Evaluation of polysomnography before and after treatment using polysomnography in children with obstructive sleep apnea.

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[Abstract]

Clear diagnostic and treatment standards have not yet been established for pediatric obstructive sleep apnea (OSA), so a considerable number of patients, including those yet undiagnosed, may be left untreated in Japan. However, it is practically impossible to conduct overnight polysomnography (PSG) tests, which are considered useful for diagnosis, for all cases of suspected pediatric OSA because of insufficient manpower in pediatric medical care and detachment of electrodes due to frequent body movements. Therefore, in order to clarify the usefulness of surgical treatment for pediatric OSA, a retrospective study was conducted using PSG parameters, including the apnea hypopnea index (AHI) on 32 patients.

Of 144 patients (93 boys, 51 girls, average age at first visit: 9.1±2.9 years, 30 preschool children under seven years old) who were able to undergo PSG, 32 patients with pre- and post-surgery PSG data were included (18 boys, 14 girls, average age at first visit: 8.4±2.4 years, eight preschool children under seven years old). Additionally, eight patients had a pre-treatment body mass index (BMI) of 25 or higher. Allergic diseases such as bronchial asthma and allergic rhinitis were the most common complications (18/32,56.3%). Comparing post- and pre-surgical PSG parameters, significant decreases were observed for AHI, apnea index (AI), and oxygen desaturation index (ODI); significant increases were observed for stage REM and REM sleep time (p<0.05).

Despite the limited number of cases, from our data suggest that polysomnography is useful in both determinations the indication of surgical treatment and its efficacy in children with OSA.

[Keywords]

Pediatric obstructive sleep apnea, overnight polysomnography, palatine tonsil hypertrophy, adenoid hyperplasia, obesity

[Introduction]

Obstructive sleep apnea (OSA) in children is relatively common; however, children cannot always receive the treatments for OSA that are used in adults, even with the same physical symptoms[1].Previous epidemiological studies[2][3] have indicated that the prevalence of pediatric OSA is approximately 1–10%. However, these used different survey methods, and clear criteria for pediatric OSA diagnosis and treatment have not yet been established. It is therefore possible that a considerable number of patients, including those who are undiagnosed, are left untreated in Japan.

OSA in children is a rather frequent pathology caused by pathophysiological alterations leading to partial and prolonged obstruction (hypoventilation) and/or intermittent partial (hypopnea) or complete (apnea) obstruction of the upper airways[4]. OSA has harmful central nervous system, cardiovascular, and metabolic consequences, which can include an inability to concentrate in school, poor academic performance, behavioral problems, cardiovascular effects, and poor growth and development in children[5].

Adenotonsillar hypertrophy is the major cause of OSA in children. A directed history and physical examination followed by tonsillectomy and adenoidectomy are effective in improving the physical sequelae and quality of life of affected children[6]. Then, one clinical practice guideline for tonsillectomy in children indicates that physicians should advocate performing polysomnography prior to tonsillectomy when the need for tonsillectomy is uncertain or when there is discrepancy between physical examination and reported severity of OSA[7].

However, in Japan, there is a lack of pediatric healthcare staff, and there are a limited number of facilities that can conduct pediatric overnight polysomnography (PSG) tests, which are essential for OSA diagnosis and evaluation. Therefore, some medical institutions use simplified, at-home sleep tests, which do not require the presence of medical staff[8], [9]. However, it has been reported that nocturnal physiological central apnea is often observed in children, even in those who are healthy[10], and there is a need for a more comprehensive pediatric PSG test that can evaluate sleep architecture and sleep efficiency. In recent years, there have been improvements in these tests, such as using an appropriate number of PSG electrodes, but the reality is that each medical institution still deals with this on an individual basis.

This study investigated parameters to evaluate pediatric OSA other than surgical outcomes, such as the apnea hypopnea index (AHI), as well as the characteristics of pediatric OSA that can be evaluated by overnight polysomnography (PSG) before and after treatment.

[Methods]

The study was approved by the ethics committee at Dokkyo Medical University. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

1. Patients

In the 13-year period from April 2008 to March 2021, 789 patients, under the age of 16 years, visited our hospital presenting with snoring and breathing problems during sleep. These patients underwent detailed medical interviews, OSA-18 questionnaires, morphological evaluation of upper airways and neck, video recordings, nasal airway tests, and body mass index (BMI) measurement. Of these patients, 144 (18.3%) could be evaluated using PSG, and 32 (22.2%) who underwent PSG before and after surgical treatment were included in the study. Patients with congenital disorders, neurological disorders, epilepsy, or other complications involving maxillofacial malformations were excluded (Fig. 1).

2. Diagnosis

Palatine tonsil hypertrophy was classified using Yamamoto's five-grade classification[11)], defined by Mackenzie, as well as the Brodsky classification[12)] based on macroscopic findings. Adenoids were classified into four grades according to the pharyngeal tonsil classification from Parikh et al.[13)].

PSG was conducted in patients suspected of having breathing problems during sleep based on interviews with parents, OSA-18 questionnaire scores, and local findings in the oropharynx and nasal cavity; in cases where this was difficult to judge, video recordings during sleep at home and/or simplified sleep tests were used.

3. Overnight polysomnography tests

All PSG tests in this study were conducted in a dedicated test room at our hospital during the natural sleep of patients. Electroencephalograms, electrooculograms, lower limb electromyograms, electrocardiograms, body position, arterial blood oxygen saturation (SpO_2), oral/nasal airflow, thoracic abdominal movement, and snoring were measured.

PSG with chin electromyogram and body position sensor was conducted using an Alice 5 or 6 (Respironics, Inc., Murrysville, PA, USA), and all analyses were conducted by a full-time physician and technician in accordance with the comprehensive PSG manual of the American Academy of Sleep Medicine (AASM)[11)]. The diagnostic criteria for respiratory events of apnea/hypopnea conformed to the Obstructive sleep apnea, pediatric: the 2005 International Classification of Sleep Disorders, Second Edition (ICSD-2)[15)]. Patients with an apnea hypopnea index (AHI) of 1/h or more were diagnosed with OSA[16)], with those with an AHI of 10/h or more requiring treatment. The AHI was used as a reference value to classify severity into three groups: mild (1/h ≤ AHI < 5/h), moderate (5/h ≤ AHI < 10/h), and severe (AHI ≥ 10/h)[17)]. Post-operative PSG tests were conducted at least 3 months after surgery. Additionally, therapeutic effects were judged based on an AHI of less than 2/hr or less than 5/hr.

4. Treatments

Cases where symptoms, such as snoring, did not improve with conservative treatments, such as oral administration of L-carbocysteine or nasal steroids (fluticasone propionate), as well as those with palatine tonsil hypertrophy of +2 or higher according to Brodsky's classification and adenoids of grade 2 or higher according to Parikh's classification were selected for routine tonsillectomy and adenoidectomy surgical treatment (Fig. 1). Surgical treatment was conducted under general anesthesia, using a mouth gag to clearly show the palatine tonsil. A mucosal incision was made on the palatal arch to expose the tonsil capsule, and vessels were cauterized as needed to conduct tonsillectomy. For adenoidectomy, a microdebriter[18)] (Medtronic, USA) was used to insert a straight-type blade through the nasal cavity; adenoid tissue was confirmed using indirect laryngoscopy and as much tissue as possible was excised.

5. Statistics

SPSS software (v28.0.0.0; IBM Corp., Armonk, NY, USA) was used for statistical analysis.

The Wilcoxon signed-rank test was used for statistical testing, and $p < 0.05$ was considered statistically significant.

[Results]

Of 144 initial pediatric patients (93 boys, 51 girls, average age at first visit: 9.1±2.9 years, 30 preschool children under seven years old), 32 were included (18 boys, 14 girls, average age at first visit: 8.4±2.4 years, 8 preschool children (25%) under 7 years old) for whom PSG evaluation before and after surgical treatment was possible. Additionally, 8 patients (25%) had a pre-treatment body mass index (BMI) of 25 or more. The most common complication was allergic rhinitis (18patients, 56.3%), and otitis media with effusion was present in 2 patients (6.3%). Using the pre-operative AHI for severity classification, the frequency of complications tended to be higher in severe cases (Fig. 2).

All 32 patients who required surgery showed local findings in the oropharynx of grade 2 or higher according to Yamamoto's classification and palatine tonsil hypertrophy of +2 or higher according to Brodsky's classification; tonsillectomy was conducted. Adenoidectomy was also conducted in 24 patients (75%) with a grade of 2 or higher according to Parikh's classification. All patients received general anesthesia, and one patient experienced hemostasis due to bleeding from the tonsil bed on the 9th post-operative day.

We compared each PSG parameter before and after surgical treatment. Significant decreases were observed for AHI, apnea index (AI), and oxygen desaturation index (ODI) ($p < 0.05$). However, post-operative AHI was 2 or higher in 8 patients with obesity (BMI > 25), and one of these patients was treated with nasal continuous positive airway pressure after surgery.

Although there were any statistically significant differences in REM stage-sift, sleep efficiency, sleep latency, and the rate of deep sleep (stage N3) between before and after surgical treatment, stage REM ($p<0.05$) and REM sleep time ($p<0.05$) significantly increased after surgical treatment (Table).

[Discussion]

We investigated patients with children with OSA in our hospital using PSG before and after surgical treatment. Then, we observed that severe reductions in values of AHI and ODI have been observed in children with OSA, and can be corrected by surgical treatment.

There are not many reports from Japan on the effects of surgical therapy using objective tests in a manner similar to the present study. Although it is impractical to conduct PSG tests on all pediatric patients with suspected OSA, we evaluated a small number of cases with the cooperation of the clinical laboratory department. Conducting PSG during natural sleep in elementary school-aged children of entering elementary school is difficult because the electrodes may detach during frequent body movements, and careful judgment is required for data analysis. There are also pediatric cases in which symptoms persist or recur after treatment; it has been reported that children with OSA have decreased memory, attention, vocabulary, and executive control abilities[19], as well as poorer academic performance[20], so the accumulation of objective test data is important for assessing therapeutic effects. The AASM, American Thoracic Society, and American College of Chest Physicians[21] investigated the validity of simplified sleep tests, providing limited recommendations even for the most commonly used Type 3 test equipment.

Interviewing parents is thought to be very important when determine whether a patient should receive surgery. In this study, parents were interviewed in detail about sleep conditions and the characteristics of snoring, presence and frequency of apnea, and presence or absence of cyanosis and retractive breathing were confirmed by our PSG analysis. Parents are often unaware of sleeping posture, presence or absence of jaw lift, and retractive breathing; here, parents were asked to record 5-min videos of the patients sleeping at home, which we used as a reference. Additionally, if the child was attending a nursery school, we also checked these characteristics during naps as well as the presence or absence of attention deficit disorder and hyperactivity/aggressive behavior.

There is no consensus on the diagnostic criteria for pediatric sleep-disordered breathing, including in the AASM. Diagnostic criteria have been established for adults, where OSA is defined as an AHI of at least 5/h, with cases where AHI is at least 20/h requiring active treatment. Meanwhile, the diagnostic criteria for children in the ICSD-2[15], proposed in 2005, set an AHI criterion of 1/hr. However, in children, it has been reported that the average AHI value tends to increase in winter due to the exacerbation of nasal symptoms, even in the same child[22], and there is a need for a comprehensive diagnosis that includes clinical symptoms and upper respiratory tract findings. Therefore, in our hospital, treatment is recommended for patients not only with clinical symptoms but also those diagnosed with OSA with an AHI of at least 2/h in PSG and in whom symptoms such as snoring do not improve after one month of oral treatment or conservative treatments such as steroid (fluticasone propionate) nasal drops; treatment is recommended in patients with an AHI of at least 10/h regardless of their symptom improvement. However, although AHI values can be used as a reference for treatment, there is not necessarily a clear cut-off based on this value. Furthermore, the diagnosis of pediatric OSA does not have criteria for judging the effects of surgery, such as Sher’s evaluation criteria for adult OSA[23]. If a post-treatment AHI less than 2/h is defined as successful, then the treatment would have been considered effective in only five of the present patients; if this is modified to an AHI less than 5/h, treatment would not be considered effective in 12 cases.

Excluding the eight preschool children, all patients in this study were elementary or junior high school students; physiological hypertrophy of adenoids or palatine tonsils[24] could have introduced selection bias. Surgical treatment resulted in the elimination of post-operative snoring symptoms in five patients (15.6%), and post-operative AHI was decreased to less than 2/hr. However, allergic rhinitis symptoms improved in only three of 18 patients (16.7%), and there was no change in obesity in the patients with a BMI of at least 25. Some patients subsequently transitioned to nasal continuous positive airway pressure therapy, indicating that surgical treatment alone was insufficient for treatment.

When considering the presence or absence of complications, allergic rhinitis was the most common, followed by obesity (BMI ≥ 25). Grouped by severity based on pre-operative AHI (Fig. 2), the severe cases (AHI ≥ 10/h) showed higher rates of complication, and it is thought that increased nasal resistance in allergic rhinitis facilitates mouth breathing-induced tongue base depression and collapse of the pharyngeal airway. Kim et al.[25)] reported that an allergic rhinitis diagnosis should be confirmed and treated before surgery. Additionally, OSA is more common in children with obesity around school age[26)], which is consistent with a report indicating a therapeutic effect of tonsillectomy of only 10–25%[27)]. In other words, as 24 of the 32 patients were elementary and junior high school students, adenoidectomy and tonsillectomy could not be uniformly selected as the first-line treatment for OSA in patients with obesity, so therapeutic interventions need to be reconsidered for these patients. It is expected that the treatment of OSA in patients with obesity will be improved by providing nutritional guidance in cooperation with pediatrics departments before and after surgery.

All patients receiving adenoidectomy and tonsillectomy in the present study had palatine tonsil hypertrophy of at least grade 2 according to Yamamoto’s classification and at least +2 according to Brodsky’s classification and adenoids with grade of at least 2 using Parikh’s classification. Meanwhile, patients with adenoid hyperplasia equivalent to Parikh’s grade 1 and where only tonsillectomy was conducted had a grade of 2–3 according to Yamamoto’s classification and +2–+4 according to Brodsky’s classification; palatine tonsil hypertrophy was not necessarily observed in all patients upon visual inspection, and similar to other reports[28)], it was not possible to judge the appropriateness of surgery using only local findings. There is a need for the development of a non-invasive method for diagnosing upper-airway obstruction during natural sleep in children that is the equivalent of a dynamic MRI and endoscopy in drug-induced sleep in adults.

Surgical treatment not only improved symptoms such as snoring, apnea, and hypopnea, but also normalized sleep architecture, increasing stage REM and REM sleep time. Improvements in sleep quality are expected to improve learning disabilities and quality of life[29].

Many cases of pediatric OSA, similar to adult cases, are multifactorial; there is a need to evaluate not only local intraoral findings but also systemic factors such as the effects of nasal respiratory disorders or obesity complications on OSA. In particular, physical development and sleep affect each other, so otolaryngologists are expected to proactively diagnose and treat pediatric OSA without simply conducting follow-up observations.

The limitation of this study was that the number of children with OSA whom could be observed polysomnography to evaluate differences by ages. Since various background factors may not be similar among children of different ages, it should be necessary to collect more cases in the future studies, to investigate the joints of the polysomnogram and the degree of improvement by surgical treatment in each age group.

[Conclusions]

Despite the limited number of cases, from our data suggest that polysomnography is useful in both determinations the indication of surgical treatment and its efficacy in children with OSA.

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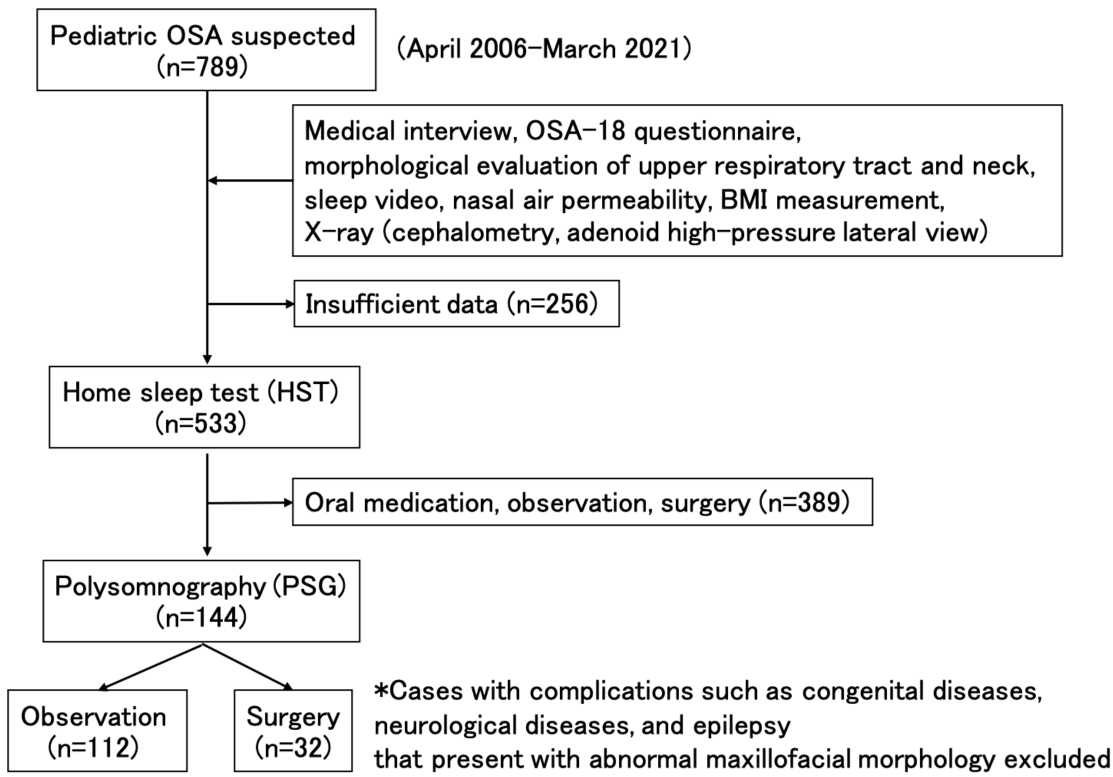
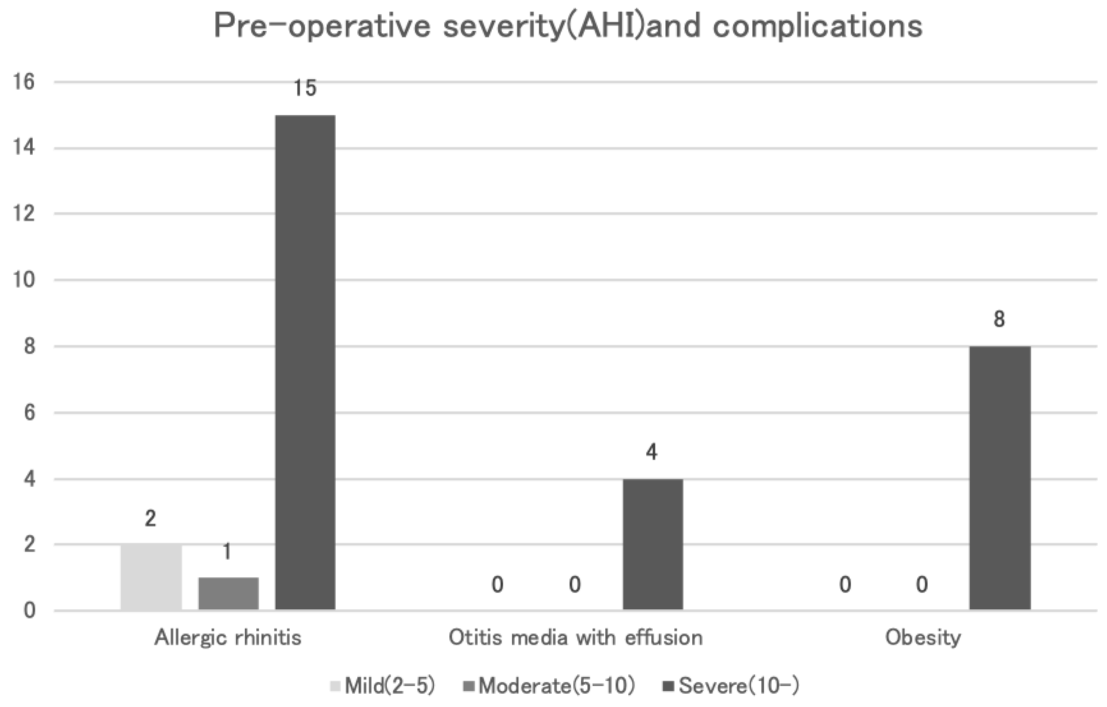
[Fig. 1]


Pediatric OSA suspected
(n=789)
(April 2006–March 2021)
Medical interview, OSA-18 questionnaire,
morphological evaluation of upper respiratory tract and neck,
sleep video, nasal air permeability, BMI measurement,
X-ray (cephalometry, adenoid high-pressure lateral view)
Insufficient data (n=256)
Home sleep test (HST)
(n=533)
Oral medication, observation, surgery (n=389)
Polysomnography (PSG)
(n=144)
Observation
(n=112)
Surgery
(n=32)
*Cases with complications such as congenital diseases,
neurological diseases, and epilepsy
that present with abnormal maxillofacial morphology excluded

[Fig. 2]



AHI: Apnea hypopnea index

[Table]

	Pre-surgery		Post-surgery		*p*-value
	Mean	SD	Mean	SD	
AHI (/hr)	30.9	26.5	5.0	3.2	<.001
ODI (/hr)	27.9	26.7	4.6	3.1	<.001
REM sleep time (min)	68.3	25.7	79.2	24.7	0.021
REM stage sift (times)	8.0	5.3	6.8	2.7	0.375
sleep efficiency (%)	87.2	9.2	88.1	11.3	0.67
sleep latency (min)	22.8	29.3	27.1	50.6	0.562
Stage REM (%)	13.9	4.6	16.1	4.3	0.013
Stage N3 (%)	31.5	9.1	33.8	8.0	0.304

AHI: Apnea hypopnea index

ODI: Oxygen desaturation index

REM: Rapid eye movement