

## Outcome of Adenotonsillectomy for Obstructive Sleep Apnea Syndrome in Children

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**Objectives:** We evaluated the outcome of adenotonsillectomy for obstructive sleep apnea syndrome (OSAS) in children using polysomnography (PSG) data and a quality-of-life (QOL) instrument.

**Methods:** We enrolled children (4 to 14 years of age) who had OSAS diagnosed by overnight PSG and who underwent both adenoidectomy and tonsillectomy between January 2003 and February 2008. All of them had completed postoperative PSG and a paired Obstructive Sleep Apnea 18-Item Quality-of-Life Questionnaire (OSA-18) survey. The statistical analyses were performed with a statistical software package.

**Results:** The study included 84 children with a mean age of 7.1 years. The mean preoperative apnea-hypopnea index (AHI) for the study population was 24.6, and the mean postoperative AHI was 3.8 episodes per hour. The percentage of children who had normal PSG parameters after adenotonsillectomy ranged from 69.0% to 86.9% because of fluctuation of the criteria used to define OSAS. Nine children (30%) with severe preoperative OSAS had persistent OSAS (an AHI of at least 5) after surgery. Improvements in QOL were comparable in the cured and not-cured groups ( $p > 0.05$ ). Risk factors for persistent OSAS were obesity and a high preoperative AHI, on multiple logistic regression analysis.

**Conclusions:** Adenotonsillectomy is associated with improvements in PSG, behavior, and QOL in children with OSAS. However, it may not resolve OSAS in all children. The efficacy and role of additional therapeutic options require more study.

**Key Words:** adenoidectomy, child, obstructive sleep apnea syndrome, polysomnography, quality of life, tonsillectomy.

### INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is a common condition in children and is associated with potentially long-lasting cardiovascular,<sup>1,2</sup> neurobehavioral,<sup>3,4</sup> and somatic growth consequences.<sup>5</sup> Given the fact that the most common cause of OSAS in children is adenotonsillar hypertrophy, adenotonsillectomy has been widely accepted as the first line of treatment. Although previous reports have shown a significant reduction in respiratory abnormalities and arousal index after surgery, persistence of abnormal polysomnography (PSG) findings is reported in approximately 20% to 40% of cases.<sup>6-10</sup> The effectiveness of adenotonsillectomy and the major determinants of postsurgical outcome have not been critically delineated.

The outcome of adenotonsillectomy for OSAS can be evaluated on the basis of objective evidence provided by preoperative and postoperative PSG. At present, PSG is the most accurate and comprehensive method for the diagnosis and quantification

of OSAS in children. However, it is expensive and time-consuming and is often unavailable. These factors have limited the sample sizes used in published studies of the outcome of adenotonsillectomy for OSAS evaluated by PSG. Furthermore, quality-of-life (QOL) assessment is increasingly recognized as an important health-related outcome measure in clinical medicine. Although a long-term improvement of QOL after adenotonsillectomy has been proved,<sup>11</sup> the correlation between a decline in the PSG index and changes in the QOL score is less well documented.

To shed more light on the outcome of adenotonsillectomy for pediatric OSAS, in the present study we used data from preoperative and postoperative PSG in combination with a paired Obstructive Sleep Apnea 18-Item Quality-of-Life Questionnaire (OSA-18) survey. Moreover, the correlation between PSG amelioration and change in OSA-18 score was evaluated. The goal was to provide a comprehensive assay of surgical outcomes and to identify variables that predispose children to persistent OSAS after surgery.

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## METHODS

### POPULATION AND STUDY DESIGN

Approval for the present study was obtained from the Institutional Review Board of Sun Yat-sen University. Parents or caregivers were asked to complete an informed consent document before enrollment in the study.

First, we identified qualified cases from the medical record database in our hospital. All children who underwent both adenoidectomy and tonsillectomy from January 2003 to February 2008 were considered for enrollment. Children of 4 to 14 years of age were included if they had had signs and symptoms of a sleep disturbance, including snoring, mouth breathing, and witnessed apnea, of at least 3 months' duration and if they had OSAS as evidenced by preoperative PSG evaluation. The exclusion criteria were an age outside the range of 4 to 14 years, an American Society of Anesthesiologists physical status score of more than 3, concomitant surgery, genetic disorders, prematurity, craniofacial abnormalities, Down syndrome, congenital heart disease, bronchopulmonary dysplasia, cerebral palsy, cystic fibrosis, neuromuscular diseases, previous adenotonsillectomy or other airway surgery procedures, and contraindications to general anesthesia. The qualified children were enrolled in our study and successively followed up between 2004 and 2009. The children were asked to return for a postoperative reevaluation including an overnight sleep study and an OSA-18 survey.

All of the included children underwent adenotonsillectomy under general anesthesia. The anesthetic and surgical techniques of adenotonsillectomy did not vary greatly during the study period. Tonsillar tissue was removed by dissection or by the guillotine method, and hemostasis was obtained with bipolar electrocautery. Adenoid tissue was removed by use of a microsecting instrument under endoscopy. At our institution, adenotonsillectomy is routinely performed by professors or senior attending physicians, and the large number of adenotonsillectomies performed has resulted in a fairly standardized surgical technique.

### DATA COLLECTION

For all studied patients, data were extracted from the medical records by 2 specialists using a specially designed case report form. This included a manual review of the laboratory data, surgical records, anesthesia forms, treatment records, progress notes, and nursing notes. All of the forms were checked by another researcher for errors. Then, the data were double-entered manually into a Microsoft Excel master sheet to build our database. The variables recorded

on the case report form and pertinent definitions are described below.

*Baseline Characteristics.* Demographic data included age, sex, height, weight, and pertinent history. Body mass index (BMI) was converted into a BMI z score according to the normal values of Chinese children.<sup>12</sup> Children were considered obese if their BMI z score was over 1.946 (corresponding to the 95th percentile). For each child, the degree of adenotonsillar hypertrophy was assessed with an endoscope by the otolaryngology clinicians within a week before surgery. Tonsil size was graded on a 4-point scale. For grade 1, the tonsils were lying lateral to the tonsillar fauces; for grade 2, at the level of the fauces; for grade 3, medial to the fauces but not to the midline; and for grade 4, touching at the midline. The degree of adenoid obstruction was evaluated as follows: grade 1, no or minimal adenoid tissue (0% to 25% obstruction); grade 2, a small amount of adenoid tissue (26% to 50% obstruction); grade 3, a large amount of adenoid tissue that might cause symptomatic nasal obstruction (51% to 75% obstruction); and grade 4, obstructing adenoid tissue (76% to 100% obstruction).

*Sleep Study.* Overnight PSG was performed at the Sleep Study Center in the Third Affiliated Hospital of Sun Yat-sen University by measuring the following standard neurophysiologic and respiratory signals: electroencephalogram with central, anterior, and occipital leads; electro-oculograms; submental and diaphragmatic electromyogram with external electrodes; and heart rate and rhythm recorded by electrocardiogram. Airflow was recorded with a nasobuccal thermistor. Nasal pressure was measured with a nasal cannula connected to a pressure transducer. Chest wall excursion was measured by respiratory inductive plethysmography. Oxygen saturation was measured by pulse oximetry set at a 2-second averaging time. Body position was noted, and digital videotaping with sound recording was performed throughout the night.

The following PSG parameters were recorded: apnea-hypopnea index (AHI), defined as the average number of obstructive apneas and hypopneas per hour of total sleep time, the oxygen saturation as measured by the pulse oximetry (pulse oxygen saturation; SpO<sub>2</sub>) nadir, and the percentage of time the oxygen saturation was lower than 90% recorded throughout the sleep study. Obstructive apnea was defined as a total absence of airflow through the mouth and nose with continued chest and abdominal movement for at least 2 respiratory cycles. Hypopneas were defined as a decrease in nasal flow of at least 50% with a corresponding decrease in SpO<sub>2</sub>

of at least 4% or arousal. We defined OSAS as an AHI of at least 5. An AHI score of more than 5 and less than 10 was considered mild OSAS; at least 10 but less than 20, moderate OSAS; and 20 or higher, severe disease.<sup>13</sup> A sleep medicine specialist interpreted the PSG results.

**QOL Survey in Children With OSAS.** The caregivers were asked to complete the OSA-18 survey before and after surgery. The first survey was completed before PSG, and the second survey, during the follow-up visit after PSG. This survey comprises 18 items in the 5 domains of sleep disturbance, physical suffering, emotional distress, daytime problems, and caregiver concerns. The domains of emotional distress and daytime problems contain 3 items, and the other domains contain 4. A point scale is used, ranging from 1 (none of the time) to 7 (all of the time), to grade the relative severity of the problems addressed in each item. The total score and the domain scores were recorded. Subtracting the mean postoperative score from the mean preoperative score derived the difference score.

#### STATISTICAL ANALYSIS

In a study by Mitchell and Kelly,<sup>9</sup> the frequencies of surgical cure (AHI score of less than 2 episodes per hour) in obese and normal-weight children were 24% and 72%, respectively. The required sample size to detect such a difference between obese and normal-weight children in the present study, assuming an average frequency of resolution of OSAS of 55% with an 80% power at the 5% level, was 18 children per group.

Continuous variables are presented as a mean  $\pm$  SD or range, and categorical variables are presented as a number (and percent). The change index of AHI was calculated as [(Preoperative AHI Score - Postoperative AHI Score)/(Preoperative AHI Score)]. The Wilcoxon signed-rank test was used to compare the mean values of PSG parameters before and after surgery. A paired *t*-test was used to evaluate the significance of differences between the preoperative and postoperative OSA-18 surveys. Differences between two groups were assessed with  $\chi^2$  statistics for categorical variables and with Student's *t*-test for continuous variables. Nonparametric analysis using the Mann-Whitney U test was used for data with nonnormal distributions. Comparisons among multiple groups were performed with the Kruskal-Wallis test. A Pearson correlation was used to assess the mean preoperative and postoperative OSA-18 total scores with the preoperative and postoperative AHI scores. Potential risk factors were first evaluated with univariate analysis, followed by multivariate logistic regression with the occurrence of postop-

erative respiratory complications as the dependent variable. The threshold for statistical significance was a *p* value of less than 0.05. All of the statistical analyses were performed with a statistical software package (SPSS for Windows, version 11.0, SPSS Inc, Chicago, Illinois).

## RESULTS

#### STUDY POPULATION

The computer identified 341 children who underwent both tonsillectomy and adenoidectomy for OSAS in our hospital from January 2003 to February 2008. Of 308 children of 4 to 14 years of age, 224 children had completed preoperative PSG and 188 children with a diagnosis of OSAS met the inclusion criteria. Five children were excluded because of a comorbid condition (cerebral palsy and craniofacial abnormalities in 1 each) or concomitant surgery (3 cases). A total of 183 children with OSAS initially constituted our study cohort. On follow-up, 63 children were lost and 36 children without paired PSG or OSA-18 data were excluded.

Therefore, a population of 84 children were entered into the final analysis. The mean age at the time of operation was  $7.1 \pm 3.2$  years, and 59 patients (70.2%) were male. Forty-nine children (58.3%) were between 4 and 8 years, 26 children (31.0%) were between 8 and 12 years, and 9 children (10.7%) were between 12 and 14 years. Regarding the tonsillar size, 39 cases (46.4%) were classified as grade 3 or 4, and 68 children (81.0%) had obvious adenoid hypertrophy of grade 3 or 4.

According to the preoperative age- and sex-corrected BMI *z* score, 59 children (70.2%) were of normal weight, 7 (8.3%) were overweight, and 18 (21.4%) were obese. The mean BMI *z* scores of the total cohort were  $1.1 \pm 1.9$  and  $1.2 \pm 1.7$  at baseline and follow-up, respectively ( $p > 0.05$ ). For the 18 obese children, the difference in BMI *z* score at follow-up compared with that at baseline was not notable ( $2.3 \pm 1.2$  versus  $2.4 \pm 1.1$ ;  $p > 0.05$ ).

#### PERSISTENT OSAS AFTER SURGERY

The mean preoperative AHI score was  $24.6 \pm 17.3$  in the 84 children. Before operation, 45 cases (53.6%) were classified as moderate OSAS and 30 patients (35.7%) had severe OSAS. The mean interval between preoperative PSG and adenotonsillectomy was 11 days (range, 2 to 34 days). The mean interval between adenotonsillectomy and postoperative PSG was 19 months (range, 18 to 23 months). The mean interval between preoperative and postoperative PSG was 20 months (range, 18 to 24 months).

TABLE 1. RESPIRATORY PARAMETERS AND SLEEP ARCHITECTURE BEFORE AND AFTER ADENOTONSILLECTOMY IN 84 CASES OF PEDIATRIC OSAS

Parameter	Preoperative	Postoperative	p
Obstructive AHI	24.6 ± 17.3	3.8 ± 7.9	<0.001
Respiratory disturbance index	26.4 ± 17.8	5.3 ± 7.0	<0.001
Obstructive apnea index	6.5 ± 12.1	2.0 ± 1.5	<0.001
Obstructive hypopnea index	16.5 ± 14.1	3.3 ± 4.4	<0.001
Mean SpO <sub>2</sub> (%)	94.6 ± 5.5	95.0 ± 6.3	NS
SpO <sub>2</sub> nadir (%)	80.4 ± 8.7	92.1 ± 11.9	<0.001
TSpO <sub>2</sub> <90% (%)	8.8 ± 10.4	3.6 ± 6.0	<0.001
Respiratory arousal index	15.4 ± 10.5	5.2 ± 7.1	<0.001
REM sleep (%)	18.6 ± 7.4	17.5 ± 6.4	NS

Data are mean ± SD.

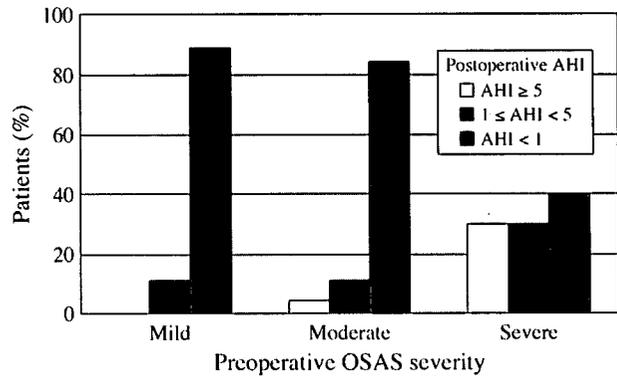
OSAS — obstructive sleep apnea syndrome; AHI — apnea-hypopnea index; SpO<sub>2</sub> — pulse oxygen saturation; NS — not significant ( $p > 0.05$ ); TSpO<sub>2</sub><90% — percentage of time oxygen saturation was lower than 90%; REM — rapid eye movement.

Respiratory and nonrespiratory parameters from PSG in children, before and after adenotonsillectomy for OSAS are summarized in Table 1. Changes were highly significant ( $p < 0.001$ ) in the AHI, respiratory disturbance index, obstructive apnea index, obstructive hypopnea index, minimum oxygen saturation, percentage of time with oxygen saturation below 90%, and arousal index. The mean postoperative AHI score was 3.8 in the current population. The changes in mean oxygen saturation and percentage of time spent in rapid eye movement sleep were not significant.

The number of children with normal PSG parameters after adenotonsillectomy was dependent on the criteria used to define surgical cure (Table 2). When an obstructive AHI score of less than 1 episode per hour was used as the criterion, 69.0% of cases (58 of 84) normalized after surgery. When the criterion was an AHI score of fewer than 5 episodes per hour, 86.9% of cases (73 of 84) normalized after surgery. A comparison of the outcomes of adenotonsillectomy

TABLE 2. OUTCOME OF ADENOTONSILLECTOMY ACCORDING TO PREOPERATIVE SEVERITY OF OSAS BASED ON VARIED DEFINITIONS OF SURGICAL CURE

Preoperative AHI	No. of Children	Postoperative AHI		
		AHI ≥ 5 (n = 11)	1 ≤ AHI < 5 (n = 15)	AHI < 1 (n = 58)
Mild (5 ≤ AHI < 10)	9	0	1 (11.1%)	8 (88.9%)
Moderate (10 ≤ AHI < 20)	45	2 (4.4%)	5 (11.1%)	38 (84.4%)
Severe (AHI ≥ 20)	30	9 (30.0%)	9 (30.0%)	12 (40.0%)



Distribution of postoperative apnea-hypopnea index (AHI) values according to initial severity of obstructive sleep apnea syndrome (OSAS) in our cohort of 84 patients.

in children with mild, moderate, and severe OSAS is presented in Table 2 and the Figure. The overnight respiratory parameters were normal (AHI score of less than 5) for all children with mild OSAS after adenotonsillectomy. Persistent postoperative OSAS, defined as an AHI score of 5 or greater after adenotonsillectomy, was present in 2 children (4.4%) with moderate preoperative OSAS and in 9 children (30.0%) with severe preoperative OSAS.

Based on the preoperative severity of OSAS, the improvement after adenotonsillectomy, as measured by a reduction in the AHI score, was significant for each group (Table 3). Furthermore, the reduction of AHI level had a significant correlation with the initial severity of OSAS ( $r = 2.66$ ;  $p < 0.01$ ). In contrast, the change index of AHI had no correlation with preoperative AHI score ( $r = 0.10$ ) or the postoperative AHI score ( $r = 0.12$ ;  $p > 0.05$ ).

The rate of surgical cure (AHI score of less than 5) was 50.0% ( $n = 9$ ) for the 18 obese children, and 97.0% ( $n = 64$ ) for the 66 nonobese children ( $p <$

TABLE 3. CHANGE IN AHI SCORE ACCORDING TO PREOPERATIVE SEVERITY OF OSAS

Variable	Preoperative Severity of OSAS		
	Mild (5 ≤ AHI < 10) (n = 9)	Moderate (10 ≤ AHI < 20) (n = 45)	Severe (AHI ≥ 20) (n = 30)
Preoperative AHI	6.6 ± 1.5	17.7 ± 6.9	39.0 ± 12.1
Postoperative AHI*	1.8 ± 1.1	2.6 ± 1.8	6.5 ± 4.4
Reduction in AHI†	4.8 ± 2.4	15.3 ± 5.8	32.5 ± 10.7
Change index of AHI‡	0.7 ± 0.4	0.8 ± 0.6	0.8 ± 0.5

Data are mean ± SD.

\*Comparison of mean Postoperative AHI Score with Preoperative AHI Score in separate group,  $p < 0.05$  for all.

†Comparison of mean reduction in AHI (Preoperative AHI Score - Postoperative AHI Score) among three groups,  $p < 0.05$ .

‡Comparison of mean change index of AHI [(Preoperative AHI Score - Postoperative AHI Score)/(Preoperative AHI Score)] among three groups,  $p > 0.05$ .

TABLE 4. POTENTIAL PREDICTORS OF SURGICAL CURE (AHI SCORE OF LESS THAN 5) ON UNIVARIATE LOGISTIC REGRESSION ANALYSIS

Characteristics	Cured (n = 73)	Not Cured (n = 11)	Unadjusted OR (95% CI)	p
Age (y; mean)	7.1	7.2	0.90 (0.24 to 2.80)	NS
Male gender	51 (69.9%)	8 (72.7%)	0.72 (0.2 to 1.99)	NS
Obesity at baseline	14 (19.2%)	4 (36.4%)	21.0 (11.1 to 34.8)	<0.001
Adenoids grade $\geq 3$	59 (80.8%)	9 (81.8%)	0.76 (0.31 to 2.57)	NS
Tonsils grade $\geq 3$	24 (32.8%)	5 (45.5%)	1.62 (0.37 to 9.36)	0.041
Snoring at baseline	55 (75.3%)	8 (72.7%)	0.66 (0.36 to 1.30)	NS
Evidence of allergic rhinitis or asthma	10 (13.7%)	2 (18.2%)	1.55 (0.59 to 7.30)	0.044
Positive family history for SDB	6 (8.2%)	1 (9.1%)	0.43 (0.23 to 1.92)	NS
Positive family history for allergy	12 (16.4%)	2 (18.2%)	0.63 (0.30 to 2.40)	NS
Positive family history for obesity	13 (17.8%)	2 (18.2%)	0.32 (0.10 to 3.27)	NS
AHI before surgery (mean $\pm$ SD)	24.1 $\pm$ 10.1	29.9 $\pm$ 15.0	15.1 (12.0 to 21.2)	<0.001
Persistence of snoring after surgery	9 (12.3%)	2 (18.2%)	1.56 (0.68 to 7.79)	0.043
Regrowth of adenoid tissue after surgery	7 (9.6%)	1 (9.1%)	0.28 (0.13 to 1.53)	NS

OR — odds ratio; CI — confidence interval; SDB — sleep-disordered breathing.

0.001). However, the mean preoperative AHI score in the obese children ( $24.8 \pm 8.1$ ) was not significantly higher than that in the nonobese children ( $24.5 \pm 9.8$ ;  $p > 0.05$ ). When the children were divided into three different age groups (4 to less than 8 years, 8 to less than 12 years, and 12 to 14 years), there was no significant difference in preoperative or postoperative AHI values between the three age groups (data not shown). The incidences of surgical cure (AHI score of less than 5) were 89.8%, 88.5%, 88.9%, respectively, in the three age groups. The improvement after adenotonsillectomy, as measured by changes in the AHI, was comparable between the groups ( $p > 0.05$ ).

#### RISK FACTORS FOR PERSISTENT OSAS AFTER SURGERY

Resolution of OSAS (surgical cure), defined as a postoperative AHI score of fewer than 5 episodes per hour, occurred in 73 children (86.9%) after adenotonsillectomy in our cohort. Persistent OSAS presented in 11 children (13.1%). As shown in Table 4, there were no statistically significant differences between the two groups with respect to age, sex, adenoid size, or a positive family history of allergy or OSAS ( $p > 0.05$ ). In summary, the children with persistent OSAS were more obese and had more severe OSAS before surgery. They also had higher incidences of tonsillar hypertrophy, a history of allergic rhinitis or asthma, and persistent snoring after adenotonsillectomy. A multiple logistic regression analysis was performed using the 5 clinical factors identified from the univariate analysis. The results showed that only obesity (odds ratio [OR], 3.239; 95% confidence interval [95% CI], 1.759 to 7.893;  $p = 0.004$ ) and preoperative AHI score (OR, 6.151; 95% CI, 3.836 to 20.637;  $p < 0.001$ ) were signifi-

cantly related to the incidence of persistent OSAS after adenotonsillectomy.

#### IMPROVEMENTS IN QOL AFTER SURGERY

The mean interval between the first OSA-18 survey and surgery was 12 days (range, 2 to 39 days). The mean interval between surgery and the second survey was 20 months. The mean interval between the two surveys was 21 months (range, 18 to 25 months). The OSA-18 total and domain scores before and after adenotonsillectomy for 84 children with OSAS are presented in Table 5. The mean total OSA-18 score was 77.6 before surgery and 32.5 after surgery ( $p < 0.001$ ). Before operation, the mean total survey and the individual domain scores were not significantly different between the two groups, and the same was true after surgery ( $p > 0.05$  for all). In both groups, the scores for the total and all domains showed an obvious decrease after surgery. Improvements in QOL as shown by change scores (preoperative score minus postoperative score) were comparable in the two groups ( $p > 0.05$ ).

#### CORRELATION BETWEEN PSG AND OSA-18 SCORES

The preoperative AHI scores had a poor correlation with the preoperative total OSA-18 scores ( $r = 0.05$ ), and the same poor correlation was seen between the postoperative AHI and the postoperative total OSA-18 scores ( $r = 0.11$ ). Neither the reduction of AHI scores ( $r = 0.14$ ) nor the change index of the AHI ( $r = 0.10$ ) had a correlation with the total OSA-18 change scores.

#### SUBGROUP STUDY OF OBESE AND NORMAL-WEIGHT CHILDREN

To further clarify the effect of obesity in persistent OSAS after adenotonsillectomy, we chose 20 normal-weight children with comparable preopera-

TABLE 5. IMPROVEMENTS IN QUALITY OF LIFE AFTER ADENOTONSILLECTOMY FOR PEDIATRIC OSAS ACCORDING TO SURGICAL CURE (AHI SCORE OF LESS THAN 5)

OSA-18 Category	Cured (n = 73)			Not Cured (n = 11)		
	Initial	Final	Change	Initial*	Final†‡	Change§
Sleep disturbance	20.4 ± 6.2	6.1 ± 5.8	14.3 ± 6.0	21.4 ± 7.1	6.2 ± 5.3	15.2 ± 7.0
Physical symptoms	15.2 ± 9.0	7.8 ± 4.9	7.4 ± 5.9	16.3 ± 7.7	8.2 ± 6.0	8.1 ± 6.2
Emotional symptoms	11.4 ± 4.7	6.7 ± 5.3	4.7 ± 2.6	11.7 ± 5.4	6.4 ± 5.3	5.2 ± 5.4
Daytime function	11.0 ± 5.5	5.3 ± 3.7	5.7 ± 4.7	10.2 ± 4.7	5.1 ± 4.5	5.1 ± 4.9
Caregiver concerns	19.6 ± 5.9	7.0 ± 5.2	12.5 ± 5.7	20.9 ± 7.4	7.1 ± 4.9	13.7 ± 8.1
Total	77.6 ± 19.0	32.5 ± 21.0	44.7 ± 23.1	80.5 ± 20.5	33.0 ± 19.7	47.5 ± 25.2

Data are mean ± SD OSA-18 scores.

\*Comparison of mean initial survey scores between two groups,  $p > 0.05$  for all.

†Comparison of mean final survey scores between two groups,  $p > 0.05$  for all.

‡Comparison of mean final survey score with initial survey score in each group,  $p < 0.05$  for all.

§Comparison of mean change scores (preoperative score minus postoperative score) between two groups,  $p > 0.05$  for all.

tive AHI values for a subgroup study. There were no significant differences between the obese and normal-weight children regarding age, gender, size of adenoids or tonsils, or preoperative AHI value ( $p > 0.05$ ). The frequency of a postoperative AHI score of less than 1 episode per hour was 50% ( $n = 10$ ) in normal-weight children and 33.3% ( $n = 6$ ) in obese subjects ( $p < 0.01$ ). The rate of surgical cure (AHI score of less than 5) in obese children (50%;  $n = 9$ ) was obviously lower than that in normal-weight children (65%;  $n = 13$ ), independent of the initial severity of the OSAS. In contrast, the improvements in AHI and OSA-18 scores were not significantly different between the two groups ( $p > 0.05$ ).

#### DISCUSSION

This study is one of several to date using the change between preoperative and postoperative PSG findings as the principal outcome measure concerning adenotonsillectomy for pediatric OSAS. We analyzed outcome on the basis of a variety of diagnostic criteria for residual OSAS. The rate of surgical cure was 86.9% if an AHI score of less than 5 episodes per hour was used to define resolution of OSAS. If a strict criterion such as an AHI score of less than 1 episode per hour was used to define normal, then 31.0% of the children had persistent OSAS after adenotonsillectomy. Thus, our results further confirmed previous findings that adenotonsillectomy may not be sufficient to completely eliminate problems of abnormal breathing during sleep, although children with OSAS showed significant improvement in respiratory parameters after surgery.

#### FACTORS RELATED TO PERSISTENT OSAS AFTER SURGERY

As described, the cure rate of adenotonsillectomy ranges widely, depending on differences in the enrolled populations and PSG criteria for OSAS.<sup>14-16</sup> In a study by Tauman et al,<sup>10</sup> normalization of sleep

parameters after adenotonsillectomy (AHI score of 1 or less) for OSAS was found in only 25% of children. However, more than 50% of the children included in their study were obese, and 71% had allergies. After excluding children with obesity, allergies, and craniofacial, neuromuscular, and genetic problems, Mitchell<sup>13</sup> found normalization (AHI score of less than 5) in 82% ( $n = 79$ ) of children after adenotonsillectomy.

**AHI.** Consistent with previous findings,<sup>9,10,13,17</sup> the present study demonstrated that the initial severity of a sleep disorder was associated with the persistence of OSAS after surgery. None of the children with a preoperative AHI score of less than 10 had persistent OSAS after surgery (AHI of at least 5). In contrast, 9 of 30 children (30%) with a preoperative AHI score of greater than 20 had persistent OSAS after surgery. Accordingly, Mitchell<sup>13</sup> found that 3 children (12%) with moderate preoperative OSAS and 13 children (36%) with severe preoperative OSAS had persistent OSAS (AHI of at least 5) after adenotonsillectomy. Moreover, the reduction of AHI level after surgery was closely linked to the initial severity of OSAS, a finding that is strikingly similar to other studies.<sup>10,17</sup> We found that surgery can lessen the preoperative AHI level by 70% to 80%, independent of the initial severity of OSAS. Therefore, the residual 20% to 30% of airway obstruction after surgery may play a critical role in the decision of whether OSAS persists or not. Rather than residual disease, persistent OSAS after adenotonsillectomy may be caused by a number of factors, such as allergic disease, adenotonsillar regrowth, and recurrent rhinitis.

**Obesity.** As reported, adenotonsillectomy can obviously ameliorate the abnormal PSG parameters in obese children with OSAS and adenotonsillar enlargement, but it may be more effective in nonobese subjects.<sup>18</sup> Tauman et al<sup>10</sup> assessed 110 children (1

to 16 years of age) and found that the cure rate (postoperative AHI score of less than 1) was 17% in obese children and 36% in nonobese children. In another series,<sup>19</sup> the postoperative AHI score was less than 2 episodes per hour in 60% of nonobese participants and 24% of obese participants. Consistently, Mitchell and Kelly<sup>20</sup> reported a postoperative AHI score of less than 2 episodes per hour in 72% of 39 normal-weight children (3.3 to 17 years of age) and in 24% of 33 obese children (3.1 to 15.6 years of age). In the current study, the surgical cure rate (AHI score of less than 5) remained lower in obese children than in normal-weight children, even after we controlled for preoperative disease severity. Indeed, the impact of obesity on the outcome of surgery for OSAS remains a controversial issue. Studies by O'Brien et al<sup>21</sup> and Apostolidou et al<sup>22</sup> both demonstrated that obesity does not necessarily predict an unfavorable outcome of adenotonsillectomy for OSAS. In brief, adenotonsillectomy improves, but does not resolve, OSAS in the majority of obese children. The coincidence of obesity and OSAS would be expected to promote and exacerbate the severity of the systemic inflammatory response separately elicited by each of these diseases, which is associated with a distinct and overall recognizable clinical phenotype.<sup>23</sup>

*Other Factors.* In accord with previous reports,<sup>10,13</sup> age was not a predictor of residual OSAS after adenotonsillectomy in the current study. It is reported that children under the age of 3 years may be at increased risk for residual upper airway obstruction after surgery.<sup>9</sup>

In contrast to early studies,<sup>13,17,24</sup> persistent snoring at follow-up poorly correlated with persistent OSAS after adenotonsillectomy in the current study. Possibly, children without symptoms tend not to be brought back for postoperative PSG because they are judged to be well by their caregivers. This loss to follow-up may skew the results toward those children with persistent symptoms.

#### QOL IMPROVEMENT

Distinct improvements in QOL have been reported in pediatric OSAS after adenotonsillectomy, regardless of the severity of the disorder.<sup>6,14,25-27</sup> In concurrence with the findings of Stewart et al,<sup>28</sup> the improvement in QOL was nevertheless significant

for the entire cohort, and the changes in OSA-18 scores were similar between the cured and noncured groups. Therefore, neither obesity nor the presence of persistent OSAS after surgery tends to impair the benefit that children with OSAS obtain from adenotonsillectomy.

A poor correlation between the severity of OSAS and total OSA-18 scores on QOL survey has been proved in most previous studies.<sup>6,13,29</sup> There is limited information about the correlation between amelioration in PSG parameters and improvements in QOL. In the present study, the change of OSA-18 scores was not parallel with either the preoperative AHI score or the reduction of AHI scores. This finding indicates that PSG and the OSA-18 survey are related but complementary, since they assess different but associated constructs.

#### LIMITATIONS

There are limitations to our study. It was performed in a single-center background, and a randomized controlled design was not used. Additionally, there were no craniofacial and anatomic measures studied for the children with OSAS. Other factors, such as regrowth of adenoid tissue and a positive history of allergy or of OSAS, may affect the surgical outcome. It is likely that larger cohorts will be needed to accurately evaluate the relative contributions of such potential risk factors to postsurgical outcomes.

#### CONCLUSIONS

In summary, although adenotonsillectomy for OSAS successfully improves the PSG parameters in the majority of children, obesity and severity of OSAS may increase the risk of residual OSAS after surgery. Better indicators of persistent OSAS after adenotonsillectomy in children should be identified. Increased awareness of the risk of residual OSAS should inform preoperative discussions and the expectations that families develop before surgery. Although QOL instruments may have a role in identifying children who will develop persistent OSAS, postoperative follow-up PSG may be more practical and consistent. For children with residual OSAS, the efficacy and role of additional therapeutic options require more study.

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