene suture. There was no complication either during or after the treatment.

No occluder had to be retrieved. During the follow up no neurological complications were observed in both groups. All patients were not receiving any medication after discharge from the hospital.

No clinically significant arrhythmia was observed in both groups before treatment and during the follow-up time. Also there was no residual ASD shunt noticed in any patient.

2.1. Methods

TTE examinations were performed just before and at the latest follow up after implantation of the ASDO or after surgery. All examinations were performed in the same conditions.

To assess the systolic and diastolic function of LV, an echocardiographic study was performed with the use of Hewlett-Packard apparatus. All the standard views were obtained using 3.5—2.5 MHz probes. Each evaluated parameter was expressed as an average of five measurements. The left ventricle end-diastolic diameter (LVEDD), right ventricle end-diastolic diameter (RVEDD) and EF were obtained from long axis parasternal projection in the M-mode. Flows through the mitral valve were measured in the four-chamber and through the aortic valve five-chamber projections, respectively. The velocity of the A and E waves

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A-1 (n = 38)</th>
<th>Group S-1 (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Median</td>
<td>Range</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>21.25</td>
<td>13.0—65</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>120.5</td>
<td>81—182</td>
</tr>
<tr>
<td>Qp:Qs</td>
<td>2.31</td>
<td>0.93—5.53</td>
</tr>
<tr>
<td>LVEDD</td>
<td>0.93</td>
<td>0.78—1.01</td>
</tr>
<tr>
<td>Heart rate (min⁻¹)</td>
<td>91.5</td>
<td>63—130</td>
</tr>
<tr>
<td>Follow-up time (years)</td>
<td>2.0</td>
<td>1—3.5</td>
</tr>
<tr>
<td>ASD ~ size in TTE</td>
<td>14.7</td>
<td>8—30</td>
</tr>
<tr>
<td>Time of hospital stay</td>
<td>3</td>
<td>3—5</td>
</tr>
<tr>
<td>Extracorporeal circulation time</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Aortic cross-clamping time</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Size of Amplatzer</td>
<td>16</td>
<td>8—38</td>
</tr>
<tr>
<td>TEE—stretch diameter of ASD</td>
<td>15.3</td>
<td>8—36</td>
</tr>
</tbody>
</table>

LVEDDI—left ventricle end-diastolic diameter index; RVEDDI—right ventricle end-diastolic diameter index.

Table 1

Pre-treatment demographic variables of groups (A-1 and S-1)
were measured as well as isovolumetric relaxation time (IVRT), deceleration time (DCT) and E to A wave ratio. The left ventricular end-diastolic diameter index (LVEDDI) as well as the right ventricular end-diastolic diameter index (RVEDDI) was calculated in relation to the mean norm for respective body weight (16).

Standard 12 lead ECG was performed during each echocardiographic examination and the heart rate was calculated.

Intra-group (Group A-1 vs A-2) and inter-group (A-1 vs S-1 and A-2 vs S-2) comparisons of measured variables were performed.

2.1.1. Statistical analysis

Distribution normality was verified by Shapiro—Wilk test. In all the verified variables the distribution was abnormal. This forced the use of non-parametric tests for further comparisons.

All the variables were described by the mean, standard deviation as well as by median and ranges.

Mann-Whitney U-test was used for inter-group comparisons of independent variables. Wilcoxon’s test served for intra-group comparisons of dependent variables. P-level smaller than 0.05 was assumed to be statistically significant.

3. Results

There was a significant decrease in the size of the right ventricle and an increase in the size of the left ventricle in Group A. After ASO closure, IVRT was longer, whereas the heart rate was slower. There was a significant decrease in the heart rate and IVRT elongation during the long-term follow-up time and the EF, MV-E/A and DCT did not change significantly (Table 2).

There was a significant decrease in the size of the right ventricle, an increase in the size of the left ventricle and a deceleration of the heart rate in Group S. There were no statistically significant differences in the systolic and diastolic function of the left ventricle (Table 2).

There were no statistically significant differences in the ventricular sizes and systolic and diastolic parameters between groups A and S before the treatment. The long-term ECHO examination revealed smaller right ventricle and bigger left ventricle in Group A in comparison to Group S. Children operated for ASD had significantly shorter IVRT than patients after ASO device application (Table 2).

4. Discussion

Perioperative factors such as extracorporal circulation and aortic cross clamping with temporary myocardial ischemia as well as postoperative sequelae, including formation of adhesions between the heart and the surrounding tissues in patients operated for ASD, encouraged us to undertake this study and to compare the systolic and diastolic functions in children treated surgically with ASO device [3,4,18,20,21].

The decrease in the right ventricular diameter and the increase in the left ventricular size are usually observed in

<table>
<thead>
<tr>
<th>Variables</th>
<th>Before A-1 (n = 38)</th>
<th>After A-2 (n = 38)</th>
<th>Before S-1 (n = 20)</th>
<th>After S-2 (n = 20)</th>
<th>A-1 versus S-1</th>
<th>A-2 versus S-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVEDDI</td>
<td>1.64 ± 0.38</td>
<td>1.61 ± 0.29</td>
<td>1.72 ± 0.29</td>
<td>1.66 ± 0.28</td>
<td>0.97 ± 0.20</td>
<td></td>
</tr>
<tr>
<td>LVEDDI</td>
<td>0.97 ± 0.20</td>
<td>1.03 ± 0.20</td>
<td>1.04 ± 0.08</td>
<td>1.01 ± 0.20</td>
<td>0.98 ± 0.20</td>
<td>0.98 ± 0.20</td>
</tr>
<tr>
<td>EF (%)</td>
<td>71 ± 5.31</td>
<td>73 ± 5.28</td>
<td>71 ± 5.48</td>
<td>73 ± 5.28</td>
<td>0.96 ± 0.15</td>
<td>0.96 ± 0.15</td>
</tr>
<tr>
<td>MV E/A</td>
<td>1.62 ± 0.31</td>
<td>1.62 ± 0.31</td>
<td>1.62 ± 0.31</td>
<td>1.62 ± 0.31</td>
<td>0.70 ± 0.20</td>
<td>0.70 ± 0.20</td>
</tr>
<tr>
<td>DCT (ms)</td>
<td>170 ± 6.15</td>
<td>182 ± 6.15</td>
<td>180 ± 6.15</td>
<td>182 ± 6.15</td>
<td>0.97 ± 0.20</td>
<td>0.97 ± 0.20</td>
</tr>
<tr>
<td>IVRT (ms)</td>
<td>40 ± 6.32</td>
<td>50 ± 6.32</td>
<td>50 ± 6.32</td>
<td>50 ± 6.32</td>
<td>0.97 ± 0.20</td>
<td>0.97 ± 0.20</td>
</tr>
<tr>
<td>HR (min)</td>
<td>90 ± 6.15</td>
<td>80 ± 6.15</td>
<td>80 ± 6.15</td>
<td>80 ± 6.15</td>
<td>0.97 ± 0.20</td>
<td>0.97 ± 0.20</td>
</tr>
</tbody>
</table>

**Table 2**

Comparison of right and left ventricle size and left ventricular systolic and diastolic function before and during follow-up after ASD closure of ASD—Groups A, S and A vs S
operated patients as well as in children after ASO device closure. The recovery of the right ventricular size is described in more than 80% of children and in 77% of adults who were operated upon [6,9,12,17,22–25].

Similar changes were observed in our series of patients. It is noteworthy that the relative diastolic right ventricular size in ASO group was closer to the norm than the surgical group. This difference between groups A and S in RVEDDI and LVEDDI was statistically significant and could be explained as a result of surgery including postoperative development of pericardial adhesions [18]. Influence of ECC and temporary myocardial ischemia during surgical closure has also to be taken under consideration [20].

The systolic function of the left ventricle was normal before and after the treatment in children from both groups. There was no statistically significant difference in EF before and after the treatment in children from both groups. This difference between groups A and S in RVEDDI and LVEDDI is noteworthy that the relative diastolic right ventricular size of surgery including postoperative development of pericardial adhesions [18]. Influence of ECC and temporary myocardial ischemia during surgical closure has also to be taken under consideration [20].

The diastolic function among children with ASD differs in healthy patients [2]. The stiffness and compliance of the left ventricle is different. These parameters are altered due to healthy patients [2]. The stiffness and compliance of the left ventricle in Group A.

5. Conclusions

1. During the follow-up period, the diastolic function of the left ventricle is better in children undergoing closure of ASD with ASO compared with patients treated surgically.
2. Postoperative changes of the left and right ventricular size indices are more favourable in patients after closure of ASD with ASO compared with surgical procedure.

References