



Obstructive hypopnea and gastroesophageal reflux as factors associated with residual obstructive sleep apnea syndrome

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ABSTRACT

Objective: The mechanism of persisting obstructive sleep apnea (OSA) after adenotonsillectomy is not fully explained. The purpose of this study was to evaluate factors associated with residual OSA. The primary outcome measures were metabolic tests and polysomnographic respiratory indices in children with residual disease compared with children who were diagnosed with OSA but were untreated. Secondary outcome measures were acid gastroesophageal reflux indices recorded parallel to the sleep study.

Methods: In the one-year study consecutive series of patients with sleep disordered breathing hospitalized in a tertiary pediatric center were evaluated. Following the study protocol a sleep interview, physical examination, metabolic blood tests (serum leptin and the homeostasis model assessment index for insulin resistance, HOMA-IR) and an overnight polysomnography with pH-metry recording were performed. Children diagnosed with OSA were analyzed in two groups: I – residual OSA (after surgery), II – non-residual OSA (newly diagnosed). Logistic regression analysis was applied to obtain significant risk factors for prediction of OSA.

Results: Fifty-seven children (mean age \pm SE, 6.9 ± 0.5 years; 66.7% boys) met the inclusion criteria and were enrolled in the study as residual ($n = 19$) or non-residual OSA ($n = 38$). The groups differed significantly in mean oxygen saturation, SpO₂ (94.3% vs. 96.2%; $p = 0.018$ respectively), in the Apnea Hypopnea Index, (20.6/h vs. 9.1/h; $p < 0.03$), the number of respiratory arousals with desaturation (2.2/h vs. 0.8/h; $p < 0.03$); mean intraluminal esophageal pH (5.36 vs. 5.86; $p = 0.007$) and the Reflux Index (9.61% vs. 4.35%; $p = 0.003$). The groups did not differ in total sleep time, tonsil size, BMI z-score and blood metabolic indices. Logistic regression analysis showed that residual OSA was significantly predicted by two polygraphic findings: the obstructive hypopnea index (OR 1.15; 95% CI 1.02–1.28; $p = 0.014$) and by the Reflux Index (OR 1.01; 95% CI 1.00–1.34; $p = 0.042$).

Conclusions: 1. Obstructive hypopneas, rather than obstructive apneas, persist after adenotonsillar surgery resulting in residual OSA. 2. Children with residual OSA are at higher risk of acid gastroesophageal reflux and should be evaluated for gastroesophageal reflux disease.

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1. Introduction

Obstructive sleep-disordered breathing (SDB) in childhood is due to a combination of high upper airway resistance and increased pharyngeal collapsibility leading to intermittent partial or complete upper airway obstruction during sleep [1]. Obstructive sleep apnea (OSA) occurs in approximately 3% of children, most frequently aged from 2 to 6 years [2]. Recurrent episodes of airflow cessation, oxygen desaturation, and sleep disruption are associated

with behavior disorders, neurocognitive deficits, disturbances of somatic development as well as cardiovascular and metabolic sequelae [3,4].

The etiology of OSA is multifactorial consisting of a complex interplay between airway anatomical characteristics and dynamic control of upper airway muscular tone [5,6]. Obstructive sleep apnea is hypothesized to be influenced by genes within pathways involved with obesity, craniofacial development, inflammation, and ventilatory control [7]. In children the most frequent cause of OSA is oversized tonsils and adenoids, therefore adenotonsillectomy (AT) is the first-line surgical treatment for obstructive sleep apnea. The views of experts on the surgical removal of the tonsils and adenoids vary. A tonsillectomy, especially in young children, should be considered carefully because the tonsils are thought to play a role in

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the mucosal immunity of the upper respiratory tract [8,9]. On the other hand, delay in the surgery may result in secondary complications.

Since the monitoring of children after an adenotonsillectomy is recommended as standard procedure there is now more information about the long-term results of treatment [2,3]. Success rates are likely lower than previously estimated and its efficacy in operated children is currently estimated at 27.2–82.9% by various authors [2,3,10]. This means residual disease may be present in a large proportion of children after AT. The mechanism of persisting OSA after surgical treatment is not fully understood [11].

Obesity at the time of diagnosis, the severity of the initial disease, complications related to OSA, a positive family history of OSA, a patient's age > 7 years, or comorbidities such as chronic asthma are the major risks for residual obstructive sleep apnea reported by various authors [2,3,12]. In previous studies acidification of the distal esophagus was also suggested in the mechanism of OSA in children and adults and in the mechanism of residual OSA in children under 2 years old [13–16]. However, the role of gastroesophageal reflux in residual OSA among children over 2 years of age is unclear.

The objective of this study was to evaluate factors associated with residual OSA taking into account metabolic indices, polysomnography, and pH-metry characteristics. We compared the severity of the residual disease with the severity of newly diagnosed obstructive sleep apnea. The primary outcome measures were metabolic tests and polysomnographic findings in post AT children and in those not treated with newly diagnosed OSA. Secondary outcome measures were indices of acid gastroesophageal reflux recorded parallel to polysomnography.

2. Methods

2.1. Participants

The one-year study included 69 consecutive children (40 boys, 58.0%) with a history of sleep-disordered breathing (SDB) hospitalized between September 2008 and August 2009 in a tertiary pediatric medical center. The patients ranged in age from 2 to 16 years (mean 6.1 ± 1.4 years). The study protocol included a clinical evaluation (sleep questionnaire and physical examination), metabolic blood tests (serum leptin and the homeostasis model assessment index for insulin resistance, HOMA-IR) and an overnight polysomnography with pH-metry recording (Fig. 1). A standard sleep questionnaire by one of the two authors (JW and MK) was completed. Difficulty breathing, apnea during sleep, or snoring for the last 3 months and an obstructive sleep apnea score > 3.5 points calculated on the basis of the above, as described by Brouillette et al., were accepted as a screening of OSA and as an indication for polysomnography [17]. Obstructive sleep apnea confirmed in polysomnography was the entry criterion for this study. Depending on the treatment history the patients were divided to one of two groups: I group – residual OSA, persisting after adenotonsillectomy, II group – newly diagnosed OSA with no surgical treatment. Details of the adenotonsillectomies were noted from patient histories during their stay at the pediatric laryngology ward. Children with only tonsillectomies were excluded.

Total sleep time was calculated as the sum of naps and nocturnal sleep time (calculated as the difference between the time of falling asleep and the hour of waking) taken from the 14-day sleep questionnaire. Total sleep time was expressed in hours and percentiles based on the centile chart compiled by Iglowstein et al. [18]. Tonsil size was graded from 0 to 4+ according to the Brodsky scale [19]. Body mass index, BMI (weight in kilograms divided by height in meters squared), was calculated and in conjunction with Polish reference values was expressed as a BMI z-

score. Children with BMI z-score values above 1.65 (>95th percentile) were classified as obese [20]. Neck circumference was also compared between children diagnosed with residual and non-residual OSA. A validated automatic oscillometric method of blood pressure measurement, along with an appropriate pediatric cuff size, was used to obtain three blood pressure measurements (at 5 p.m., 9 p.m. and 6 a.m.) from which an average was calculated [21].

Genetic, metabolic, neurological, endocrine, and acute or chronic infectious diseases were exclusion criteria. Twelve children were excluded from the study (17.4%): five children with primary snoring were diagnosed on the basis of a normal polysomnographic result (an OSA score > 3.5 in these children was considered false positive and accounted for 7.2% of the studied patients), three children had a unilateral tonsillectomy, two children had concomitant urinary tract diseases, one child had a concomitant acute *Helicobacter pylori* infection and thrombocytopenia, and one child was diagnosed with Prader Willi Syndrome.

2.2. Polysomnography and 24-h pH-metry

Overnight polysomnography (Alice 4, Respironics, USA), in addition to a 24-h pH probe (single channel), was performed at the pediatric sleep laboratory. Throughout the test the child was accompanied by a parent and trained personnel constantly supervised the test. Parameters were recorded from the following registrations: electroencephalogram (C3/A2, C4/A1, O1/A2), bilateral electro-oculogram (LEOG, REOG), chin electromyogram (EMG), nasal and oral airflow detected using a thermistor (FLW), chest and abdominal wall movement by respiratory impedance (THO, ABD, Imp), heart rate by electrocardiogram (ECG), oxygen saturation of hemoglobin (SpO₂) assessed by pulse oximetry with simultaneous recording of pulse wave form (PLR), body position (body), actimeter and a digital time-synchronized video recording. All measures were digitized using a commercially available polysomnography system. Sleep studies were interpreted according to standard pediatric criteria [22–24]. Obstructive apnea was defined as the absence of airflow with continued chest and abdominal wall movement for a duration of at least two breaths [25]. Hypopnea was defined as a reduction in the airflow signal amplitude of at least 50% compared to baseline in the presence of chest/abdominal wall motion and associated with oxygen desaturation of hemoglobin equal to or greater than 4%, or with an EEG arousal [22]. The obstructive apnea hypopnea index (oAHI) was defined as the number of obstructive apneas and hypopnea events per hour of total sleep time (TST); oAHI greater than one was the diagnostic criterion of OSA [26]. Mean SpO₂, the SpO₂ nadir, and the oxygen desaturation index (events per hour of sleep) were recorded. Arousals were defined as recommended by the American Sleep Disorders Association Task Force report. Respiratory-related arousals (occurring immediately after apnea, hypopnea, or snoring) were expressed as the total number of arousals per hour of sleep time [23].

Twenty-four-hour pH-metry was performed (patients did not take any medications for at least 5 days prior). A pH antimony electrode was introduced through the nose and the tip was sited at 87% of the distance from the nares to the lower esophageal sphincter. The reference electrode was attached to the anterior chest wall. The acid gastroesophageal reflux index (RI), which represents the proportion of the total time of the recording for which the esophageal pH was less than 4.0, was calculated and expressed as a percentage value. RI > 7% was the cut-off value for the diagnosis of acid gastroesophageal reflux [27]. The lowest values of pH, lasting at least 5 s during wakefulness and during sleep, were noted for each patient.

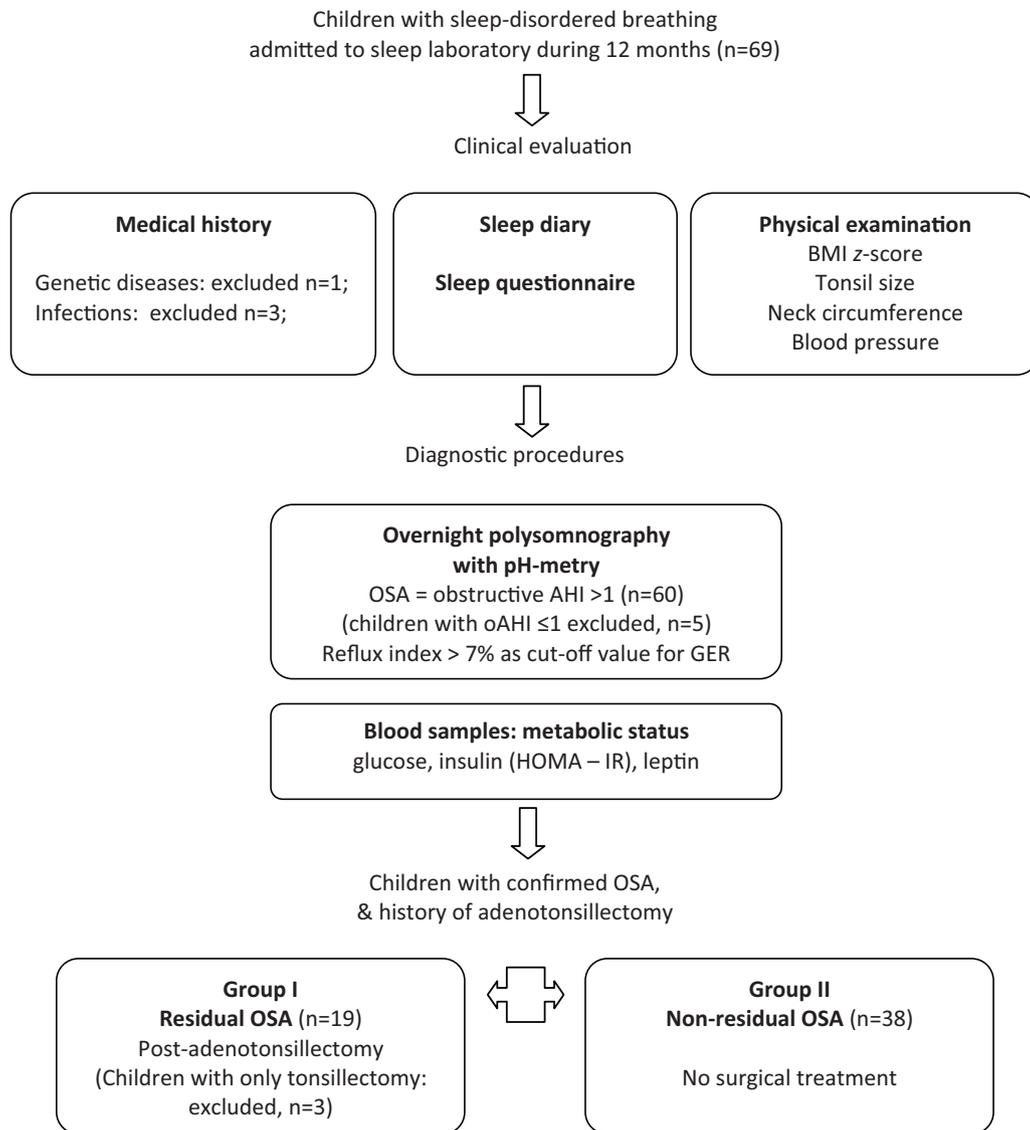


Fig. 1. Study design. OSA, obstructive sleep apnea; AHI, apnea hypopnea index; BMI, body mass index and HOMA-IR, homeostasis model assessment index for insulin resistance.

2.3. Assays

Serum samples were obtained from all children the morning after their diagnostic polysomnograms. Blood samples obtained after an overnight fast were centrifuged immediately after collection and stored frozen at -80°C until assayed. Insulin resistance was measured in all subjects to identify a subgroup of children diagnosed with OSA with obesity-associated metabolic alternations, referred to by Capdevila et al. as “OSA type II” [28]. Fasting plasma glucose was measured by the glucose oxidase method and serum insulin was measured by radioimmunoassay. Insulin resistance was determined using the HOMA method. The homeostasis model assessment index for insulin resistance (HOMA-IR) was calculated as fasting insulin (mU/liter) multiplied by fasting glucose (mmol/liter) divided by 22.5. HOMA-IR of ≥ 2.5 was accepted as abnormal. Serum leptin, a protein produced by fat cells and involved in regulating food intake and fat storage in the body, was measured with the Human Leptin Immunoassay kit (R&D Systems Inc., USA; minimum detectable dose – 0.0078 ng/ml, intra-assay CV < 3.3%, inter-assay CV < 5.4%).

This study protocol followed ethical guidelines and was approved by the Bioethics Committee of the Medical University of Białystok (R-I-002/154/2008). Informed consent was obtained from the parents prior to participation.

2.4. Statistical analysis

The Student’s *t*-test was applied to compare continuous variables of a normal distribution, the Mann–Whitney *U*-test to compare variables of non-parametric distribution, and the Shapiro–Wilk test to verify the statistical shape of the tested variable distribution. The chi-square (χ^2) test for independence was applied to compare the qualitative and categorized variables. Correlation between variables was assessed using Spearman coefficient correlations. For the analysis of qualitative and quantitative variables that determine residual OSA (dichotomous variable), the logistic regression model was used. Residual OSA (Y) was coded as follows: 1 – residual OSA-positive and 0 – residual OSA-negative. Two-tailed probability values of less than 0.05 were considered significant. Analyses were performed with StatSoft (STATISTICA Data Analysis Software System, Version 9.0, www.statsoft.com).

Table 1
Baseline characteristics of the study participants.

Characteristics	Residual OSA (n = 19)	Non-residual OSA (n = 38)	p Value
Age, years	8.31 (0.92)	6.92 (0.66)	0.082 ^a
Gender, male no. (%)	12 (63.2)	26 (68.4)	0.920 ^b
Tonsil size			
Grade 1, no. (%)	4 (21.1)	10 (26.3)	
Grade 2, no. (%)	10 (52.6)	17 (44.7)	0.814 ^b
Grade 3, no. (%)	5 (26.3)	8 (21.1)	
Grade 4, no. (%)	0 (0.0)	3 (7.9)	
BMI z-score	0.733 (0.34)	0.745 (0.26)	0.898 ^a
(95% confidence interval)	(0.01–1.45)	(0.23–1.27)	
Obesity – BMI z-score > 1.65, no. (%)	4 (21.05)	7 (18.42)	0.975 ^b
Neck circumference (cm)	27.95 (0.82)	28.4 (0.60)	0.501 ^a
Systolic blood pressure (mmHg)	104.84 (3.53)	99.36 (2.02)	0.191 ^a
Diastolic blood pressure (mmHg)	61.05 (2.84)	57.84 (1.51)	0.528 ^a
HOMA-IR (mmol x mU/L ²)	1.517 (0.33)	1.342 (0.21)	0.728 ^a
HOMA-IR ≥ 2.5, no. (%)	3 (15.79)	2 (5.26)	0.320 ^b
Leptin (ng/mL)	4.828 (1.80)	7.604 (1.48)	0.213 ^a

Data expressed as mean ± SE; BMI, body mass index and HOMA-IR, homeostasis model assessment index for insulin resistance.

^a Mann–Whitney *U*-test.

^b Chi-square test with Yates' correction.

3. Results

3.1. Patient characteristics

Fifty-seven consecutive children diagnosed with OSA, aged from 2 to 16 years (age mean ± SEM, 6.9 ± 0.5 years) (38 boys, 66.7%), met the inclusion criteria for the study. They were enrolled in one of two studied groups: I – residual OSA (*n* = 19) and II – non-residual OSA (*n* = 38). Twenty-eight of the children (49.1%) were referred to the clinic by laryngologists. In the group diagnosed with residual disease the time since adenotonsillectomy ranged from 8 to 40 months (mean ± SEM, 23 ± 0.5 months). There was no significant difference in gender and age distribution as well as anthropometrical and metabolic measurements between the residual OSA and non-residual OSA groups (Table 1). There were a comparable percentage of obese children in both groups (21.05% vs. 18.42%; *p* = 0.975). Subjects did not differ in terms of quantity of sleep in hours (11.0 ± 0.25 h vs. 10.6 ± 0.38 h; *p* = 0.153) and in percentiles (91.5 ± 1.4 percentile vs. 71.1 ± 2.8 percentile; *p* = 0.115).

3.2. Patient characteristics according to polysomnographic results

The polysomnographic findings are summarized according to study group in Table 2. Children diagnosed with residual OSA were characterized by a significantly higher number of obstructive respiratory events expressed as the Apnea Hypopnea Index, (20.6/h vs. 9.1/h; *p* < 0.03) due to a higher number of hypopnea (not apnea) events. Residual OSA was characterized by a higher number of children with a hypopnea index > 10/h (47.4% vs. 16.2%, *p* = 0.039). Children after insufficient AT demonstrated lower

mean oxygen saturation (SpO₂) as compared to non-residual OSA (94.32% vs. 96.16%; *p* = 0.018) as well as a higher index of respiratory arousals with desaturation (2.2/h vs. 0.8/h; *p* < 0.03).

In pH-metry, children diagnosed with residual OSA had lower mean intraluminal esophageal pH (5.36 vs. 5.86; *p* = 0.007) and a higher reflux index (9.61% vs. 4.35%; *p* = 0.003) (Table 3).

Minimum pH values during sleep in children with persisting OSA was lower than in the reference group (1.53 vs. 2.15; *p* < 0.044). The difference between the minimum value of pH during wakefulness and sleep was noted in non-residual OSA (*p* = 0.004), but not in residual OSA (*p* = 0.343). The lowest pH during sleep correlated positively with mean SpO₂ (*r* = 0.441 and *p* = 0.0009) and correlated negatively with the hypopnea index (*r* = −0.424 and *p* = 0.001) and the apnea–hypopnea index (*r* = −0.385 and *p* = 0.004). Of the 19 patients who underwent AT, 8 (42.1%) were subsequently diagnosed with an increased mean acid reflux index of 14.7% (95% CI 11.45–18.05%). In the remaining 11 of 19 children, the mean acid reflux index was 3.79% (95% CI 2.12–5.45%).

3.3. Risk factors for residual obstructive sleep apnea

Logistic regression analysis for the various factors contributing to residual OSA was performed. The hypopnea index (HI) and the reflux index (RI) were regarded as the only significant risk factors for residual OSA. The overall model evaluation is presented in Table 4. The odds ratio for the obstructive hypopnea index was 1.15 (95% CI 1.02–1.28; *p* = 0.014) and for the reflux index was 1.01 (95% CI 1.00–1.03; *p* = 0.038). The overall correction prediction of this model was 72.3%, with sensitivity and specificity 53.3% and 81.3%

Table 2
Polysomnographic study results.

Variable	Residual OSA (n = 19)	Non-residual OSA (n = 38)	<i>p</i> [*]
Oxygen saturation, SpO ₂ mean (%)	94.32 (0.51)	96.16 (0.39)	0.018
Oxygen saturation, SpO ₂ nadir (%)	78.0 (1.84)	81.96 (1.42)	0.149
Oxygen desaturation index, ODI (n/h)	22.67 (3.62)	10.36 (2.67)	0.317
Hypopnea index, HI (n/h)	13.56 (2.38)	4.35 (1.83)	0.022
Apnea–hypopnea index, AHI (n/h)	20.61 (3.93)	8.57 (3.03)	0.034
Obstructive apnea index, OAI (n/h)	4.04 (1.67)	2.78 (1.29)	0.085
Obstructive apnea duration, mean (s)	14.88 (1.75)	13.15 (1.35)	0.761
Respiratory arousal index with desaturation (n/h)	2.20 (0.61)	0.58 (0.47)	0.032

Data expressed as mean ± SE.

^{*} Mann–Whitney *U*-test.

Table 3
Summary of pH-metry recorded during the polysomnographic study.

pH-metry	Residual OSA (n = 19)	Non-residual OSA (n = 38)	p Value
Mean intraluminal esophageal pH (95% CI)	5.36 ± 0.13 (5.07–5.64)	5.86 ± 0.09 (5.66–6.06)	0.007 ^a
Reflux index, RI (%) (95% CI)	9.61 ± 1.6 (6.08–13.15)	4.35 ± 0.7 (2.89–5.83)	0.003 ^a
Reflux index ≥ 7, number of children (%)	8 (42.1)	4 (10.5)	0.006 ^b
Lowest pH during wakefulness (95% CI)	1.26 ± 0.2 (0.96–1.56)	1.36 ± 0.1 (1.13–1.58)	0.320 ^a
Lowest pH during TST (95% CI)	1.53 ± 0.2 (1.04–2.02)	2.15 ± 0.2 (1.67–2.63)	0.044 ^a

Data expressed as mean ± SE; 95% CI, confidence interval and TST, total sleep time.

^a Mann-Whitney *U*-test.

^b Chi-square test with Yates' correction.

respectively. The odds ratio, calculated as the ratio of correctly classified cases (true positives and true negatives) to incorrectly classified cases (false positives and false negatives) amounted to 4.952.

4. Discussion

There are several important observations in the current study. Children diagnosed with residual disease differed significantly in polysomnographic findings from children with newly diagnosed OSA. Children who underwent adenotonsillectomy, unexpectedly had a lower saturation, a higher number of hypopnea events, and a higher number of respiratory arousals. Additionally, they were more exposed to abnormally low pH in the esophagus. Children from both groups demonstrated similar severe symptoms of SDB and did not differ in total sleep time per day. However, it is worth noting that the average sleep time for children with residual OSA was near the 90th percentile. The high need for sleep in this group of children could be due to worse sleep conditions secondary to lower oxygen saturations and a greater number of respiratory arousals.

In the current study the polysomnographic results indicate that residual OSA was more severe than newly diagnosed OSA. The higher apnea–hypopnea index was mainly due to the high hypopnea number. The number of obstructive apnea events was similar in both groups. It can be assumed that the causes of apnea were partly treated by surgery, but the causes of hypopnea were not. This may suggest that OSA may have a multifactorial background with causative factors which are not curable by AT, such as anatomical craniofacial deformities/abnormalities and neuromuscular disorders [6,29,30]. An effective adenotonsillectomy results in relief of OSA symptoms as well as improves polysomnography findings to less than one obstructive apnea per hour of sleep (which is the accepted normal value for healthy children) [29]. In children with multifactorial OSA, an adenotonsillectomy temporarily ameliorates or resolves OSA but does not correct all of the etiologies [2,31]. Occasionally, a deterioration of respiratory rates after surgery, along with an aggravation in polysomnographic indices compared with a baseline test before surgery, is possible [12].

Among the many potential causes of OSA, gastroesophageal reflux is one of the most widely discussed. Apnea is one extraesophageal sign of gastroesophageal reflux disease. However, according to NASPGHAN and ESPGHAN, the sensitivity, specificity, and clinical utility of pH monitoring for diagnosis and management

of possible extraesophageal complications of GER are not well established [27]. Several mechanisms, from accidental coincidences to mutual feedback between apnea and reflux, have been proposed in the pathogenesis of the joint occurrence of sleep apnea and reflux [16,32,33]. One proposed mechanism is increased respiratory effort leading to enhancement of the pressure gradient across the lower esophageal sphincter. Also, large negative intrapleural pressure oscillations during apnea may facilitate retrograde movement of gastric contents [34]. And vice versa, acid exposure may result in local edema and secretion of respiratory mucosa as well as inducing lymphoid tissue enlargement [16]. It seems that various mechanisms are possible in different patients.

In the current study the number of children with gastroesophageal reflux was higher in the group of children diagnosed with residual OSA and affected 8 of 19 patients (42.1%). Residual OSA cases had a significantly lower mean intraluminal esophageal pH and a significantly lower minimal value of pH during sleep. Similar to a study by Noronha et al. no correlation occurred between OSA severity and GER standard parameters [15]. Of all recorded GER parameters, only minimal values of pH during night sleep were associated with respiratory indices. These values positively correlated with mean oxygen saturation and negatively correlated with the number of obstructive respiratory events (hypopnea and apnea). Minimum value of intraluminal esophageal pH is not routinely used to diagnose gastroesophageal reflux. These parameters were assessed because it was interesting to know whether the level of esophageal acidification could influence respiratory functions. The results indicate that minimal pH should be more precisely examined in further studies. This may explain if negative routine pH-metry tests are truly negative and if brief nocturnal exposures to very low pH can influence upper respiratory tract function. Based on the results of this study, intraluminal esophageal acidification may be suspected to have an influence on the upper respiratory tract and may be involved in obstructive hypopnea. However, this hypothesis requires confirmation through an evaluation of a pre- and post-AT polysomnography and analysis of the influence of antireflux therapy on respiratory events. In the current study differences between groups could have been a fortuitous association secondary to previous existing differences in the degree of OSA severity. There are studies showing a beneficial effect of antireflux therapy on respiratory indices in adults [14,33]. Although AT is the method of choice in the treatment of OSA, it is quite possible that some children with residual OSA may derive benefits from antireflux therapy. Gastroesophageal reflux is also likely to be important in

Table 4
Logistic regression model with the obstructive hypopnea index and the gastroesophageal reflux index as the outcome variables predicting residual obstructive sleep apnea.

Predictor	Coefficient	SE	Wald statistic	p Value	OR	95% CI for OR lower upper
Constant	–2.752	0.743	13.731	0.0002	0.06	0.01–0.28
Hypopnea index (n/h)	0.136	0.055	6.024	0.014	1.15	1.02–1.28
Reflux index pH < 4 (%)	0.014	0.007	4.290	0.038	1.01	1.00–1.03

SE, standard error; OR, odds ratio and CI, confidence interval.

the pathogenesis of arousals [34,35]. Respiratory arousals with desaturation were observed more often in children with residual OSA. It was not possible to explain this mechanism through GER. No correlation was found between GER indices and respiratory and spontaneous arousals. These results are consistent with a previous study by Oztruk and are contrary to a study by Ing who found that antireflux therapy reduced the arousal index in adult patients with OSA [34,36]. In this study, respiratory arousals with desaturation can only be explained by respiratory events. Arousals correlated significantly only with AHI ($p < 0.00001$) and did not correlate with other metabolic indices (BMI z-score, HOMA-IR, serum leptin level).

Enlarged upper airway lymphoid tissues is the most common cause responsible for sleep disordered breathing in children. After surgical treatment the regrowth of adenoids and the compensatory hypertrophy of the contralateral tonsils could occur causing the recurrence of OSA [8]. In this study, however, residual OSA cannot be explained by tonsil size because the palatine tonsils were small in both groups. Children with newly diagnosed OSA had relatively small tonsils and this was the reason for referral for polysomnography by a laryngologist. Children with clearly enlarged tonsils and evident clinical symptoms are usually immediately sent to surgery without polysomnography. Small tonsil size in children with residual OSA has also been described by other authors. Attention is brought to other mechanisms responsible for the impairment of airflow through the upper airways in children without the participation of enlarged upper airway lymphoid tissues. Shintani et al. found that, among children who underwent an adenotonsillectomy, those who did not improve tended to have smaller tonsils, a narrower epipharyngeal airspace, and a more poorly developed maxillary and mandibular protrusion than children who did improve [8].

In this study the anthropometric-metabolic indices were not useful in differentiating residual disease and predicting the outcome of an adenotonsillectomy, similarly as in other studies [10,12,37]. This could be explained by the low number of obese patients in the current study. It should be emphasized that obesity is one of the risk factors of residual disease postoperatively [30]. In a recent multicenter study adenotonsillectomy was less effective for obese individuals which constituted 50% of the study participants with residual disease [3].

There are, however, limitations in this study. The double pH probe is the current standard for diagnosing GERD. A single pH probe was used in this study which limited information about gastroesophageal reflux. Patients were also previously treated surgically in different otolaryngology departments which could have affected postoperative outcomes. Thirdly, sample size was relatively small. In this study factors which significantly determined the presence of persisting OSA were searched for. Two variables were entered in the logistic regression model as significant: the hypopnea index and gastroesophageal reflux index. However, the role of both predictors, despite the fact that according to the statistical evaluation is significant, should not be overestimated. An evaluation of the logistic model indicates a relatively low sensitivity of these factors in the prediction of residual OSA. Interpreting these results, it can be assumed that these factors may complement the list of previously described predictors for residual OSA (the regrowth of adenoids or tonsils, craniofacial deformities, neuromuscular disorders, or obesity). Despite these limitations the study results indicate that children without improvement after surgery should be evaluated for other causes (such as GER). Further studies with pre- and post-AT polysomnographic assessment and evaluation of response to antireflux therapy are needed to determine if gastroesophageal reflux contributes to hypopnea in the course of residual disease.

Conflict of interest

We state no conflict of interest.

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