Comparison of Polygraphic Parameters in Children With Adenotonsillar Hypertrophy With vs Without Obstructive Sleep Apnea

Xiao-Wen Zhang, MD; Yuan Li, MD; Feng Zhou, MD; Chang-Kai Guo, MD; Zhao-Tong Huang, MD

Objective: To compare the polygraphic parameters in children with adenotonsillar hypertrophy (ATH) with vs without obstructive sleep apnea (OSA).

Design: Prospective controlled study.

Setting: Hospital-based pediatric otolaryngology practice.

Patients: Children with ATH.

Interventions: The children enrolled in the study underwent polysomnography. According to the apnea index (AI) (a patient who has at least 1 episode of apnea per hour of sleep is considered to have apnea), they were classified as having ATH with OSA or ATH without OSA.

Main Outcome Measures: We evaluated polysomnography parameters to describe the macrostructure of sleep (sleep efficiency, nonrapid eye movement stages 1-4, and rapid eye movement) and the microstructure of sleep (using electroencephalogram results and movement arousals) and respiratory events.

Results: Twenty children were classified as having ATH with OSA and 17 as having ATH without OSA. We found no significant differences in sleep macrostructure and microstructure between the ATH groups with vs without OSA. Apnea-hypopnea indices (AHI), respiratory disturbance events, hypopnea events in rapid eye movement and AHI, AI, respiratory disturbance events, obstructive events, hypopnea events, the duration of obstructive events, and hypopnea events during non-rapid eye movement were more frequent or of longer duration in children with OSA vs those without OSA (P<.05).

Conclusions: Obstructive sleep apnea should be considered a disorder on the continuum of ATH. To our knowledge, our results clearly and for the first time demonstrate that more severe respiratory disturbances seem to be important risk factors for ATH to develop into OSA in children.

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were recruited from the Department of Otolaryngology–Head and Neck Surgery, Third Affiliated Hospital, Sun Yat-Sen University, Guangzhou, China, from November 13, 2004, to October 26, 2005. Twenty children were diagnosed as having OSA, as defined as an apnea index (AI) of 1 or greater (at least 1 episode of apnea per hour of sleep). Seventeen children were classified as having ATH without OSA. All the children underwent PSG, and the assessment of ATH was performed by the otolaryngologists (X.-W.Z. and Y.L.) at the same visit to the outpatient clinic. The nasal endoscopy images of the choanal openings were divided into 4 segments from the upper choanal border to the nasal floor. Adenoidal hypertrophy was graded according to the following classifications:

- **Grade 1:** Adenoid tissue occupied only the upper segment in the rhinopharyngeal cavity (<23%), and choanal openings were free.
- **Grade 2:** Adenoid tissue was confined to the upper half (<50%) of the rhinopharyngeal cavity.
- **Grade 3:** Adenoid tissue extended over the rhinopharynx (<75%) with obstruction of choanal openings and partial closure of tube ostium.
- **Grade 4:** The adenoid obstructed almost all of the choana.

Tonsillar hypertrophy was graded as follows:

- **Grade 1:** Tonsils were in the tonsillar pillar.
- **Grade 2:** Tonsils were protruding from the tonsillar pillar.
- **Grade 3:** Tonsils reached the midpoint between the anterior tonsillar pillar and uvula.
- **Grade 4:** Tonsils reached the uvula.

Children with craniofacial anomalies and neurologic abnormalities were not included in the study. The protocol was approved by the institutional review boards of the Third Affiliated Hospital and Sun Yat-Sen University, informed consent was obtained from the parents, and a control group was recruited. No sedation or sleep deprivation was used.

**POLYSOMNOGRAPHY**

During nocturnal PSG, the following parameters were recorded: electroencephalogram (EEG) C4A1, C3A2, submental surface electromyogram (EMG), electrooculogram right to left, surface EMG right to left tibialis anterior, electrocardiogram, heart rate evaluated from the electrocardiogram (right to right heart interval triggered), nasal airflow (thermistor), thoracic and abdominal effort (strain gauge), hemoglobin saturation (pulse oximetry [Oxycon; Rembrandt, Denver, Colo]), and snoring (microphone). The examinations followed guidelines from the criteria of the American Thoracic Society. The Rembrandt PSG system was used. Subjects were videotaped and attended to by a PSG technician. Patients, in the company of their parents, arrived in the laboratory at 9:30 PM, and studies were terminated at 7:00 AM.

**ANALYSIS OF PSG RECORDINGS**

The following parameters were analyzed: macrostructure of sleep (sleep efficiency, nonrapid eye movement [NREM] stages 1-4, and rapid eye movement [REM]), and microstructure of sleep (EEG and movement arousals). The computerized evaluation (Rembrandt) of all parameters was visually confirmed. Sleep was staged to standard criteria adapted for age. There was only 1 trained analyzer to exclude interindividual differences of sleep staging. The accepted definition of arousal for the adult PSG, an EEG frequency shift greater than 3 seconds, was modified for children to frequency shifts greater than 1 second. Depending on a child’s maturation, there is mostly rhythmic θ activity (4-7 Hz) or frequencies greater than 16 Hz (mostly EMG artifacts) that correspond to activation; in older children we also see α activity (8-13 Hz). Delta bursts were scored as arousals only when they occurred within an EEG frequency shift. During REM sleep, arousals were scored if the change in EEG was accompanied by an increase in the amplitude of the submental EMG signal. A minimum of 10 continuous seconds of intervening sleep was necessary to score a second arousal. At the same time, parameters were used to characterize leg movement arousals by tibialis anterior EMG. Movement arousals were defined by an EMG activation; in this case, the activation of musculus tibialis anterior together with an activation in any other polygraphic parameter (eg, heart rate or EEG).

The following respiratory parameters were evaluated: obstructive, mixed, and central apneas, and hypopnea longer than 3 seconds in duration were included to calculate the apnea-hypopnea index (AHI) per hour of total sleep time. Furthermore, heart rate and oxygen saturation during the total sleep time were analyzed. Artifacts in heart rate and oxygen saturation recordings were excluded before they were automatically analyzed using Analysis Manager software (version 7.1; Rembrandt).

**STATISTICAL ANALYSIS**

We performed statistical analysis using SPSS statistical software (version 10.0; SPSS Inc, Chicago, Ill). Nonparametric statistical analysis was used. We performed analysis of changes in score over time using the Wilcoxon signed rank test and comparisons between groups by calculating change scores and using the Mann-Whitney test. We performed comparisons between multiple groups using the Kruskal-Wallis test. P < .05 was considered significant.

**RESULTS**

Thirty-seven children who were involved in the study had a medical history of ATH. There were 28 boys (76%) and 9 girls (24%). The mean age was 7.5 years (range, 3-15 years).

Of those 37 children, 20 (17 boys [85%] and 3 girls [15%]) had OSA according to PSG criteria. The median age was 6.5 years, the mean (SD) age was 7.38 (2.43) years, and the mean (SD) body mass index (calculated as weight in kilograms divided by height in meters squared) was 17.84 (3.70). Among the 17 children with ATH but without OSA, the median age was 8.0 years, the mean (SD) age was 8.12 (3.79) years, and the mean (SD) body mass index was 17.23 (3.29). There was no difference in distribution of the age ranges between children with ATH with vs without OSA (Figure 1).

There was no difference in sleep efficiency between children with ATH with vs without OSA (Figure 2).

The percentage of sleep stages NREM 1 through 4 and REM did not differ in children with ATH with vs without OSA. Also, there were no differences in EEG arousals (Figure 2).

In children with both ATH and OSA, 93.70% of all obstructive apneas and 92.99% of all hypopnea occurred during NREM sleep.

The AHI, number of respiratory disturbance events, and AI were significantly greater in children with ATH with vs without OSA. Also, there were no differences in EEG arousals (Figure 2).

**DISCUSSION**

The percentage of sleep stages NREM 1 through 4 and REM did not differ in children with ATH with vs without OSA. Also, there were no differences in EEG arousals (Figure 2).

In children with both ATH and OSA, 93.70% of all obstructive apneas and 92.99% of all hypopnea occurred during NREM sleep.

The AHI, number of respiratory disturbance events, and AI were significantly greater in children with ATH with vs without OSA. Also, there were no differences in EEG arousals (Figure 2).
with vs without OSA (Table). The number of respiratory disturbance events, AHI, AI during NREM and respiratory disturbance events, and AHI during REM were significantly greater in children with ATH with vs without OSA (Table). The AIs during REM were higher in children with ATH with vs without OSA, but there were no significant differences.

During REM sleep, only hypopnea events were significantly more frequent in children with ATH with vs without OSA (Table); however, among obstructive events, central events, and mixed events and their average, longest, and total durations, there were no significant differences between children with ATH with vs without OSA. Among the average, longest, and total hypopnea event durations, there were also no significant differences between the 2 groups.

Hypopnea events, obstructive events, and their total duration in NREM sleep were significantly more frequent and of longer duration in children with ATH with vs without OSA (Table). There were no significant differences between children with ATH with vs without OSA on central events, mixed events, and their average, longest, and total durations.

### Table. The Differences in Polygraphic Parameters of Children With ATH With OSA vs Without OSA*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ATH Without OSA</th>
<th>ATH With OSA</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total respiratory disturbance events, No.</td>
<td>22.59 (17.14)</td>
<td>104.30 (74.50)</td>
<td>.001</td>
</tr>
<tr>
<td>AHI (TST), No. per hour</td>
<td>4.02 (5.55)</td>
<td>13.42 (9.16)</td>
<td>.001</td>
</tr>
<tr>
<td>AI (TST), No. per hour</td>
<td>0.20 (0.30)</td>
<td>8.87 (14.37)</td>
<td>.01</td>
</tr>
<tr>
<td>Respiratory disturbance events during REM sleep, No.</td>
<td>1.76 (0.03)</td>
<td>6.75 (6.49)</td>
<td>.005</td>
</tr>
<tr>
<td>AHI during REM sleep, No. per hour</td>
<td>3.99 (5.58)</td>
<td>13.48 (9.77)</td>
<td>.001</td>
</tr>
<tr>
<td>AI during NREM sleep, No. per hour</td>
<td>0.20 (0.27)</td>
<td>5.96 (7.00)</td>
<td>.002</td>
</tr>
<tr>
<td>Hypopnea events during REM sleep, No.</td>
<td>1.29 (2.62)</td>
<td>4.25 (4.14)</td>
<td>.01</td>
</tr>
<tr>
<td>Obstructive events during NREM sleep, No.</td>
<td>1.70 (2.26)</td>
<td>38.72 (46.38)</td>
<td>.002</td>
</tr>
<tr>
<td>Duration of obstructive events during NREM sleep, min</td>
<td>1.65 (4.92)</td>
<td>17.34 (15.74)</td>
<td>.001</td>
</tr>
<tr>
<td>Hypopnea events during NREM sleep, No.</td>
<td>19.12 (16.68)</td>
<td>54.70 (45.72)</td>
<td>.003</td>
</tr>
<tr>
<td>Duration of hypopnea events during NREM sleep, min</td>
<td>7.86 (7.43)</td>
<td>22.75 (15.93)</td>
<td>.001</td>
</tr>
</tbody>
</table>

*Data are given as mean (SD).

### Abbreviations: AHI, apnea-hypopnea index; AI, apnea index; ATH, adenotonsillar hypertrophy; NREM, nonrapid eye movement stage; OSA, obstructive sleep apnea; REM, rapid eye movement; TST, total sleep time.

### COMMENT

This study evaluated macrostructure of sleep, microstructure of sleep arousals, and respiratory disturbance events in children with ATH. We found that there were no differences in sleep macrostructure and microstructure between ATH with OSA and ATH without OSA. The AHI, respiratory disturbance events, and hypopnea events in REM and the AHI, AI, respiratory disturbance events, obstructive events, hypopnea events, and the duration of obstructive and hypopnea events in NREM were found to be more frequent or of longer duration in children with ATH with vs without OSA.

Several investigators have found that sleep pattern changes are less marked in children with OSA. Adults with OSA often have decreased slow wave and REM sleep. Infants with OSA have decreased REM time. The reason for these differences between these age groups is unclear. As shown in this study, there was reduction of REM and increase of NREM stage 1 in children with ATH compared with healthy children. A possible explanation is that children with OSA may have subtle changes in sleep architecture that cannot be detected by standard EEG techniques and that may require more sophisticated types of analysis, such as EEG spectral analysis. The proportions of the various sleep stages in our study were unbalanced,
but there was no significant difference of sleep macrostructure between ATH with OSA and ATH without OSA.

Children with OSA have more arousals than healthy children. Arousals in the context of sleep-related breathing disorders are thus beneficial because ventilation is restored, but the adverse consequences of frequent arousals include sleep disturbance and deficits in daytime functioning. Mograss et al described EEG arousals after only 39.3% of respiratory events in quiet sleep and 37.8% of events in active sleep of children. In our study, the arousals index was higher than the AHI, and the different conclusions probably stem from differences in the definition of arousals: one group included subcortical arousals (ie, without EEG changes) and the other was confined to EEG arousal. But there was no significant difference in sleep microstructure between ATH with OSA and ATH without OSA.

In addition, there was no significant difference in sleep macrostructure and sleep microstructure between ATH with OSA and ATH without OSA, suggesting that OSA should be considered a disorder on the continuum of ATH.

In children, airway obstruction is often predominant in REM sleep owing to the loss of upper airway and intercostal muscle tone that is most marked in this sleep state. Despite this, REM sleep continues to be present in normal amounts in children with OSA, although microdisruption of REM sleep may be present. We found that few respiratory events occurred during REM sleep; this is in contrast to a report by Morielli et al. In our study, 6.30% of all obstructive apneas and 7.01% of all hypopnea occurred during REM sleep. We also found that the AHIs and the numbers of total respiratory disturbance events and hypopnea events were higher in children with ATH with vs without OSA. Our findings demonstrate that a distinct increase in the frequency of hypopnea events was the main difference between children with ATH with vs without OSA during REM sleep.

In the current study, 93.70% of all obstructive apneas and 92.99% of all hypopnea occurred during NREM sleep. This finding is similar to reports in adults, in whom obstruction occurs more commonly during NREM sleep than during REM sleep. As with adults, the apneas were of longer duration during REM sleep than during NREM sleep and were associated with more profound desaturation. In the present study, the durations of obstructive events and hypopnea events in NREM were longer in children with ATH with vs without OSA. The AHI, AI, and frequency of respiratory disturbance events, obstructive events, and hypopnea events were higher in children with ATH with vs without OSA.

We found significant differences of respiratory disturbance events between ATH with OSA and ATH without OSA, especially in NREM sleep. We speculate that hypopnea events, obstructive events, and their total duration in NREM sleep played important roles in OSA owing to ATH.

In summary, this study demonstrated that there were no significant differences in sleep macrostructure and sleep microstructure between ATH with OSA and ATH without OSA, and that OSA should be considered to be a disorder on the continuum of ATH. To our knowledge, these results clearly and for the first time demonstrate that hypopnea events, obstructive events, and their total duration in NREM sleep and hypopnea events in REM may be important pathologic mechanisms of OSA owing to ATH.

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Author Contributions: Drs Zhang and Li had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Zhang, Li, and Guo. Acquisition of data: Zhang and Huang. Analysis and interpretation of data: Zhang and Zhou. Drafting of the manuscript: Zhang and Guo. Critical revision of the manuscript for important intellectual content: Zhang, Li, Zhou, and Huang. Statistical analysis: Zhang, Zhou, and Huang. Administrative, technical, and material support: Zhang, Li, and Guo.

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REFERENCES


