The effect of adenotonsillectomy on right ventricle function and pulmonary artery pressure in children with adenotonsillar hypertrophy

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ABSTRACT

Objectives: Adenotonsillar hypertrophy (ATH) is the most common cause of upper airway obstruction in children. Severe upper airway obstruction may have an effect on chronic alveolar hypoventilation, which consequently may lead to right ventricle (RV) dysfunction induced by hypoxic pulmonary vasoconstriction. The investigators aimed to study RV function and mean pulmonary artery pressure (mPAP) in patients with ATH who were undergoing adenotonsillectomy by using tissue Doppler echocardiography (TDE).

Methods: The study examined 27 children with ATH who had a mean age of 8 ± 2 years. The subjects were comprised of 17 (63%) males and 10 (37%) females. Hypertrophy of the tonsils was graded according to the Brodsky scale. Children having either grade 3 or 4 hypertrophied adenotonsils were recruited for the study. Adenotonsillectomy was performed on all subjects in the study group and echocardiographic examination was repeated 3 months postoperatively.

Results: Tricuspid Em significantly increased after adenotonsillectomy (17.7 ± 3.6 vs. 19.1 ± 5.5, p = 0.04). The RV myocardial performance index (MPI) and mPAP significantly decreased after adenotonsillectomy (RV MPI: 0.57 ± 0.13 vs. 0.40 ± 0.12, p < 0.001 and mPAP (mm Hg): 31 ± 9 vs. 25 ± 7, p = 0.001).

Conclusion: The results of this study, evaluated with the results of previous studies, demonstrated that adenotonsillectomy improved RV performance and reduced mPAP in children with ATH.

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1. Introduction

Adenotonsillar hypertrophy (ATH) is an important health condition, and is seen especially during childhood. The relationship between ATH and other diseases such as cardiovascular and pulmonary disorders was reported in previous studies [1–4]. It is well known that ATH is one of the most common causes of upper respiratory tract obstruction, obstructive sleep apnea (OSA) and hypoxia in children [2]. Severe upper respiratory tract obstruction may have an effect on chronic alveolar hypoventilation, which consequently may lead to right ventricle (RV) dysfunction induced by hypoxic pulmonary vasoconstriction. This RV dysfunction may result in increased pulmonary vascular resistance and pulmonary artery pressure (PAP) [5]. Echocardiography is one of the most important noninvasive methods to diagnose for structural heart disease in children [6]. Previous conventional echocardiography studies have shown that upper respiratory tract obstruction causes pulmonary hypertension (PH) and right ventricle (RV) dysfunction [2,7–12]. Although the standard test for the evaluation of pulmonary artery pressure is performed by highly invasive cardiac catheterization, Doppler echocardiography has been demonstrated to have a perfect correlation with cardiac catheterization [13,14]. Tissue Doppler echocardiography (TDE) also gives more detailed quantitative information about myocardial function compared with conventional echocardiography [6].

In the current study, the investigators aimed to study RV function and mean pulmonary artery pressure (mPAP) in patients with ATH who were undergoing adenotonsillectomy by using TDE.
2. Patients and methods

2.1. Study population

A prospective trial was performed on children with ATH. The study was approved by The Ethics Committee of Erciyes University, Medical Faculty. Twenty-seven children with ATH were selected from children admitted to the clinic with complaints of snoring, mouth breathing, pausing of breathing during sleep and recurrent adenotonsillar infection for at least 6 months. All children underwent a complete ear–nose–throat (ENT) examination and flexible nasopharyngoscopy in appropriate cases for additional assessment of nasal patency and adenoid size. A lateral neck X-ray was obtained in patients for whom a nasal endoscopic examination could not be performed. Hypertrophy of the tonsils was graded according to the Brodsky scale as follows [15]: Grade I: tonsils were in the tonsillar fossa, barely visible behind the anterior pillars; Grade II: tonsils were easily visible behind the anterior pillars; Grade III: tonsils extended three-quarters of the way to the midline; and Grade IV: tonsils were completely obstructing the airway. Adenoid hypertrophy was defined as an obstruction of more than 50% of the nasopharyngeal airway [16]. Patients with adenoid hypertrophy and 3+ or 4+ tonsillar hypertrophy were enrolled in the study. Children with upper airway obstruction due to other causes such as allergic rhinitis, septum deviation, sinonasal infection and craniofacial anomalies, grade I and grade II tonsillar hypertrophy, Down Syndrome and known or suspected cardiovascular diseases were excluded from the study.

2.2. Echocardiographic examination

Two-dimension pulsed-wave Doppler and TDE were performed for all patients using a 2.5 MHz transducer (Philips, EnVisor C Ultrasound, Bothell, WA) in the left decubitus position during normal respiration according to the recommendations of the American Society of Echocardiography [17]. Echocardiographic examination was repeated 3 months postoperatively. From the apical four-chamber view, Doppler recordings were obtained with the pulsed sample volume placed at the tip of the tricuspid leaflets. The peak early (E) and late (A) velocities were measured. The mPAP levels were calculated from the echocardiographic records of the pulmonary flow trace using the Mahan Formula (mPAP = 79 – (0.62 x acceleration of the pulmonary flow trace)) [17]. All measurements were obtained by calculating the mean of three consecutive measurements and were accompanied by electrocardiographic recording upon expiration. Echocardiographic measurements were made by the same cardiologists who were blinded to the clinical information of the patients.

Pulsed-wave TDE parameters were measured by an echocardiography device with active TDE functions (Philips, EnVisor C Ultrasound, Bothell, WA). The filter settings and gains were adjusted to the minimal optimal level to reduce noise and eliminate signals produced by flows. A 3.5 mm sample volume was used. The TDE cursor was placed by the apical four-chamber view to the lateral wall of the RV. A Doppler velocity range of –20 to 20 cm/s was selected and the velocities were measured online at a sweep of 100 mm/s. Peak systolic velocity (Sm), peak early (Em) and late (Am) diastolic velocities were measured and the Em/Am ratio was calculated. The isovolumetric relaxation time (IRT) was measured from the end of Sm to the beginning of Em, the isovolumetric contraction time (ICT) was measured from the end of Am to the beginning of Sm and the time period of Sm was measured as the ejection time (ET).

The myocardial performance index (MPI) was calculated using the equation (ICT + IRT)/ET. All Doppler parameters were obtained by calculating the mean of three consecutive cycles. Echocardiography measurements were made by the same cardiologists.

2.3. Statistical analysis

The number of cases was 27 for each group which was determined by power analysis using power = 0.82, α = 0.05, β = 0.20 and 1 – β = 0.80 values.

Categorical variables were presented as count and percentage. The Kolmogorov–Smirnov test was used to evaluate whether the distribution of variables was normal. All continuous variables were normally distributed. Continuous variables were presented as mean (standard deviation [SD]). A paired t test was used to detect differences between preoperative and postoperative periods. SPSS software 15.0 for Windows (Chicago, IL, USA) was used for all statistical analysis. Calculated p-values were considered statistically significant when they were <0.05.

3. Results

3.1. Hypertrophy of tonsils

Baseline characteristics of the children are shown in Table 1. The study patients consisted of a total of 27 children, 17 (63%) males and 10 (37%) females aged 8 ± 2 years. Hypertrophy of the tonsils was graded according to the Brodsky scale and it was found that 44% of children were grade III and 56% were grade IV.

3.2. The Echocardiographic findings

The echocardiographic findings of the study are presented in Table 2. Tricuspid Em significantly increased after adenotonsillectomy (p = 0.04). At the postoperative term, the Em value increased in 18 (67%) patients. However Em in 9 (33%) patients decreased after the tonsillectomy procedure (Fig. 1). There was no significant change in other echocardiographic parameters.

### Table 1

<table>
<thead>
<tr>
<th>n</th>
<th>Age, years</th>
<th>Male, n (%)</th>
<th>Female, n (%)</th>
<th>Adenotonsillar hypertrophy, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>8 ± 2</td>
<td>17 (63)</td>
<td>10 (37)</td>
<td>12 (44)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Grade IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15 (56)</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right ventricle end-diastolic diameter, mm</td>
<td>2.65 ± 0.34</td>
<td>2.55 ± 0.12</td>
<td>NS</td>
</tr>
<tr>
<td>Right ventricle end-systolic diameter, mm</td>
<td>1.76 ± 0.28</td>
<td>1.88 ± 0.29</td>
<td>NS</td>
</tr>
<tr>
<td>Tricuspid E/A</td>
<td>1.68 ± 0.39</td>
<td>1.88 ± 0.53</td>
<td>NS</td>
</tr>
<tr>
<td>Tricuspid TDE parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sm, cm/s</td>
<td>14.5 ± 2.5</td>
<td>14.1 ± 2.1</td>
<td>NS</td>
</tr>
<tr>
<td>Em, cm/s</td>
<td>17.7 ± 3.6</td>
<td>19.1 ± 5.5</td>
<td>0.04</td>
</tr>
<tr>
<td>Am, cm/s</td>
<td>11.4 ± 4.4</td>
<td>12.2 ± 4.9</td>
<td>NS</td>
</tr>
<tr>
<td>Em/Am</td>
<td>1.60 ± 0.44</td>
<td>1.72 ± 0.72</td>
<td>NS</td>
</tr>
<tr>
<td>E/Em</td>
<td>4.18 ± 1.09</td>
<td>3.77 ± 1.17</td>
<td>0.09</td>
</tr>
</tbody>
</table>

E, early diastolic tricuspid inflow velocity; A, late diastolic tricuspid inflow velocity; Sm, systolic myocardial velocity; Em, early myocardial velocity; Am, late myocardial velocity; TDE, tissue Doppler echocardiography; NS, not significant.
3.3. Decreased levels of RV MPI and mPAP after adenotonsillectomy

mPAP and RV MPI levels in children with ATH were compared between the preoperative period and after 3 months during the postoperative period. The RV MPI and mPAP significantly decreased after adenotonsillectomy (RV MPI: 0.57 ± 0.13 vs. 0.40 ± 0.12, \( p < 0.001 \) and mPAP (mm Hg): 31 ± 9 vs. 25 ± 7, \( p = 0.001 \), Fig. 2A and B).

4. Discussion

The main finding of the present study was that TDE-derived RV MPI and mPAP levels were significantly decreased in patients with ATH undergoing adenotonsillectomy. Pulmonary vascular disease may result in elevated resting pulmonary artery pressures and increases in pulmonary artery pressure with exertion. ATH may stimulate PH due to the vasoconstrictive effects of hypoxia and hypercarbia. The vasodilative effects of normoxia after adenotonsillectomy may decrease the levels of mPAP and RV MPI. Continuous partial upper respiratory tract obstruction can result in obstructive hypoventilation and chronic alveolar hypoventilation. Hypoxia may result in respiratory acidosis which in turn may lead to pulmonary artery vasoconstriction and increased RV dysfunction. Pulmonary vascular resistance was clearly increased to maintain cardiac output and resulted in a dilated RV, increased pulmonary pressure and the development of cor pulmonale [2,5]. Symptoms of PH may not be obvious until severe cardiac decompenstation [10]. Nabigolu et al. [1] showed elevated mPAP (mPAP = 26 mm Hg) in children with chronic upper respiratory obstruction resulting from ATH compared with a control group. They observed that mPAP levels significantly decreased and became the same as those in the control group 6 months postoperatively (mPAP = 17 mm Hg, \( p = 0.001 \)). Other studies also demonstrated a significant decrease of mPAP after adenotonsillectomy [8,18,19].

Diastolic disorders are seen earlier than systolic dysfunctions [20]. The Em velocity is a sensitive marker of TDE in evaluating diastolic functions and Em has the strongest effect on cardiac outcomes among the TDE parameters [21]. Previous studies demonstrated a significant association between decreased Em and diastolic dysfunction [22,23]. Moustafa et al. [24] reported tricuspid Em velocity to be lower in patients with PH compared with normal individuals. Akcay et al. [25] showed that tricuspid Em was lower in patients with PH compared to controls and is significantly increased with the decreased PH after therapy. Further, Ugur et al. [2] reported tricuspid Em to be lower in patients with ATH compared to normal controls. Tricuspid Em velocity improved after a 6 month postoperative period. As in the present study, tricuspid Em was significantly increased while mPAP was significantly decreased following adenotonsillectomy. These results are comparable with previous studies [2,24,25].

RV MPI has been found to be clinically useful to define RV function [3]. MPI is a new echocardiographic parameter which correlates with invasive measurements and has been used to evaluate both systolic and diastolic functions. It can be measured from the valve annulus with pulse-wave TDE, and is not affected by cardiac rate, blood pressure, or ventricular geometry [26,27]. MPI is prolonged in patients with PH compared with normal subjects [3]. El-Damraway et al. [28] demonstrated that MPI had high efficacy, sensitivity and positively predicted values in defining RV dysfunction. Duman et al. [10] investigated RV function and mPAP in patients with ATH. They found RV MPI and mPAP to be significantly higher in the ATH group compared to the control group. In addition, preoperative RV MPI correlated with mPAP in children with ATH. At a six month postoperative follow up, RV MPI was found to be similar between the ATH group and the normal control group. Pac et al. [29] investigated cardiac functions in 28 patients with ATH during preoperative and postoperative periods. They found no significant differences in any echocardiographic findings during preoperative and postoperative periods. The investigators in the present study also found significantly decreased levels of RV MPI and mPAP three months postoperatively compared to initial levels. Although Pac et al. [29] did not see any changes in the levels of RV MPI and mPAP in the postoperative period, the present studies findings are compatible with the studies of Ugur et al. [2] and Duman et al. [10]. One possible reason for the contradiction may be that the postoperative period in which the observation was made was much shorter (one month) in the study of Pac et al. [29] compared to other studies and this study. It may also be speculated that RV function requires much more time to recover. Nevertheless, using TDE to evaluate RV functions in this study could be another reason for discrepancy. Conventional Doppler was used in this previous study [29]. TDE provides direct quantitative information on myocardial function and can be a guide for treatment in terms of response and follow up [5]. TDE is minimally affected by cardiac geometry compared to Conventional Doppler and can provide an objective evaluation of RV global functions [5]. Similarly, Attia et al. [30] reported that RV TDE-derived MPI was significantly higher in patients with ATH compared to the control group.
4.1. Study limitations

First, relatively few patients were included in this study, so the number of participating centers should be increased and the results should be confirmed with more comprehensive studies. Another limitation may be that, in the present study, only TDE was performed for calculating MPI and not Conventional Doppler. However, TDE has also been used to estimate MPI, with strong associations with standard pulse Doppler measurements [31]. Third, although polysomnography is one of the most important tests for diagnosis and determination of the severity of sleep-related upper respiratory obstruction, it was not used in our study due to it being difficult to perform in children. Also, previous studies have reported an increase in PAP and RV dysfunction in children without performing polysomnography [2,6–10,18,21]. The final limitation of the present study was the lack of control group. However, it has been shown in previous studies that failure of RV functions and PAP exists in patients with ATH compared to control subjects [1,2,5,11]. Therefore the investigators only showed whether there was an improvement after the therapy in an in-patient group.

5. Conclusion

The results of this study, evaluated with the results of previous studies, demonstrate that adenotonsilllectomy improves RV performance and reduces mPAP in children with ATH. However, further studies with a greater sample size and different approaches are needed to find the mechanistic pathways of these observations.

References