Obstructive sleep apnea (OSA) occurs due to fixed and/or dynamic upper airway obstruction caused by anatomical factors and abnormal upper airway motor tone.¹ Upper airway obstruction may be caused by collapse of single or multiple structures such as the soft palate, uvula, palatine tonsils, lateral pharyngeal walls, base of the tongue, and epiglottis.² Tonsillectomy and adenoidectomy (TA) is commonly used as an initial procedure to treat OSA; however, TA may not be curative in 21% to 75% of the children with OSA.³⁻⁶ In children with Down syndrome or neurological impairments, partial glossectomy, and genioglossus advancement have been used with varying results to cure OSA. Addition of new surgical techniques to the surgeon’s armamentarium potentially improves the management of OSA in children.

Lateral pharyngeal wall collapse has been documented in adults and children with OSA.²,⁷⁻⁸ Lateral pharyngoplasty and expansion sphincter pharyngoplasty (ESP) have been used to address lateral pharyngeal wall collapse in adults with OSA.⁹⁻¹² The ESP procedure involves a combination of tonsillectomy, expansion pharyngoplasty, rotation of the palatopharyngeus muscle, a partial uvulectomy, and closure of the anterior and posterior tonsillar pillars.¹⁰ Treatment with ESP prevents lat-
eral pharyngeal collapse and reduces apnea episodes in adults with OSA.\textsuperscript{10-12} Outcomes of ESP have not been studied in children with OSA. The aim of the present study is to describe a modified ESP technique and compare outcomes of modified ESP to those of TA in children with OSA.

**Methods**

This study was approved by the University of Texas Southwestern Medical Center institutional human research review board, and informed consent was waived.

**Evaluation of Study Participants**

The medical records were retrospectively reviewed for patients who underwent modified ESP and control subjects who had TA from September 2008 to September 2013. All patients in both the ESP and TA groups were younger than 21 years and underwent both preoperative and postoperative polysomnography for OSA assessment. The TA group included children whose apnea-hypopnea index (AHI) was matched to the children in the ESP group so as to obtain similar levels of OSA severity in both groups. No patients were excluded for craniofacial anomalies, developmental delay, psychiatric illness, immunodeficiency, possible neoplasia, possible posttransplant lymphoproliferative disorder, or other chronic conditions. All participants were identified using an electronic medical record system documenting surgical procedures performed by the author.

All participants underwent all-night, attended polysomnography by computerized polygraph performed in the dedicated pediatric sleep laboratory at a tertiary care children's hospital; sleep measurements were based on the criteria of the 2007 American Academy of Sleep Medicine guidelines. Polysomnograms were scored by pediatric sleep medicine specialists, and the AHI was calculated as the sum of obstructive apneas and hypopneas per hour. Central apnea, central hypopnea, and mixed apnea were not included in the AHI. The severity of OSA was categorized according to AHI as mild (AHI, 1-5); moderate (AHI, 5-10); or severe (AHI >10).\textsuperscript{2} In the modified ESP group, drug-induced sleep endoscopy (DISE) was performed during induction of anesthesia by using the previously described protocol.\textsuperscript{2}

**ESP Indications and Techniques**

Indications for modified ESP included severe OSA and lateral pharyngeal wall collapse documented by DISE. At the time of surgery planning during the clinic visit, caregivers were offered the option of modified ESP, in addition to TA, if the DISE findings indicated lateral pharyngeal wall collapse.

The detailed description of modified ESP is as follows. After the patient was placed in a supine position on the operating table; general anesthesia was induced, during which DISE was performed. All patients received 1 intravenous dose of dexamethasone, 0.5 mg/kg.

The patient was then placed in the Rose position. The palate tonsils were exposed using a Crowe–Daviss mouth retractor. A bilateral tonsillectomy was performed using bipolar cautery (Figure 1A).\textsuperscript{12} The anterior fascicles of the palatopharyngeus muscle were transected horizontally at the junction of upper third and mid-third portions using a protected needle-tip bovie (Figure 1B). Superficial fibers of the upper third portion of the palatopharyngeus muscle were isolated, and deep fibers left with the muscle's posterior surface attached to the pharyngeal constrictor muscles.

A blunt palate tunneling extending superolaterally from the arching fibers of the palatoglossus muscle into soft palate was created using a curved hemostatic forceps (Figure 1C). The isolated portion of palatopharyngeus muscle was pulled superoanteriorly laterally into the palate tunnel while the lateral pharyngeal wall tension was observed. Then the isolated portion of palatopharyngeus muscle was attached to the arching muscle fibers of soft palate with a single mattress stitch using Vicryl 4-0 suture (Ethicon Inc) and a round-bodied needle (Figure 1D). The same steps were repeated on the opposite side (Figure 1E).

In the modified ESP technique, increased distance is created between, and tension within, the lateral pharyngeal walls. In the present study, the modifications to previously described ESP techniques included (1) transection of the palatopharyngeus muscle at the upper third portion instead of the inferior end; (2) transection of the superficial fibers of the palatopharyngeus muscle instead of full-thickness transection of the palatopharyngeus muscle; (3) blunt palate tunneling without mucosal incision; (4) preservation of the uvula instead of partial uvulectomy; (5) no apposition of the entire anterior and posterior pillars; and (6) lack of palate incision for second intermediate suturing of flap.\textsuperscript{14}

A microdebrider was used to remove the adenoid, and suction electrocautery was used for hemostatic control of the adenoid bed. The tonsillar fossae and adenoid bed were examined after oropharyngeal and gastric suctioning and before reversal of anesthesia.

Postoperatively, overnight monitoring consisted of continuous measurement of pulse oximetry, blood pressure, and pulse rate. Analgesia was achieved by alternating between acetaminophen and ibuprofen. For the next 2 weeks, adequate oral fluid intake for proper hydration and a soft blended diet were recommended. Parents were instructed to return to the hospital for evaluation if they saw any volume of oropharyngeal bleeding or epistaxis during the postoperative period.

**Data Collection and Statistical Analysis**

Data pertaining to age, sex, medical history, surgical history, comorbid conditions, body mass index (BMI), tonsil size,\textsuperscript{2} adenoid size,\textsuperscript{2} and findings of polysomnography were obtained from the charts. Centers for Disease Control and Prevention growth standards were used to determine BMI percentiles. Children with a BMI greater than the 95th percentile were considered obese. The primary outcome measure of the study was the rate of cure, defined as an AHI lower than 1. Additionally, the rates of cure were assessed for the following criteria used in previous studies: AHI lower than 2,\textsuperscript{5,15} AHI lower than 5,\textsuperscript{5,16,17} 50% reduction in AHI and AHI lower than 15,\textsuperscript{10} and 50% reduction in AHI and AHI lower than 20.\textsuperscript{10} The secondary outcome measures included percentage AHI reduction, improvement in minimum saturation of peripheral oxygen level.
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(min $\text{SpO}_2$), and reduction in percentage of total sleep time with oxygen level less than 90%.

Statistical comparisons between groups were performed using a 1-way analysis of variance or a Kruskal-Wallis 1-way analysis of variance, and within-group analyses were performed by a paired t test or a Wilcoxon signed rank test, as appropriate. The $\chi^2$ test was used to test the cure rate between treatment groups. Statistical significance was set at $P < .05$. Data are presented as mean (SD).

Results

Twenty-five patients, aged 2 to 17 years (median age, 8 years), underwent modified ESP with no complications on the day of the surgery (Table 1). One patient had bleeding 3 days after the surgery. There was no dysphagia or voice change at the postoperative follow-up visit. Comorbid conditions included asthma in 6 patients, type 1 diabetes mellitus in 2, and allergic rhinitis in 2. The BMI ranged from 13.3 to 48.7 (median, 32), and 18 patients (72%) were obese. Most children had grade III hypertrophy of the adenoids and grade II and grade III hypertrophy of the tonsils (Table 1). All patients had severe OSA before the surgery. After the surgery, 16 patients had no OSA; 4 had mild OSA; 3 had moderate OSA; and 2 had severe OSA. In children with persistent OSA, DISE revealed base-of-the-tongue obstruction with lingual tonsil hypertrophy in 1 patient (postoperative AHI, 13.6), complete concentric velum obstruction in 1 (AHI, 12.7), partial concentric velum obstruction in 1 (AHI, 2.2), partial anterior-posterior velum obstruction in 2 (AHIs, 6.0 and 9.5), and no other sites in 4 (AHIs, 1.3, 1.6, 2.3, and 5.4). Postoperative reduction in AHI ranged from 66% to 100% (mean [SD] reduction, 95% [9.2%]). Postoperative AHI (median, 0.8; range, 0-13.6) was lower than preoperative AHI (median, 52.0; range, 20.0-154.2) ($P < .001$) (Table 2). Postoperative min $\text{SpO}_2$ was greater than preoperative min $\text{SpO}_2$ ($P < .001$) (Table 2). Postoperative percentage of total sleep time with oxygen level less than 90% was less than preoperative percentage of total sleep time with oxygen level less than 90% ($P < .001$).
Twenty-five patients, aged 2 to 16 years (median age, 5 years), had TA with no complications on the day of TA. There was no bleeding, dysphagia, or voice change at the follow-up visit. Comorbid conditions included asthma in 5 patients, seizure disorder in 2, allergic rhinitis in 2, Down syndrome in 1, and sickle cell disease in 1. The BMI ranged from 14.4 to 54 (median BMI, 20.3). Eleven patients were obese. Most children in TA group had grade III hypertrophy of the tonsils and grade II and grade III hypertrophy of the adenoids (Table 1). All patients had severe OSA. Postoperatively, OSA was resolved in 2 patients, mild in 13, moderate in 2, and severe in 8. Postoperative reduction in AHI ranged from 53.6% to 99.2% (mean [SD] reduction 87.4% [13.8%]). Postoperative AHI (range, 0.9-20.2; median, .2) was lower than the preoperative AHI (range, 20.7-142.0; median, 49.2) (P < .001). Postoperative min SpO₂ was higher than preoperative min SpO₂ (P < .001) (Table 2). Postoperative percentage of the total sleep time with oxygen saturation less than 90% was less than preoperative total sleep time with oxygen saturation less than 90% (P < .001) (Table 2).

As a group, patients who underwent modified ESP were older than TA patients (P = .002) (Table 1). The BMI in the modified ESP group was greater than that in the TA group (P = .02) (Table 1). Grades of tonsil hypertrophy and adenoid hypertrophy in the modified ESP group were lower than those in TA group (P < .05). The preoperative AHI in the modified ESP group was similar to that in the TA group (P = .90) (Table 2). The postoperative AHI in the modified ESP group was lower than that of the TA group (P < .001). The postoperative reduction in AHI in the modified ESP group (median, 98.1%; 25th percentile-75th percentile, 96.7%-99.7%) was more than that in the TA group (median, 93.1%; 25th percentile-75th percentile, 80.4%-96.9%) (P < .001). Preoperative and postoperative percent-ages of the total sleep time with oxygen saturation less than 90% were similar between modified ESP and TA groups (Table 2).

In the modified ESP group, cure rates (AHI <1, 64%; AHI <2, 72%; and AHI <5, 80%) and 50% reduction in AHI and AHI lower than 15(100%) were greater than those in the TA group (AHI <1, 8%; AHI <2, 44%; and AHI <5, 60%, and 50% reduction and AHI <15, 92%) (P < .05) (Figure 2). Cure rate for the criteria 50% reduction in AHI and AHI lower than 20 were similar between the modified ESP and TA groups.

### Table 1. Patient Characteristics and Grades of Tonsils and Adenoids in the Study Population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Modified ESP</th>
<th>TA</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>9.0 (4.3)</td>
<td>5.0 (3.4)</td>
<td>.002</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>14 (56)</td>
<td>15 (60)</td>
<td>NR</td>
</tr>
<tr>
<td>Female</td>
<td>11 (44)</td>
<td>10 (40)</td>
<td></td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>29.0 (9.5)</td>
<td>23.0 (10.0)</td>
<td>.02</td>
</tr>
<tr>
<td>Obese</td>
<td>18 (72)</td>
<td>11 (44)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Tonsil grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>1 (4)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>II</td>
<td>12 (48)</td>
<td>3 (12)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>12 (48)</td>
<td>14 (56)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>1 (4)</td>
<td>7 (28)</td>
<td></td>
</tr>
<tr>
<td>Adenoid grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>4 (16)</td>
<td>3 (12)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>II</td>
<td>4 (16)</td>
<td>4 (16)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>13 (52)</td>
<td>10 (40)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>4 (16)</td>
<td>8 (32)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Comparison of The 3 Major Study Parameters in the Modified ESP and TA Groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Modified ESP</th>
<th>TA</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHI Preoperative</td>
<td>60.5 (38.5) [20.0-154.2]</td>
<td>59.8 (33.6) [20.7-142]</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Postoperative</td>
<td>2.0 (3.9) [0-13.6]</td>
<td>6.2 (6.0) [0.9-20.2]</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Min SpO₂ Preoperative</td>
<td>79.8 (9.5)</td>
<td>74.6 (9.0)</td>
<td>.003</td>
</tr>
<tr>
<td>Postoperative</td>
<td>92.6 (4.2)</td>
<td>88.2 (5.3)</td>
<td>.01</td>
</tr>
<tr>
<td>%TST at SpO₂ &lt; 90% Preoperative</td>
<td>9.9 (17.8)</td>
<td>13.8 (22.6)</td>
<td>.10</td>
</tr>
<tr>
<td>Postoperative</td>
<td>0.3 (0.9)</td>
<td>0.7 (2.1)</td>
<td>.40</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); ESP, expansion sphincter pharyngoplasty; NR, not reported; TA, tonsillectomy and adenoidectomy.

*a Unless otherwise indicated, data are presented as mean (SD) [range] or mean (SD).
Discussion

Collapse of the lateral pharyngeal wall contributes to the pathogenesis of OSA by increasing airway resistance and causing partial or complete obstruction of the airway.\(^2,10\) To date, no gold standard surgical procedure has been identified to address lateral pharyngeal wall collapse. Lateral pharyngoplasty and ESP have been suggested as effective surgical procedures to treat lateral pharyngeal wall collapse in adults with OSA.\(^3,12\) In the present study, modified ESP was evaluated as an effective surgical treatment option for lateral pharyngeal wall collapse in children with OSA.

Lateral pharyngoplasty consists of dissection of the superior pharyngeal constrictor muscle in the tonsillar fossa, suturing the muscle flap to the palatoglossus muscle, and palatopharyngeal Z-plasty to prevent retropalatal collapse.\(^9\) Complications of lateral pharyngoplasty include dysphagia, oronasal reflux of liquids, and wound dehiscence. The ESP procedure creates lateral wall tension and removes the bulk of lateral pharyngeal wall by isolating and rotating the palatopharyngeus muscle superoanterolaterally. Partial or complete uvulectomy is also performed in ESP.\(^10\) Dysphagia or voice change has not been reported after ESP. Lateral pharyngoplasty and ESP provide better improvement in AHI than uvulopalatopharyngoplasty.\(^9,10\) Lateral pharyngoplasty and ESP have not been used to treat lateral pharyngeal wall collapse in children with OSA. In the present study, modified ESP was used as a conservative technique to address lateral pharyngeal wall collapse in children with OSA. The modifications made to the ESP procedure addressed concerns over possible dysphagia and oronasal reflux of liquids associated with lateral pharyngoplasty as well as concerns over potential hypernasality and velopharyngeal dysfunction due to excision of soft palate and uvula tissue performed as part of unmodified ESP.

The modified ESP techniques were formulated based on those used in previously described ESP procedures.\(^10-12\) The original ESP involves transecting the palatopharyngeus muscle to decrease the bulk of the lateral pharyngeal wall while creating lateral pharyngeal wall tension and partial or complete excision of the uvula.\(^10\) Transecting a long segment of the palatopharyngeus muscle to debulk the lateral pharyngeal wall potentially impairs swallowing function in children because the palatopharyngeus muscle narrows the pharynx, lowers the soft palate, narrows the velopharyngeal orifice, and elevates the larynx. Therefore, in the modified ESP procedure, a short segment of the palatopharyngeus muscle is transected, and no uvulectomy is performed in an effort to reduce the risks of dysphagia and oronasal reflux. The modified ESP procedure provides lateral pharyngeal wall tension, expands the pharynx by widening the interpalatopharyngeal muscle distance, and reduces the bulk of the palatopharyngeus muscle. Complications such as dysphagia, oronasal reflux, wound dehiscence, and voice change did not occur in this group of children after modified ESP.

Tonsillectomy and adenoidectomy is commonly used as the first-line surgical procedure for treatment of OSA in children. Resolution of OSA was documented in 66% of children after TA in a meta-analysis.\(^15\) Persistent OSA after TA indicates additional obstruction at other sites of the upper airway. In these cases, DISE and cine magnetic resonance imaging have been used to identify single and multiple sites of airway obstruction in children with OSA.\(^2,10,20\) DISE has revealed that the oropharynx/lateral wall area is the most common site of obstruction in children with single-site airway obstruction.\(^2\) The velum and oropharynx/lateral wall are the most common sites of obstruction in OSA children with multiple-site airway obstruction.\(^2\)

In the present study, modified ESP was used to address lateral pharyngeal wall collapse in addition to obstruction caused by palatine tonsils and adenoids in children with OSA. Lateral pharyngeal wall collapse was documented in all children who underwent modified ESP. DISE also revealed obstructions at other sites in 5 patients who had persistent OSA (AHI >1) after modified ESP. The presence of additional obstruction sites may be responsible for the residual OSA; however, in 4 of the 9 children with persistent OSA, DISE did not reveal other obstruction sites.

In the present study, the modified ESP patients were older and had greater BMI than the TA patients. Given that previous studies have reported obesity, older age, and severe sleep apnea as risk factors for persistent OSA after TA, the modified ESP group was expected to have poorer outcomes than the TA group in the present study. However, the modified ESP group showed a higher cure rate, greater postoperative reduction in AHI, and lower postoperative AHI than the TA group. Similar to previous studies, cure rates for modified ESP and TA varied depending on the AHI criteria used. In previous studies, cure rates of TA ranged from 27% to 59% for AHI lower than 1,\(^2,17,18\) 28% to 82% for AHI lower than 2,\(^2,15\) and 21% to 84% for AHI lower than 5.\(^2,16,17\) In the present study, cure rates after TA were lower than in previous studies. Differences in AHI criteria to define cure and patient characteristics such as BMI, age, obesity, and presence of comorbidities may account for the interstudy differences in cure rates of TA.

The limitations of the present study include its retrospective nature, precluding comparison of modified ESP outcomes with TA outcomes in age-matched, BMI-matched, tonsil- and adenoid-size matched children with lateral pharyngeal wall collapse and varying severity of OSA. In the present study, differences in BMI, age, and size of tonsils and adenoids placed the modified ESP group at a higher risk of residual OSA after surgery compared with the TA group. Lateral pharyngeal wall collapse was documented in the modified ESP group; however, presence of lateral pharyngeal wall collapse could not be assessed in the TA group because DISE was not performed in children who underwent TA. Nonetheless, the modified ESP group had better cure rates and improvement in AHI than the TA group.

In the present study, the modified ESP group included children with OSA whose AHI was higher than 20. The outcomes of modified ESP in children with OSA and lateral pharyngeal collapse and AHI lower than 20 merit further investigation.
Pharyngoplasty for Pediatric Obstructive Sleep Apnea

Research Original Investigation

Conclusions

Modified ESP is a simple procedure to address lateral pharyngeal wall collapse in children with severe OSA and carries minimal risk of potential complications such as dysphagia, voice change, and velopharyngeal dysfunction. Modified ESP provides objective clinical improvement as determined by reduction in AHI, min SpO2, and percentage of total sleep time with oxygen saturation less than 90% in children with severe OSA and lateral pharyngeal wall collapse. Modified ESP was more effective than TA for achieving better cure rates and improvement in the majority of children with severe OSA and lateral pharyngeal wall collapse.

ARTICLE INFORMATION

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REFERENCES


