Clinical and Polysomnographic Parameters of Children with Sleep Disordered Breathing: Comparison between Surgical and Non-surgical Candidates

Thananard Kriengkraikasem, M.D.[1], Archwin Tanphaichitr, M.D.[2], Sarin Rungmanee, M.D.[3], Chawanont Pimolsri, M.D.[3], Wattanachai Chotinaiwattarakul, M.D.[3,4], Wish Banhiran, M.D.[2,3]

Received: 8 Febuary 2023
Revised: 23 August 2023
Accepted: 1 September 2023

Abstract

Objective: To compare clinical and polysomnography (PSG) parameters in children with sleep-disordered breathing (SDB) that influence the treatment decision between surgical and non-surgical treatment.

Study design: Retrospective study.

Material and methods: Patients aged 2–15 years with SDB who underwent PSG were recruited. Clinical and PSG parameters were compared between surgical and non-surgical candidates.

Results: Three hundred and eighty patients were included, with a mean age of 8.72 ± 3.78 years. In terms of sleep architecture, the surgical group had a significant increase in total sleep time, sleep stages N3, and REM ($P<0.05$), but had a significant reduction in sleep stage N2 ($P<0.05$) compared to the non-surgical group. In terms of respiratory parameters, there was a significant increase in the AHI, obstructive AHI, apnea index, hypopnea index, the longest time of apnea and hypopnea, mean oxygen saturation, oxygen desaturation index and the total arousal index in surgical group compared to non-surgical group ($P<0.05$). Multivariate analysis demonstrated age 2-5 years, tonsil size 3+ and 4+, and obstructive AHI ≥ 5 events/h were significant risk factors for surgical treatment ($P<0.05$).

Conclusion: Both clinical and PSG parameters should be taken into consideration in the treatment decision for pediatric patients with SDB, especially age, tonsil size, and obstructive AHI. A prospective multicenter study with a larger sample size to create comprehensive care for patients with SDB is needed.

Keyword

Pediatric, Polysomnography, Sleep-disordered breathing, Obstructive sleep apnea, Adenotonsillectomy, Surgical treatment

[1] Department of Otorhinolaryngology, Bhumibol Adulyadej Hospital, Bangkok 10220, Thailand.

[2] Department of Otorhinolaryngology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

[3] Siriraj Sleep Center, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

[4] Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

Corresponding Author:

Archwin Tanphaichitr, M.D.

Associate Professor

Department of Otorhinolaryngology, Faculty of Medicine Siriraj Hospital, Mahidol University

2 Wanglang Road, Bangkoknoi, Bangkok, Thailand, 10700.

Email: archwin.tan@mahidol.ac.th

Introduction

Pediatric sleep-disordered breathing (SDB) is a spectrum of breathing disorders ranging from primary snoring to obstructive sleep apnea (OSA), characterized by recurrent events of partial or complete upper airway obstruction during sleep which leads to abnormal ventilation and sleeps pattern.[1] In pediatric population, the prevalence of habitual snoring and OSA is ranging from 1.5-27.6% and 1-5%, respectively.[2] In Thai children, the prevalence of habitual snoring and OSA was 4.3-8.5% and 0.69-1.3%, respectively.[3, 4] SDB affecting children's sleep quality, ventilation function, physical development, brain function, and quality of life.[2, 5-8]

Polysomnography (PSG) has been recognized as the gold standard for diagnosing OSA.[9] According to the American Academy of Sleep Medicine (AASM) and the American Academy of Pediatrics (AAP) guidelines, PSG should be performed to confirm the diagnosis of OSA in children before undergoing adenotonsillectomy (TA)[2]. However, the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) guidelines recommended performing PSG in children who are less than 2 years of age, children with any of the following: obesity, Down syndrome, craniofacial abnormalities, neuromuscular disorders, sickle cell disease, or mucopolysaccharidoses, or if there is discordance between clinical symptoms and physical examination.[10,11] In Thailand, OSA was the most common diagnosis with a prevalence of 92.7% among pediatric patients who presented by snoring or other SDB symptoms. In addition, the prevalence of sleep disorders in Thai children who underwent PSG at a tertiary-care hospital is very high because of limited availability and high cost in a non-tertiary-care hospital.[5]

TA is the mainstay surgical treatment for pediatric patients with SDB[12] who have adenotonsillar hypertrophy.[10, 13] Other surgical interventions beyond TA include lingual tonsillectomy, supraglottoplasty, oropharyngeal surgery, and nasal surgery, which depends on the site of obstruction. Nonsurgical management for pediatric OSA includes continuous positive airway pressure (CPAP), weight control, intranasal corticosteroids, and leukotriene receptor antagonist.[14] However, treatment decision for pediatric SDB requires further understanding.[14] Studies indicated that as compared with watchful waiting, TA can reduce symptoms and improve the

secondary outcomes of behavior, quality of life, and PSG parameters in children with OSA.[15, 16] However, other studies suggest a more conservative method before conducting TA.[17] Chervin et al. reported that after 7 months of watchful waiting, many patients who were suitable for TA no longer had OSA on PSG.[17] In addition to PSG, indications for TA may depend, in part, on practice settings and otolaryngologists' backgrounds. However, research has yet to prove that diagnoses based on PSG, as opposed to a bedside history and physical examination, better predict outcomes of TA. In addition, pre-operative PSG could add considerable costs or delay effective treatment.

Many children who receive TA for OSA also have other indications sufficient to warrant surgery. More data will be needed to establish optimal approaches to a highly prevalent sleep disorder and one of the most common surgical procedures in children. Possibilities raised by current data include inadequate availability of pediatric sleep laboratory beds outside large academic centers, insufficient training in pediatric otolaryngology, and relative lack of experience in practice.[18]

Currently, in Thailand, the chance of most children with SDB getting PSG done before definite surgical treatment is relatively low because PSG is mostly available in tertiary-care hospitals. No more than 10% of the children were objectively tested for OSA, particularly laboratory-based PSG. No PSG parameters were identified as indications of TA.[18] To explore if the PSG was needed before surgical treatment, there should be some parameters other than just an oversimplified apnea-hypopnea index (AHI) potentially useful for selecting proper treatment. Unfortunately, those parameters may be frequently overlooked or not appropriately considered. Among these PSG parameters, obvious improvements were observed in postoperative AHI, arousal index, oxygen desaturation index (ODI), and snore index compared with the preoperative measurements.[19] ODI has been reported as a good tool for predicting both the presence and severity of OSA in children, which may be an alternative tool for postoperative evaluation and follow-up of children with OSA.[19] In the study by Zhao et al., age, mouth breathing frequency, and obstructive AHI were the most important factors which were involved in the surgical decision.[14] The aim of this study is to comprehensively review and

compare clinical and PSG parameters in children with SDB who underwent surgical and non-surgical treatment. We hypothesize that there might be some clinical and PSG parameters beyond AHI that are also useful for treatment planning.

Materials and methods

Study Design

This retrospective study was approved by the Institutional Review Board of the Faculty of Medicine Siriraj Hospital, Mahidol University (Si 231/2021). The clinical and PSG parameters were compared between surgical and non-surgical candidates to identify the parameters that influence the treatment decision, i.e. surgical and non-surgical treatment.

Study Population

We recruited 380 pediatric patients aged 2-15 years diagnosed with SDB (documented history of labored snoring, witness apnea, struggling, and/or gasping during sleep) and underwent attended PSG in Siriraj Hospital Bangkok, Thailand. The study period was from January 2018 to December 2019. Patients with incomplete PSG information including total sleep time less than 2 hours, technical error, or severe artifacts were excluded.

Polysomnography (PSG)

Sleep studies were performed with Somnomedics; SOMNO HD EEG32 (Germany). All PSG were obtained using standard electroencephalographic monitoring, including frontal leads (F3, F4), central leads (C3, C4), occipital leads (O1, O2), and reference leads at the mastoids (M1, M2); electromyography; and electrooculography. Peripheral capillary oxygen saturation was measured with a finger probe. Airflow was measured by two methods: a nasal pressure transducer and an oral-nasal thermocouple. The thoracic and abdominal respiratory movements were monitored by respiratory inductance plethysmography. The body position was measured by a position sensor, which was attached to the anterior chest wall on the thoracic belt. Sleep stages were scored in 30-s epochs according to the American Academy of Sleep Medicine (AASM) standard criteria.[20] Apnea was defined using oral-nasal thermocouple excursion, and hypopnea was defined using nasal pressure transducer excursion. Apnea and hypopnea were scored using the standard criteria from the AASM manuals 2012.[20] The severity of OSA was classified by using obstructive AHI (OAHI) as mild (OAHI 1.0-4.9 events/h), moderate (OAHI 5.0-9.9 events/h), or severe

(OAHI ≥ 10.0 events/h).[21] Central apneas and central hypopneas in rapid eye movement (REM) and post-arousal were included in the apnea-hypopnea index (AHI) and were excluded from OAHI.

General information

Electronic medical records were used to collect the following demographic and clinical information: age, sex, clinical symptoms, allergic status, underlying disease, height (centimeter), and weight (kilogram). The height and weight of the patients were measured and recorded on the day of the PSG monitoring, and their body mass indices (BMI) were calculated accordingly. Weight status was classified using the BMI z-score which was calculated using weight and height. World Health Organization (WHO)-defined BMI Categories were based on standard deviation (Thinness, <-2SD; normal weight, -2SD to +1SD; Overweight, +1SD to +2SD; Obesity, >+2SD).[22] Tonsillar size was obtained from electronic medical records and graded on the Brodsky scale: 1+ if less than 25% obstruction of the oropharynx, 2+ if 25% to 50 %, 3+ if 50 to 75%, or 4+ if ≥ 75%.[23] Tonsillar hypertrophy was defined as tonsil grade 3+ or 4+.

Surgical vs. Non-surgical Group

Included subjects were followed at least 12 months after undergoing PSG, and information regarding the treatment was collected. Subjects were divided into a surgical and non-surgical group depending on the treatment they received. The surgical group was patients who receive any upper airway surgery to correct OSA, including TA, nasal surgery, pharyngeal surgery, lingual tonsillectomy, supraglottoplasty, and tracheostomy. The non-surgical group was patients who did not receive surgical treatment.

Statistics

PASW Statistics version 18.0 (SPSS Inc., Chicago, IL) was used for statistical analysis. Independent sample t-test and Chi-Square test were used to compare continuous and categorical variables, respectively. Univariate logistic regression was used to select related variables, and the factors were pooled into multivariate regressions to further identify significant factors by a backward elimination process. A P-value of < 0.05 was considered statistically significant.

Results

Three hundred and eighty patients were included in this study; consisting of 250 males and 130 females. The mean age was 8.72 ± 3.78 years. The surgical group was significantly younger than the non-surgical group (7.14 ± 3.12 vs. 9.75 ± 3.83 years, p<0.001). Overweight was present among 61 patients (16.1%), while 143 patients (37.7%) were obese. Almost all children (97.1%) had snoring symptoms. All of the children (100%) in the surgical group had snoring symptoms. The surgical group had more clinical symptoms of snoring, apnea, and struggle than the non-surgical group (p<0.05). In terms of underlying disease, the non-surgical group had significantly more underlying diseases than the surgical group, especially neuromuscular disease (0 vs. 18.3%, p<0.001). The majority of the surgical group had tonsillar hypertrophy (3+/4+) compare with the non-surgical group (81.1% vs. 25.7%, p<0.001). The mean adenoidal nasopharyngeal ratio (ANR) of the surgical group was also significantly higher than the non-surgical group (0.71 ± 0.15 vs. 0.61 ± 0.15, p<0.001). The baseline demographic and clinical characteristics of the patients were presented in **Table 1**.

Table 1. Baseline Demographic and Clinical Characteristics (n = 380)

Factors	Total (n=380)	Surgery (n=150)	Non-surgery (n=230)	p-value*
Age, mean ± SD, years	8.72 ± 3.78	7.14 ± 3.12	9.75 ± 3.83	**<0.001**
Age, n (%)				**<0.001**
2 to 5 years	83 (21.8)	52 (34.7)	31 (13.4)	
>5 to 12 years	219 (57.7)	85 (56.7)	134 (58.3)	
> 12 years	78 (20.5)	13 (8.6)	65 (28.3)	
Sex: Male, n (%)	250 (65.8)	102 (68.0)	148 (64.3)	0.463
BMI, mean ± SD, kg/m^2	21.41 ± 7.83	20.32 ± 6.68	22.13 ± 8.43	**0.021**
Nutritional status, n (%)[a]				0.203
Obesity (>+2SD)	143 (37.7)	57 (38)	86 (37.6)	
Overweight (+1SD to+2SD)	61 (16.1)	19 (12.7)	42 (18.3)	
Normal (-2SD to +1SD)	151 (39.8)	68 (45.3)	83 (36.2)	
Underweight (<-2SD)	24 (6.3)	6 (4.0)	18 (7.9)	
Missing data	1 (0.3)			

Factors	Total (n=380)	Surgery (n=150)	Non-surgery (n=230)	p-value*
Clinical symptoms				
Snoring	369 (97.1)	150 (100.0)	219 (95.2)	**0.004**
Apnea	83 (21.8)	47 (31.3)	36 (15.7)	**<0.001**
Struggle	94 (24.7)	51 (34.0)	43 (18.7)	**0.001**
Awake by shaking	6 (1.6)	2 (1.3)	4 (1.7)	1.000
Underlying disease, n (%)[b]	217 (57.1)	69 (46.0)	148 (64.3)	**<0.001**
Down syndrome	18 (4.7)	7 (4.7)	11 (4.8)	1.000
Craniofacial syndrome	25 (6.6)	8 (5.3)	17 (7.4)	0.528
Psychiatric disorders	14 (3.7)	4 (2.7)	10 (4.3)	0.425
Neuromuscular disease	42 (11.1)	0 (0.0)	42 (18.3)	**<0.001**
ADHD	27 (7.1)	11 (7.3)	16 (7.0)	1.000
Hematologic disease	9 (2.4)	7 (4.7)	2 (0.9)	**0.032**
Heart disease	17 (4.5)	5 (3.3)	12 (5.2)	0.455
Asthma	27 (7.1)	10 (6.7)	17 (7.4)	0.841
Chronic rhinitis	152 (40.6)	58 (39)	94 (41.8)	0.249
Others	62 (16.3)	19 (12.7)	43 (18.7)	0.155
Nasal examination, n (%)				
Normal	315 (85.8)	126 (85.7)	189 (85.9)	0.958
Congest	52 (14.2)	21 (14.3)	31 (14.1)	
Tonsil size, n (%)				
1+ and 2+	199 (52.6)	28 (18.9)	171 (74.3)	**<0.001**
3+ and 4+	179 (47.4)	120 (81.1)	59 (25.7)	
ANR[c], mean ± SD	0.66 ± 0.15	0.71 ± 0.15	0.61 ± 0.15	**<0.001**

Abbreviations: BMI, body mass index; SD, standard deviation; ADHD, attention deficit hyperactivity disorder; ANR, adenoidal nasopharyngeal ratio.

[a]Nutritional status was defined by BMI z-score. Thinness, BMI z-score < -2 SD; normal weight, BMI z-score –2 SD to +1 SD; overweight, BMI z-score +1 SD to +2 SD; obesity, BMI z-score > + 2 SD.[22]

[b]One patient may have many diseases.

[c]ANR was calculated in 271 patients who underwent lateral skull X-ray.

*P-value was calculated by unpaired t-test, Mann-Whitney U test for continuous data, and chi-square test for categorical data. Bold values indicate statistical significance.

Among 150 patients in the surgical group, the most common operation was TA (87.33%), followed by tonsillectomy (8%), and TA with the combination of pharyngeal or tongue base surgery (1.99%). The details of the operation were presented in **Table 2**.

Table2. Types of the operation in surgical group (n=150).

Types of the operation	n (%)
TA	131 (87.3)
Tonsillectomy	12 (8.0)
TA and lateral pharyngoplasty	2 (1.3)
TA + Modified UPPP + RFVTR base of tongue	1 (0.7)
Adenoidectomy	1 (0.7)
RFVTR inferior turbinate	1 (0.7)
Lingual tonsillectomy	1 (0.7)
Supraglottoplasty	1 (0.7)

Abbreviations: TA, adenotonsililectomy; UPPP, uvulopalatopharyngoplasty; RFVTR, radiofrequency volumetric tissue reduction.

The parameters obtained from PSG were compared between the surgical and non-surgical groups. In terms of sleep architecture, the surgical group had a significant increase in total sleep time, sleep stage N3, and REM (P<0.05), but had a significant reduction in sleep stage N2 (P<0.05) compared to the non-surgical group. In terms of respiratory parameters, there was a significant increase in the AHI, obstructive AHI, apnea index, hypopnea index, the longest time of apnea and hypopnea, mean oxygen saturation, oxygen desaturation index and the total arousal index in surgical group compared to non-surgical group (P<0.05). The details of PSG parameters were presented in **Table 3**.

Table3. Comparison of the PSG parameters between surgical and non-surgical group (n=380)

PSG parameter	Total (n=380)	Surgery (n=150)	Non-surgery (n=230)	p-value*
TST, mean ± SD, min	394.63 ± 74.32	405.28 ± 54.49	387.69 ± 84.18	**0.014**
SE, mean ± SD, %	86.61 ± 11.40	87.63 ± 10.11	85.94 ± 12.15	0.157
SL, median (range), min	11.33 (0.00, 184.30)	11.10 (0.00, 140.24)	11.72 (0.00, 184.28)	0.948

PSG parameter	Total (n=380)	Surgery (n=150)	Non-surgery (n=230)	p-value*
REM latency, mean ± SD, min	166.57 ± 74.79	159.28 ± 75.04	171.45 ± 74.39	0.126
Stage N1, mean ± SD, %	6.80 ± 7.08	6.16 ± 6.13	7.22 ± 7.63	0.153
Stage N2, mean ± SD, %	47.40 ± 11.71	43.50 ± 12.18	49.95 ± 10.68	**<0.001**
Stage N3, mean ± SD, %	29.88 ± 11.99	32.72 ± 12.62	28.02 ± 11.21	**<0.001**
Stage R, mean ± SD, %	15.47 ± 6.48	16.96 ± 6.25	14.50 ± 6.46	**<0.001**
AHI[a], median (range), events/h	7.60 (0.00, 110.60)	10.40 (0.10, 77.30)	5.70 (0.00, 110.60)	**<0.001**
Normal				**<0.001**
Mild	9 (2.4)	1 (0.7)	8 (3.5)	
Moderate	110 (28.9)	24 (16.0)	86 (37.4)	
Severe	120 (31.6)	47 (31.3)	73 (31.7)	
	141 (37.1)	78 (52.0)	78 (52.0)	
OAHI[a], median (range), events/h	7.30 (0.00, 110.60)	9.45 (0.10, 77.30)	5.90 (0.00, 110.6)	**<0.001**
Normal				**0.001**
Mild	11 (2.9)	2 (1.3)	9 (3.9)	
Moderate	117 (30.8)	32 (21.3)	85 (37.0)	
Severe	111 (29.2)	44 (29.3)	67 (29.1)	
	141 (37.1)	72 (48.0)	69 (30.0)	
CAI[a], median (range), events/h	0.10 (0.00, 78.80)	0.10 (0.00, 6.90)	0.05 (0.00, 78.80)	0.054
Normal				0.058
Mild	320 (84.2)	120 (80.0)	200 (87.0)	
Moderate	56 (14.7)	28 (18.7)	28 (12.2)	
Severe	2 (0.5)	2 (1.3)	0 (0.0)	
	2 (0.5)	0 (0.0)	2 (0.9)	
AI, median (range), events/h	0.45 (0.00, 46.50)	0.90 (0.00, 30.90)	0.30 (0.00, 46.50)	**<0.001**
HI, median (range), events/h	6.85 (0.00, 77.60)	8.80 (0.10, 66.80)	5.40 (0.00, 77.60)	**<0.001**
Mean time of apnea, median (range), sec	11.60 (0.00, 55.70)	11.60 (0.00, 55.70)	11.50 (0.00, 40.60)	0.486
Longest time of apnea, median (range), sec	14.00 (0.00, 137.00)	15.00 (0.00, 137.00)	14.00 (0.00, 74.00)	**0.031**
Mean time of hypopnea, mean ± SD, sec	20.20 ± 5.95	20.33 ± 5.52	20.12 ± 6.22	0.740
Longest time of hypopnea, mean ± SD, sec	52.57 ± 25.70	57.38 ± 26.34	49.43 ± 24.84	**0.003**
Mean SpO_2, mean ± SD, %	96.66 ± 1.93	96.90 ± 1.34	96.50 ± 2.22	**0.029**
Min SpO_2, mean ± SD, %	85.37 ± 10.39	84.19 ± 9.83	86.14 ± 10.69	0.074
ODI, median (range), events/h	3.76 (0.00, 98.00)	5.52 (0.00, 66.80)	3.10 (0.00, 98.00)	**0.002**
Total arousal index, median (range), events/h	9.80 (0.00, 76.40)	11.85 (3.20, 63.40)	8.85 (0.00, 76.40)	**<0.001**

Abbreviations: TST, total sleep time; SE, sleep efficiency; REM, rapid eye movement; Mean SpO2, mean oxygen saturation; Min SpO2, minimum oxygen saturation; SL, sleep latency; AHI, apnea hypopnea index; OAHI, obstructive apnea hypopnea index; CAI, central apnea index; AI, apnea index; HI, hypopnea index; ODI, oxygen desaturation index.

[a]AHI, OAHI, and CAI severity were classified as normal, mild, moderate, and severe by using cut-off at less than 1.0, 1.0 to 4.9, 5.0 to 9.9, and equal or more than 10.0 events/h, respectively.

*P-value was calculated by unpaired t-test and Mann-Whitney U test. Bold values indicate statistical significance.

The logistic regression of predicting variables for the final surgical decision was presented in **Table 4**. In univariate analysis, younger age, apnea, struggling symptoms, tonsil size 3+ and 4+, OAHI ≥ 5 events/h, ODI ≥ 5 events/h, and total arousal index ≥ 10 events/h were identified as significant risk factors for surgical treatment. However, in multivariate analysis, age 2-5 years (OR=5.22, 95% CI: 1.97–13.83, P=0.001), tonsil size 3+ and 4+ (OR=14.91, 95% CI: 8.02–27.73, P<0.001), OAHI 5-9.9/h (OR = 3.03, 95% CI: 1.40–6.54, P=0.017), and OAHI ≥ 10/h (OR=2.60, 95% CI: 1.02–6.60, P=0.017) were significant risk factors for surgical treatment.

Table 4. Logistic regression for the factors influencing the surgical decision.

Factor	Univariable analysis		Multivariable analysis	
	Unadjusted odds ratio (95% CI)	p-value*	Adjusted odds ratio (95% CI)	p-value**
Age (years)		**<0.001**		**0.001**
2 – 5	8.39 (3.99, 17.64)		5.22 (1.97, 13.83)	
>5 – 12	3.17 (1.65, 6.10)		1.83 (0.78, 4.26)	
>12	1.00		1.00	
Nutritional status, n (%)[a]		0.203		0.059
Obesity (>+2SD)	143 (37.7)		86 (37.6)	
Overweight(+1SD - +2SD)	61 (16.1)		42 (18.3)	
Normal (-2SD - +1SD)	151 (39.8)		83 (36.2)	
Underweight (<-2SD)	24 (6.3)		18 (7.9)	
Missing data	1 (0.3)			
Apnea	2.46 (1.50, 4.04)	**<0.001**	2.15 (0.99, 4.63)	0.052
Struggle	2.24 (1.40, 3.60)	**0.001**	1.63 (0.77, 3.44)	0.199
Tonsil size		**<0.001**		**<0.001**

1+ and 2+	1.00		1.00	
3+ and 4+	12.42 (7.48, 20.62)		14.91 (8.02, 27.73)	
OAHI		**<0.001**		**0.017**
< 5 events/h	1.00		1.00	
5 – 9.9 events/h	1.82 (1.05, 3.14)		3.03 (1.40, 6.54)	
≥ 10 events/h	2.89 (1.73, 4.82)		2.60 (1.02, 6.60)	
AI ≥ 1 events/h	2.45 (1.59, 3.77)	**<0.001**	-	-
AI ≥ 5 events/h	2.21 (1.09, 4.46)	**0.030**	-	-
HI ≥ 5 events/h	2.71 (1.71, 4.29)	**<0.001**	-	-
Min SpO_2	1.13 (0.99, 1.29)	0.053	1.00 (0.97, 1.03)	0.871
ODI ≥ 5 events/h	1.85 (1.21, 2.81)	**0.004**	0.54 (0.26, 1.13)	0.100
Total arousal index ≥ 10 events/h	2.09 (1.38, 3.18)	**0.001**	0.65 (0.34, 1.26)	0.205

Abbreviations: CI: confidence interval; OAHI, obstructive apnea hypopnea index; AI, apnea index; HI, hypopnea index; Min SpO2, minimum oxygen saturation; ODI, oxygen desaturation index.

*P-value was calculated by univariate logistic regression

**P-value was calculated by multivariate logistic regression. Only significant variables were taken into multivariate logistic regression and shown in the table. AI ≥ 1, AI ≥ 5, HI ≥ 5 events/h were not included in multivariate analysis because these parameters were included in OAHI.

Bold values indicate statistical significance.

Discussion

This study demonstrated the risk factors for surgical decisions in children with SDB who underwent PSG. The predictive factors for surgical decision in our study included age 2-5 years, tonsil size 3+ and 4+, and OAHI ≥ 5 events/h. All of the factors were consistent with previously published reports.[14]

Age has long been recognized as an important factor in the development and management of SDB, as well as the revision of TA and residual SDB. However, Bhattacharjee et al. concluded that residual disease is present in a large proportion of children after TA, particularly among older (age > 7 years) or obese children.[24] In our study, children with age 2-5 years were determined to be more likely to receive surgery, as compared with the older age group. This result was consistent with previous studies that TA was more commonly observed in younger children [25] and the incidence of SDB significantly decreased with children's age.[26]

As we know that tonsil size is one of the most clinically relevant parameters for diagnosing OSA in children. In our study,

tonsil size 3+ and 4+ had a significant influence on the final surgical decision. The previous study also concluded that tonsil size is one of the most significant parameters for diagnosing OSA, in comparison to a PSG and correlation with AHI.[27] In our center, SDB children with comorbidities, discordance between history and physical examination, or caregivers' preference undergo PSG before TA according to the AAO-HNS guidelines.[10,11] Otherwise normal children with adenotonsillar hypertrophy can undergo TA without preoperative PSG if the caregivers agree with the treatment plan.

Despite the most important PSG parameter for treatment decisions whether the patients should undergo surgery being AHI, other PSG parameters should be used for decision planning as well. In this study, the respiratory parameters including the percentage of sleep stages, AHI, OAHI, and mean SpO2 were significantly different between the surgical and non-surgical groups, with higher severity in the surgery group. After multivariate analysis, OAHI ≥ 5 events/h was considered significant for surgical decisions. This finding might be related to the previous publication that this AHI cut-off value has been associated with substantial increases in the risk of cardiovascular and cognitive morbidities.[28-30]

In addition, we found that the total sleep time, percentage of stage N3 (deep sleep), and percentage of stage REM were substantially higher in the surgery group. However, these results were different from the previously published literature stating that sleep architecture was globally preserved in children with OSA.[31] The reason might because the previous literature compared the sleep architecture between children with OSA and control group, while we compared the sleep parameters between the surgical and non-surgical groups. However, most of our patients in both surgical and non-surgical group were diagnosed with OSA, with more severe disease in the surgical group. The longest time of hypopnea and the longest time of apnea showed a significantly higher in the surgical group, which is correlated with the previous study that the patients with OSA with long average duration were found to have more negative effects of sleep apnea than the patients with short average duration.[32] Among the parameters of oxygen saturation, only mean SpO_2 and ODI were proved to be significantly different between surgical and non-surgical groups in this study.

Tsai et al. reported that the desaturation index had the highest correlation with AHI and may be a good tool for predicting both the presence and the severity of OSA in children.[33]

This study has some potential limitations. First, this study was done in a tertiary care hospital. So, the patient population may not represent the patients in primary care hospitals in other parts of Thailand. Second, we included only patients with SDB who underwent PSG in our hospital. In addition, several patients who underwent surgery without preoperative PSG were not included. Third, the data were retrospectively reviewed. The treatment decision for each patient was already done and we tried to find the potential risk factors for the previous decision. So, this research may have a selection bias.

Conclusion

Both clinical and PSG parameters should be taken into consideration in the treatment decision for pediatric patients with SDB, especially age, tonsils size, and obstructive AHI. The integration of this information would be useful for decision planning on whether patients should undergo surgical treatment. However, a prospective multicenter study with a larger sample size to create comprehensive care for patients with SDB is needed in the future.

Data availability statement

The datasets presented in this article are not readily available because no potentially identifiable data was provided. Requests to access the datasets should be directed to archwin.tan@mahidol.ac.th.

Acknowledgment

The authors gratefully acknowledge Julaporn Pooliam of the Division of Clinical Epidemiology, Department of Health Research and Development, Faculty of Medicine Siriraj Hospital, Mahidol University for her assistance with sample size calculation and statistical analysis, and Jeerapa Kerdnoppakhun, Ngamrat Treerassapanich, and Chutima Polsrimueng of the Department of Otorhinolaryngology, Faculty of Medicine Siriraj Hospital for secretarial support.

References

1. Wakefield TL LD, Ishman SL. Sleep Apnea and Sleep Disorders. Cummings Otolaryngology–Head & Neck Surgery. 6th Philadelphia, PA: Saunders Elsevier2015. p. 252-72.

2. Marcus CL, Brooks LJ, Draper KA, et al. Diagnosis and management of childhood obstructive sleep apnea syndrome. Pediatrics. 2012;130(3):576-84.

3. Anuntaseree W, Rookkapan K, Kuasirikul S, et al. Snoring and obstructive sleep apnea in Thai school-age children: prevalence and predisposing factors. Pediatr Pulmonol. 2001;32(3):222-7.

4. Sritipsukho P KP, Satdhabudha A, Tanakitivirul N. Sleep Disordered Breathing in Thai Primary School Children. J Med Assoc Thai 2017.100(6):175.

5. Veeravigrom M, Desudchit T. Prevalence of Sleep Disorders in Thai Children. Indian J Pediatr. 2016;83(11):1237-41.

6. Halbower AC, Degaonkar M, Barker PB, et al. Childhood obstructive sleep apnea associates with neuropsychological deficits and neuronal brain injury. PLoS Med. 2006;3(8):e301.

7. Castronovo V, Zucconi M, Nosetti L, et al. Prevalence of habitual snoring and sleep-disordered breathing in preschool-aged children in an Italian community. J Pediatr. 2003;142(4):377-82.

8. Xu Z-f, Shen K-l. The epidemiology of snoring and obstructive sleep apnea/hypopnea in Mainland China. Biol Rhythm Res. 2010;41(3):225-33.

9. Bitners AC, Arens R. Evaluation and Management of Children with Obstructive Sleep Apnea Syndrome. Lung. 2020;198(2):257-70.

10. Mitchell RB, Archer SM, Ishman SL, et al. Clinical Practice Guideline: Tonsillectomy in Children (Update). Otolaryngol Head Neck Surg. 2019;160(1_suppl):S1-s42.

11. Roland PS, Rosenfeld RM, Brooks LJ, et al. Clinical practice guideline: Polysomnography for sleep-disordered breathing prior to tonsillectomy in children. Otolaryngol Head Neck Surg. 2011;145(1 Suppl):S1-15.

12. Sulman CG. Pediatric sleep surgery. Frontiers in pediatrics. 2014;2:51.

13. Erickson BK, Larson DR, St Sauver JL, et al. Changes in incidence and indications of tonsillectomy and adenotonsillectomy, 1970-2005. Otolaryngol Head Neck Surg. 2009;140(6):894-901.

14. Zhao G, Li Y, Wang X, et al. The predictive value of polysomnography combined

with quality of life for treatment decision of children with habitual snoring related to adenotonsillar hypertrophy. Eur Arch Otorhinolaryngol. 2018;275(6):1579-86.

15. Garetz SL, Mitchell RB, Parker PD, et al. Quality of life and obstructive sleep apnea symptoms after pediatric adenotonsillectomy. Pediatrics. 2015;135(2):e477-86.

16. Marcus CL, Moore RH, Rosen CL, et al. A randomized trial of adenotonsillectomy for childhood sleep apnea. N Engl J Med. 2013;368(25):2366-76.

17. Chervin RD, Ellenberg SS, Hou X, et al. Prognosis for Spontaneous Resolution of OSA in Children. Chest. 2015;148(5):1204-13.

18. Weatherly RA, Mai EF, Ruzicka DL, et al. Identification and evaluation of obstructive sleep apnea prior to adenotonsillectomy in children: a survey of practice patterns. Sleep Med. 2003;4(4):297-307.

19. Liu JF, Tsai CM, Su MC, et al. Application of desaturation index in post-surgery follow-up in children with obstructive sleep apnea syndrome. Eur Arch Otorhinolaryngol. 2017;274(1):375-82.

20. Berry RB, Budhiraja R, Gottlieb DJ, et al. Rules for scoring respiratory events in sleep: update of the 2007 AASM Manual for the Scoring of Sleep and Associated Events. Deliberations of the Sleep Apnea Definitions Task Force of the American Academy of Sleep Medicine. J Clin Sleep Med. 2012;8(5):597-619.

21. Montgomery-Downs HE, O'Brien LM, Holbrook CR, et al. Snoring and sleep-disordered breathing in young children: subjective and objective correlates. Sleep. 2004;27(1):87-94.

22. de Onis M, Onyango AW, Borghi E, et al. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;85(9):660-7.

23. Brodsky L. Modern assessment of tonsils and adenoids. Pediatr Clin North Am. 1989;36(6):1551-69.

24. Bhattacharjee R, Kheirandish-Gozal L, Spruyt K, et al. Adenotonsillectomy outcomes in treatment of obstructive sleep apnea in children: a multicenter retrospective study. Am J Respir Crit Care Med. 2010;182(5):676-83.

25. Gates GA. Sizing Up the Adenoid. Archives of Otolaryngology–Head & Neck Surgery. 1996;122(3):239-40.

26. Guo Y, Pan Z, Gao F, et al. Characteristics and risk factors of children with sleep-disordered breathing in Wuxi, China. BMC Pediatr. 2020;20(1):310.

27. Kljajic Z, Glumac S, Deutsch JA, et al. Feasibility study of determining a risk

assessment model for obstructive sleep apnea in children based on local findings and clinical indicators. Int J Pediatr Otorhinolaryngol. 2020;135:110081.

28. Hunter SJ, Gozal D, Smith DL, et al. Effect of Sleep-disordered Breathing Severity on Cognitive Performance Measures in a Large Community Cohort of Young School-aged Children. Am J Respir Crit Care Med. 2016;194(6):739-47.

29. Amin R, Somers VK, McConnell K, et al. Activity-adjusted 24-hour ambulatory blood pressure and cardiac remodeling in children with sleep disordered breathing. Hypertension. 2008;51(1):84-91.

30. Lau EY, Choi EW, Lai ES, et al. Working memory impairment and its associated sleep-related respiratory parameters in children with obstructive sleep apnea. Sleep Med. 2015;16(9):1109-15.

31. Goh DY, Galster P, Marcus CL. Sleep architecture and respiratory disturbances in children with obstructive sleep apnea. Am J Respir Crit Care Med. 2000;162(2 Pt 1):682-6.

32. Saraç S, Afsar GC. Effect of mean apnea-hypopnea duration in patients with obstructive sleep apnea on clinical and polysomnography parameter. Sleep & breathing = Schlaf & Atmung. 2020;24(1):77-81.

33. Tsai CM, Kang CH, Su MC, et al. Usefulness of desaturation index for the assessment of obstructive sleep apnea syndrome in children. Int J Pediatr Otorhinolaryngol. 2013;77(8):1286-90.