Original Article

Impact of Transcatheter Closure of Atrial Septal Defects in Pediatric Patients on Body Weight

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Background/Purpose: Pediatric patients with atrial septal defect (ASD) may have failure to thrive. This study aimed to investigate body weight changes in pediatric patients after transcatheter closure of ASD.

Methods: From June 2003 to September 2008, we enrolled 60 pediatric patients who underwent transcatheter closure of ASD. Changes in body weight percentile, heart rate, and resolution of right ventricular hypertrophy were compared before and after ASD closure. Patients were divided into two groups according to initial weight percentile: group A, < 50th percentile (n = 39) and group B, ≥ 50th percentile (n = 21). Echocardiography and routine weight measurements were performed before the procedure and at 3, 6, and 12 months during follow-up. Clinical presentations, laboratory data, and outcomes were measured.

Results: Increased body weight percentile (41 ± 4 vs. 48 ± 4, p < 0.01), lower heart rate (100 ± 2 beats/min vs. 89 ± 2 beats/min, p < 0.01), and resolution of right ventricular hypertrophy (59/60 vs. 1/60, p < 0.01) were achieved after ASD closure at the 12-month follow-up. Patients in group A were significantly younger (4.6 ± 0.5 years vs. 7.0 ± 0.9 years, p = 0.016), had a higher pulmonary/systemic blood flow ratio (2.2 ± 0.1 vs. 1.8 ± 0.1, p = 0.044), a larger ratio of ASD diameter/body surface area (25.0 ± 1.4 vs. 16.4 ± 1.9, p < 0.01), and higher percentage of weight gain increase ≥ 5 percentile compared with patients in group B (22/39 vs. 6/21, p = 0.039).

Conclusion: Transcatheter closure of ASD positively affects weight gain. An increase of 7 percentile weight was observed at 1 year of follow-up. Patients with a younger age, higher pulmonary/systemic blood flow ratio, and a larger ratio of ASD diameter/body surface area may have better weight gain after ASD closure.

Key Words: Atrial septal defect, children, transcatheter closure, weight percentile

Atrial septal defect (ASD) is a common congenital heart disease. Most pediatric patients are asymptomatic, but patients with large ASD or significant left to right shunt may have failure to thrive.1,2 Improvement in body weight after surgical repair of ASD has been reported.3,4 With improved catheterization techniques, transcatheter closure of ASD has become an alternative procedure to...
There are only a few reports assessing the outcome of weight change after transcatheter closure of ASD. The objective of this study was to investigate the impact of transcatheter closure of ASD on body weight gain in pediatric patients.

**Patients and Methods**

From June 2003 to September 2008, 60 children (16 boys and 44 girls) who underwent transcatheter closure of ASD with an Amplatzer septal occluder (ASO) (AGA Medical Corp., Golden Valley, MN, USA) were enrolled. The study was retrospective and the data collection was approved by the Institutional Review Board of Chang Gung Memorial Hospital. Among these patients, all except one patient had right heart dilatation. Five patients had dyspnea on exercise. Four patients had other associated cardiac anomalies, including three with pulmonary valvular stenosis and one patent ductus arteriosus. Among patients with pulmonary stenosis, one received balloon angioplasty at infancy because of critical stenosis, and the other two had conservative treatment because their pressure gradient was less than 30 mmHg. The patient with patent ductus arteriosus received a Gianturco coil implantation in the same procedure.

The indication for closure was an age over 2 years and less than 18 years, the presence of right ventricular hypertrophy (RVH) and/or a ratio of pulmonary blood flow to systemic blood flow (Qp/Qs ratio) ≥ 1.5. RVH was determined by electrocardiogram (ECG) and echocardiogram. The diagnosis of RVH by ECG fulfilled at least three of the following criteria: right axis deviation, tall P waves (> 2.5 mm), an rsR’ pattern in the right precordial leads with the second R wave taller than the initial one, a qR pattern in the right precordial leads, age-corrected increased voltage of the R wave in lead V1, increased voltage of the S wave in leads V5–V6, and a positive T wave in lead V1 between the ages of 6 days and 6 years. On echocardiographic assessment, RVH was diagnosed by the demonstration of paradoxical motion of the interventricular septum on an M-mode study and/or the presence of a larger right ventricular volume than the left ventricular counterpart, as seen on the apical four-chamber view of a two-dimensional echocardiogram. After device closure of ASD, the right ventricular volume was considered normal when there was no paradoxical motion of the interventricular septum as observed from the M-mode study, and regressive change of the right ventricle with ventricular volume equal to or less than that of the left ventricle as seen on the apical four-chamber view of a two-dimensional echocardiogram. Patients with chromosomal abnormalities, congestive heart failure, severe gastrointestinal tract malformation, or diseases that potentially caused failure to thrive were excluded.

The procedure was performed under general anesthesia. The morphological characteristics of the defect and size were evaluated by transesophageal echocardiography in most of our cases and a cylindrical Amplatzer sizing balloon (AGA Medical Corp.) was used in some of the cases. Echocardiographic study was performed using the Philips SONOS 7500 system (Philips, Andover, MA, USA). Right and left heart catheterization was performed and pressures were determined with a Berman angiocatheter (Arrow International, Mt. Holly, NJ, USA). Pulmonary and systemic flows were determined by the Fick method.

Since weight gain naturally increases as children grow up, we adopted body weight percentile as a parameter to investigate the effect of ASD closure on weight changes. The World Health Organization (WHO) child growth standard database (www.who.int/childgrowth/) depicts normal growth under optimal environmental conditions and can be used to assess children everywhere, regardless of ethnicity, socio-economic status, and type of feeding. Therefore, WHO charts were adopted in this study, and the body weight percentile was calculated via the least mean square method.

The size of the ASD was unable to be used as a parameter to evaluate the effect on weight gain because it was variable depending on the children’s age and body mass. Therefore, an ASD size/body surface area (BSA) ratio was applied for evaluation.
of the effect on body weight gain. The BSA was calculated by means of the following formula:\textsuperscript{14}

\[
BSA = \sqrt{\text{height (cm)} \times \text{weight (kg)}}/60
\]

In most patients, heart rate was recorded by using a complete 12-lead surface ECG with the patients in a quiet condition after resting for at least 5 minutes. In young children or patients with poor cooperation, heart rate was assessed when the patients were sleeping. Among these 60 patients, changes in body weight percentile, heart rate, and the resolution of RVH were compared before and after ASD closure. In addition, the patients were divided into two groups according to initial weight percentile: group A, < 50\textsuperscript{th} percentile; group B, ≥ 50\textsuperscript{th} percentile. Echocardiography, ECG, and weight measurements were performed before the procedure and at the 3\textsuperscript{rd}, 6\textsuperscript{th}, and 12\textsuperscript{th} months during follow-up. Clinical presentations, laboratory data, and outcomes were compared. Comparisons between these two groups were made regarding their sex, age, heart rate, mean pulmonary artery pressure, Qp/Qs ratio, ASD size, and ratio of ASD diameter/BSA.

\textbf{Results}

The median age of the 60 children was 4.1 years (range, 2–17.2 years). The clinical presentations are shown in Table 1. Increased body weight percentile (41 ± 4 vs. 48 ± 4, \(p < 0.01\)), a lower heart rate (100 ± 2 beats/min vs. 89 ± 2 beats/min, \(p < 0.01\)), and resolution of RVH (59/60 vs. 1/60, \(p < 0.01\)) were achieved after ASD closure at the 12-month follow-up. In addition, resolution of RVH was detected by echocardiography at the 6-month follow-up in all patients, except for one patient. The only patient who had persistent right heart dilatation was a 6-year-old boy who had critical pulmonary stenosis. Follow-up echocardiography showed no residual stenosis but a moderate degree of pulmonary regurgitation, which contributed to persistent right heart volume overload.

There were 39 patients in group A and 21 patients in group B. The clinical manifestations are shown in Table 2. There were no statistically significant differences between the two groups regarding sex distribution, heart rate, mean pulmonary artery pressure, ASD size, and the presence of residual shunt at the 12-month follow-up. Patients in group A were significantly younger (4.6 ± 0.5 years vs. 7.0 ± 0.9 years, \(p = 0.016\)), had a higher pulmonary/systemic blood flow ratio (2.2 ± 0.1 vs. 1.8 ± 0.1, \(p = 0.044\)) and a larger ratio of ASD diameter/BSA (25 ± 1.4 vs. 16.4 ± 1.9, \(p < 0.01\)) compared with patients in group B. In addition, a higher percentage of weight gain increase ≥ 5 percentile was observed in group A patients compared with that in group B (22/39 vs. 6/21, \(p = 0.039\)). During follow-up, the mean weight gain was 1.7 kg, 2.0 kg, and 3.4 kg at the 3\textsuperscript{rd}, 6\textsuperscript{th}, and

\begin{table}[ht]
\centering
\caption{Clinical presentations of atrial septal defect patients before and after closure}
\begin{tabular}{|l|c|c|c|c|}
\hline
          & Before closure & Third month after closure & Sixth month after closure & Twelfth month after closure \\
\hline
Heart rate (beats/min) & 100 ± 2 & 93 ± 2\textsuperscript{*} & 92 ± 2\textsuperscript{*} & 89 ± 2\textsuperscript{*} \\
Presence of RVH & 59/60 & 6/60\textsuperscript{*} & 1/60\textsuperscript{*} & 1/60\textsuperscript{*} \\
BW (kg) & 20.7 ± 1.6 & 22.4 ± 1.9\textsuperscript{*} & 22.7 ± 1.8\textsuperscript{*} & 24.1 ± 1.8\textsuperscript{*} \\
BW percentile & 41 ± 4 & 46 ± 4\textsuperscript{*} & 48 ± 4\textsuperscript{*} & 48 ± 4\textsuperscript{*} \\
\hline
\end{tabular}
\end{table}

\textsuperscript{*}p < 0.05. BW = body weight; RVH = right ventricular hypertrophy.
Among the 60 patients, 28 (22 in group A and 6 in group B) demonstrated a body weight increment ≥5 percentile 1 year after transcatheter closure of ASD. Patients in group A had weight gain increments of 4, 8, and 11 percentile at the 3rd, 6th, and 12th months of follow-up, respectively. Weight improvement by 5 percentile was achieved at the 6th and 12th months of follow-up in patients of group A only (Table 3). This finding indicates that thinner children have a better improvement in weight gain.

**Discussion**

ASD is a structural defect between the right and left atria. Although ASD is often asymptomatic in childhood, it may potentially cause heart failure or failure to thrive. After early ASD closure by surgery or by transcatheter device implantation, good improvement in right ventricular and right atrial volume overload can be achieved. In our study, there was no significant difference in ASD size between the two groups. However, patients in group A had a larger ASD/BSA ratio than patients in group B. Right heart volume resolution has been reported as early as 3 to 6 months after device closure. In our study, right heart dilatation had regressed to normal in most children during 6 months of follow-up.

### Table 2. Clinical manifestations of patients with atrial septal defect

<table>
<thead>
<tr>
<th></th>
<th>Group A (n = 39)</th>
<th>Group B (n = 21)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (male:female)</td>
<td>10:29</td>
<td>6:15</td>
<td>0.807</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>4.6 ± 0.5</td>
<td>7.0 ± 0.9</td>
<td>0.016*</td>
</tr>
<tr>
<td>Initial heart rate (beats/min)</td>
<td>103 ± 3</td>
<td>95 ± 3</td>
<td>0.083</td>
</tr>
<tr>
<td>Mean pulmonary artery pressure (mmHg)</td>
<td>18.6 ± 0.7</td>
<td>17.4 ± 0.8</td>
<td>0.251</td>
</tr>
<tr>
<td>Qp/Qs ratio</td>
<td>2.2 ± 0.1</td>
<td>1.8 ± 0.1</td>
<td>0.044*</td>
</tr>
<tr>
<td>ASD size (mm)</td>
<td>16.1 ± 0.8</td>
<td>14.5 ± 1.5</td>
<td>0.318</td>
</tr>
<tr>
<td>ASD size/BSA ratio</td>
<td>25.0 ± 1.4</td>
<td>16.4 ± 1.9</td>
<td>&lt; 0.01*</td>
</tr>
<tr>
<td>Weight increased ≥5 percentile at the 12th month</td>
<td>22/39</td>
<td>6/21</td>
<td>0.039*</td>
</tr>
<tr>
<td>Residual shunt after 12 months follow-up</td>
<td>2/39</td>
<td>0/21</td>
<td>0.537</td>
</tr>
</tbody>
</table>

*p < 0.05. Group A = weight < 50th percentile; Group B = weight ≥ 50th percentile; ASD = atrial septal defect; BSA = body surface area; Qp/Qs = ratio of pulmonary blood flow to systemic blood flow.

### Table 3. Weight percentile increased after atrial septal defect closure

<table>
<thead>
<tr>
<th></th>
<th>Group A (n = 39)</th>
<th>Group B (n = 21)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd month</td>
<td>4 ± 2</td>
<td>3 ± 2</td>
<td>0.635</td>
</tr>
<tr>
<td>6th month</td>
<td>8 ± 2</td>
<td>3 ± 2</td>
<td>0.145</td>
</tr>
<tr>
<td>12th month</td>
<td>11 ± 3</td>
<td>0 ± 3</td>
<td>0.023*</td>
</tr>
</tbody>
</table>

*p < 0.05. Group A = weight < 50th percentile; Group B = weight ≥ 50th percentile.

Previous studies have concluded that body weight gain improves after surgical repair of ASD. Rhee et al reported improvement in growth after surgical or transcatheter device closure of an ASD in asymptomatic children in the lower 16th percentile for height or weight. Fraisse et al observed that transcatheter closure of ASD in children weighing 15 kg or less with retarded growth tends to recover within 1 year of closure. In contrast, our study applied body weight percentile as a parameter to investigate the effect of body weight change after transcatheter closure of ASD. Our results demonstrated that transcatheter closure of ASD has a positive effect on weight gain, especially for children whose weight was < 50th percentile, were a younger age, had a higher Qp/Qs ratio, and had a larger ratio of ASD/BSA.

Failure to thrive is a very complex condition in children. The pathophysiology includes prematurity, genetic factors, congenital anomalies or syndrome, anemia, decreased immunologic...
function, increased metabolic rate, maldigestion, malabsorption, or endocrine disorders. Therefore, we excluded such patients from the study. In addition, constitutional status or other factors such as food intake, nutrition and activities could also be important factors affecting body weight gain in these children. In general, weight gain improves in patients after transcatheter closure of ASD. However, in our study, there were 17 patients in group A whose weight increase was <5 percentile at the 1-year follow-up. Such poor body weight gain might be due to poor caloric intake or slim condition of the patients.

Our study was limited by the absence of a control group (ASD patients without closure). However, recruitment of such a control group was difficult. More importantly, it is not ethical without applying appropriate management for ASD patients with right heart failure. In addition, the present study aimed at assessing the effect of transcatheter closure of ASD in the improvement of body weight. Therefore, other biochemical markers that might affect body weight gain, such as prealbumin, insulin-like growth factors or growth hormone, were not included. The results of this study suggest that patients with ASD and poor weight gain may have a potential benefit after early transcatheter closure.

In summary, transcatheter closure of ASD has a positive effect on weight gain. An increase of 7 percentile weight is found in children at the first year of life. Patients who have a younger age, a higher pulmonary/systemic blood flow ratio, and a larger ratio of ASD diameter/BSA may have better weight gain after ASD closure.

References

