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Relationship Between Drug-Induced Sleep Endoscopy Findings, Tonsil Size, and Polysomnographic Outcomes of Adenotonsillectomy in Children

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Abstract

Objective: 1) Determine the correlation of awake tonsil scores and pre-adenotonsillectomy sleep endoscopy findings and 2) Assess the relationship between polysomnographic adenotonsillectomy outcomes with awake tonsil scores and sleep endoscopy ratings of tonsil and adenoid obstruction.

Study Design: Retrospective case series with chart review

Setting: Tertiary care children's hospital

Subjects and Methods: Children ages 1–18 years who underwent sleep endoscopy and adenotonsillectomy from 1/1/2013 to 8/30/2016 were included. Pre-adenotonsillectomy sleep endoscopy findings were scored with the Sleep Endoscopy Rating Scale. Awake tonsil scores and sleep endoscopy ratings were compared using Spearman correlation. Associations between changes in pre- and post-adenotonsillectomy polysomnography parameters and a) awake tonsil scoring and b) sleep endoscopy scoring were assessed using one-way analysis-of-variance and linear regression.

Results: N = 36, mean age 6.8 ± 4.3 years, 68% male, 44% obese. Awake tonsil scores and sleep endoscopy ratings were strongly correlated ($R = 0.58$, $P = 0.003$). Awake tonsil scores were not associated with changes in any polysomnography parameters after adenotonsillectomy (all $p > 0.05$) while sleep endoscopy ratings of adenotonsillar obstruction were significantly associated (all $p < 0.05$, R-squared 0.16–0.35). Patients with minimal adenotonsillar obstruction during sleep endoscopy had less improvement than those with partial or complete obstruction (mean obstructive apnea-hypopnea index change -8.2 ± 11.5 vs. -15.9 ± 14.3 and -46.8 ± 31.3 , respectively, $p < 0.001$).

Conclusions: In children at risk for adenotonsillectomy failure, assessment of dynamic collapse using sleep endoscopy may better predict the outcome of adenotonsillectomy than awake tonsil size assessment, thus helping to inform surgical expectations.

Keywords

obstructive sleep apnea; pediatric; drug-induced sleep endoscopy; adenotonsillectomy; polysomnography

INTRODUCTION

Although adenotonsillectomy (AT) is the primary treatment for obstructive sleep apnea (OSA) in children, complete resolution of OSA after AT may be seen in only 25–75% of patients depending on the criteria used for diagnosing childhood OSA.^{1–3} The influence of tonsil size on the outcome of AT has not been well studied. It seems intuitive to assume that small tonsils observed during a routine exam are unlikely to contribute significantly to OSA, and therefore AT is not likely to offer significant improvement. However, assessments of tonsil size during awake clinic examination have not correlated well with disease severity or outcome of AT.^{4–7}

Drug-induced sleep endoscopy (DISE) allows for the assessment of dynamic obstruction during sedated sleep. DISE, therefore, may be beneficial in the evaluation of children who have not yet undergone AT by allowing a dynamic assessment of anatomic contributors to obstruction rather than a limited awake oropharyngeal exam in the clinic.^{8,9} While a few studies have compared pre-AT DISE findings and awake tonsil scoring and generally found good correlation between these assessments,^{8–10} there is a paucity of literature examining the relationship of either assessment with the outcome of AT.^{7,11} This study aimed to 1) determine the correlation of assessment of tonsil size and pre-AT DISE findings and 2) assess the relationship between polysomnographic (PSG) outcomes of AT with tonsil scores and DISE ratings of tonsil and adenoid obstruction.

MATERIALS AND METHODS**Study Population**

This study is a case series with chart review of children ages 1–18 years who underwent DISE at the time of AT for OSA or sleep-disordered breathing from 1/1/2013 to 8/30/2016. Indications for DISE were based on risk factors for persistent post-AT OSA, specifically obesity (BMI >95 percentile for age), severe baseline OSA (obstructive apnea-hypopnea index > 10), neuromuscular disorder, Down syndrome (DS), or small (1+) tonsils. Only patients with pre- and post-AT polysomnography (PSG) were included in the final analysis. Demographic data (age and sex), body mass index (BMI), clinic assessment of tonsil size, comorbidities (neuromuscular disorders, craniofacial anomalies, DS, asthma, prematurity, etc), and pre- and post-AT PSG data were extracted from the electronic medical record. Awake tonsil scores and DISE ratings made at the time of surgery were all assessed by the primary author (D.L.). This study was approved by the Oregon Health and Science University Institutional Review Board.

Tonsil Scoring

Tonsil size was assessed during an awake clinic exam using the Friedman scoring¹²: 1+ within the tonsillar fossa, 2+ beyond the tonsillar pillars but <50% towards midline, 3+ >50% towards midline, 4+ meeting at midline (“kissing tonsils”). With cooperative children, this scoring was made over 1 to 3 attempts with maximal oral opening and a relaxed tongue position in the floor of the mouth. With uncooperative children or, where the tonsils could not be clearly visualized with mouth opening alone, one or more tongue blades were inserted into the oral cavity to depress the tongue and allow visualization of the oropharynx.

DISE Rating and Patterns of Obstruction

DISE was performed using a flexible 2.8 mm fiberoptic endoscope prior to AT. Patients breathed spontaneously and were sedated using a combination of dexmedetomidine (1–2mcg/kg bolus over 5–10 min followed by 0.5–1mcg/kg/hour infusion) and ketamine (1mg/kg boluses up to 40mg, as needed). Topical decongestant was not applied to the nasal cavities prior to endoscopic evaluation. After the optimal sedation level was achieved (defined as lack of response to transnasal insertion of the endoscope with active snoring), the DISE evaluation was completed over a period of 5–15 minutes depending on the ease of visualization due to severity of obstruction or presence of excess secretions. DISE findings were scored according to the previously published Sleep Endoscopy Rating Scale (SERS)¹³. The SERS is a validated tool for the systematic assessment of upper airway obstruction from the nose to the supraglottis in children undergoing DISE. Briefly, ratings were assessed on a 3-point scale (0 = no obstruction, 1 = partial obstruction, 2 = complete obstruction) at 6 anatomic levels of the upper airway (nasal airway, nasopharynx, velopharynx, oropharynx (including tonsils), base of tongue (including epiglottis), and arytenoids. Patterns of adenotonsillar obstruction were defined based on the combined obstructive ratings of both the adenoids and tonsils as follows: *minimal* - no significant obstruction of both adenoids and tonsils (SERS ratings = 0 for both, defined as tonsils occupying < 50% of oropharynx, adenoids not extending beyond Eustachian tube opening), *partial* - complete obstruction at one site (SERS = 2) and no or partial obstruction at the other (SERS = 0 or 1) or *complete* - complete obstruction at both sites (SERS = 2 for both).

Polysomnography

All PSG was performed in an attended overnight sleep laboratory according to American Academy of Sleep Medicine guidelines.¹⁴ This included electroencephalography (EEG), electrooculography (EOG), electromyography (EMG) of the submental and anterior tibialis, electrocardiography (ECG), nasal and oral airflow monitoring, thoracic and abdominal sensor belts, pulse oximetry, and audio/video recording. PSG parameters obtained from pre- and post-AT and included in the analysis were, obstructive apnea-hypopnea index (oAHI), rapid eye movement (REM) AHI, oxygen nadir, and oxygen desaturation index (ODI). OSA severity was defined mild, moderate, or severe according to oAHI (1–4.9, 5–9.9, and ≥ 10, respectively). Residual OSA was defined as a oAHI > 1 on post-AT PSG.

Analysis

Cohort Characteristics—Patient characteristics were recorded for all patients who underwent DISE during the study period, regardless of PSG testing. To test for possible selection bias, patient characteristics of those included and excluded from the study were compared using one-way ANOVA for parametric continuous variables, Kruskal-Wallis test for non-parametric continuous variables, and either Chi-square or Fisher's exact test for categorical variables.

Comparison of Clinic Tonsil Size Assessment and DISE Findings—The correlation between awake tonsil score and SERS oropharyngeal/tonsil rating was quantified using a Spearman correlation coefficient. To test for differences in SERS ratings across awake tonsil scores, we used a Fisher's exact test.

Response to AT Based on Awake Tonsil Score versus SERS Rating—Differences in mean pre- and post-AT PSG parameters were compared using a Student's t-test. To test for significant differences in the change from baseline of each of these parameters across categories of awake tonsil scoring or SERS rating of adenotonsillar obstruction (as described above), we used a one-way ANOVA. Univariate linear regression was used to quantify the strength of association between the change in each PSG parameter and 1) the awake tonsil score, and 2) SERS rating of combined adenotonsillar obstruction, as described above.

RESULTS

A total of 88 children underwent DISE at the time of AT during the study period. Of these, 22 (25%) had no PSG testing at all, 22 (25%) underwent only pre-AT PSG, 7 (8%) underwent only post-AT PSG, and 36 (41%) underwent both pre- and post-operative PSG. Overall, there were no significant differences in patient characteristics based on pre or post-AT PSG testing. However, children who underwent pre-AT testing only had fewer comorbidities than other subgroups, and those who had only post-AT PSG were more likely to be obese. The remainder of the analysis focused only on patients who underwent both pre- and post-operative PSG. Among these patients, age at the time of AT ranged from 1.5 to 16.2 years with a mean of 6.8 years which was slightly younger than the other subgroups, with a slightly high proportion of boys (25 of 36, 69%), though these differences were not statistically significant (Table I). Nearly half were obese (16 of 36, 44%). The most common comorbidities were asthma (4 of 36, 11%) and DS (5 of 36, 14%). All patients were treated with AT but some patients also underwent other concurrent procedures: tympanostomy tube placement (7), direct laryngoscopy and bronchoscopy (6), marsupialization of an ear dermoid cyst (1), interarytenoid injection laryngoplasty (1), and endoscopic repair of a type I laryngeal cleft (1). Residual post-AT OSA (oAHI ≥ 2) was present in 27 (75%) patients, and 18 (50%) patients had at least moderate residual OSA (oAHI ≥ 5). A total of 16 (44%) patients had minimal AT obstruction during DISE, while 7 (19%) had complete obstruction of the adenoids and tonsils. The most common sites of obstruction based on DISE findings were the oropharynx (including tonsils), velopharynx, and nasal airway (Table II).

Tonsil scores and SERS oropharyngeal ratings demonstrated a strong correlation ($R = 0.58$, $p = 0.003$). There was perfect agreement for small (1+) tonsils and for very large (4+) tonsils. However, there was a broad range of SERS scores among patients with tonsil scores of 2+ or 3+ (Table III). One patient did not have awake tonsil scores available due to lack of cooperation with clinic exam.

PSG parameters showed significant improvement after AT, with the exception of mean and maximal end tidal CO₂ (ETCO₂) (Table IV). When stratified by the degree of AT obstruction during DISE, patients with minimal adenotonsillar obstruction had less post-AT improvement than those with partial or complete adenotonsillar obstruction (mean oAHI change -8.2 ± 11.5 vs. -15.9 ± 14.3 and -46.8 ± 31.3 , respectively, $p < 0.001$, Table V). In general, there was significant improvement in most PSG parameters (oAHI, REM AHI, O₂ nadir, and ODI) when more severe AT obstruction was observed pre-operatively (Table V).

There was no significant association between awake tonsil scores and any PSG parameter change after AT (all $p > 0.05$, Table VI). In contrast, SERS ratings of adenotonsillar obstruction were significantly associated with change in oAHI, REM AHI, oxygen nadir, and ODI (all $p < 0.05$, Table VI). The ratings of AT obstruction accounted for approximately one third of the variance of change in oAHI and REM oAHI (R -squared = 0.35 and 0.33 respectively).

DISCUSSION

In this sample of children at high-risk for persistent OSA, we report that the pattern of adenotonsillar obstruction observed during DISE, but not tonsil size scored during awake clinical assessment, was significantly associated with the magnitude of improvement after AT. Children with increasing degrees of adenotonsillar obstruction showed greater improvement with respect to oAHI and several other PSG parameters after AT. We believe the ability to account for dynamic pharyngeal collapse during DISE better reflects the physiologic process of obstruction during natural sleep than awake clinic assessment of tonsil size and therefore is better correlated with outcome of AT. This finding may seem intuitive, but has not been clearly demonstrated to date. Our finding that there was agreement between DISE scores and awake tonsil grading for small (1+) and kissing (4+) tonsils, but wide variation in DISE scores for intermediate awake tonsil grades (2+ or 3+) may further reflect the dynamic lateral pharyngeal collapse observed during DISE, thus changing tonsil position and degree of obstruction, that could not be appreciated during awake clinic exam. Alternatively, the accuracy of findings during the awake clinic exam may have been negatively impacted by poor patient cooperation during the exam. Both of these factors likely contribute to our finding that DISE scores were significantly associated with changes in multiple PSG parameters while awake tonsil scores were not.

Previous studies have found that subjective assessment of tonsil and adenoid size during awake clinical examination are not reliable in predicting the severity of OSA or the outcome of AT.⁴⁻⁷ Although DISE is most often used in cases of residual OSA after AT,¹⁵ it is a low-risk procedure that has been shown to predict the outcome of upper airway procedures in adults^{16,17} and has been used in some children for pre-AT evaluation and identification of

obstruction.^{8,9,11} Boudewyns et al. reported a significant correlation between the awake tonsil score and the degree of tonsillar obstruction observed during DISE. However, they reported no correlation between tonsil score or DISE tonsil rating and AHI.⁹ Miller et al. noted a similar correlation between the awake tonsil score and DISE tonsil rating and a moderate correlation between DISE tonsil rating and AHI in children without any significant comorbidities.¹⁰ Ulualp et al. reported greater lateral oropharyngeal (tonsillar) obstruction among patients with moderate and severe OSA compared to those with mild OSA.¹⁸ In contrast to these studies of baseline correlations, Alsufyani et al.¹¹ attempted to examine pre-AT DISE findings and outcomes of AT, noting that tonsil size was negatively correlated with treatment failure (i.e. larger tonsils during DISE correlated with success). However, the primary outcome in this study was a positive screen on a validated sleep questionnaire; they did not examine polysomnographic outcomes.¹¹

This study reports a substantial improvement in PSG parameters following AT, consistent with previous studies.^{2,3,19,20} However, using a criterion of AHI ≥ 2 to diagnose OSA, 75% of the study population continued to have residual OSA. This is a higher prevalence of residual OSA than what has been reported in most previous studies.^{2,3,19,20} This is likely due to the inclusion criteria in this study that specifically selected for patients at greater risk for residual OSA after AT. Post-AT OSA has been associated with several risk factors, including severe preoperative OSA, obesity, neuromuscular disorders, DS, and craniofacial anomalies.^{3,21–24} As many as 88% of obese children have residual OSA after AT,²⁵ and at least 30–50% of children with DS have persistent OSA after AT.^{22,26–28} DISE has identified multilevel obstruction in 85.4% of children with DS²⁸ and 57%–71% of non-syndromic children.^{9,18}

Our results suggest that in patients at risk for AT failure, performing DISE prior to or at the time of AT may better predict the outcome of AT than relying on clinical exam or comorbidities alone. While one could choose to schedule routine follow-up or even routine post-AT PSG in all patients with risk factors for persistent OSA, this would be an inefficient use of resources and may not be feasible at most centers. Therefore, to help more efficiently identify patients most likely to fail AT who would most benefit from closer postoperative follow-up or an alternative treatment plan, we recommend consideration of routine pre-AT DISE in any patient where there is high risk for AT failure or uncertainty about the optimal surgical intervention. In this study, this included patients with severe baseline OSA, neuromuscular disorders, Down syndrome, obesity, or clinically small tonsils. However, this study was not designed or intended to determine the optimal indications for DISE, and specific subgroup analysis was not possible due to the small sample size. It is worth noting that routinely performing DISE prior to AT does add a small but substantial amount of time to each procedure, particularly considering the initial loading dose of dexmedetomidine and the subsequent slower recovery. Operating room and anesthesia efficiency, reimbursement for DISE, and productivity expectations all vary widely by setting and institution, and it may be impractical for some otolaryngologists to routinely perform DISE for all patients considered high risk for AT failure. While we believe that there is prognostic value in routinely performing DISE in this population, larger multi-institutional studies are needed to better elucidate which patients would most benefit from this evaluation.

There are significant strengths to this study including the systematically collected DISE assessments using a previously validated rating scale, with ratings documented at the time of AT so that the outcomes of surgery did not influence the DISE ratings, and the inclusion of patients with both pre- and post-operative PSG data. However, there are important limitations as well. First, this is a retrospective study with a large number of excluded patients because of missing pre- or post-AT PSG. It is possible that patients with complete symptom resolution would be less likely to return for a postoperative PSG, therefore selecting patients with a greater likelihood of AT failure and creating a possible selection bias. However, comparison of baseline characteristics between patients with pre- and post-AT PSG and those without did not reveal any significant differences in demographics or comorbidities. Examination of the differences in awake tonsil size stratified by PSG testing suggests that patients with pre-AT PSG only were more likely to have small (1+) tonsils than any other subgroup though this difference did not reach statistical significance ($p = 0.10$). However, the pattern of AT obstruction observed during DISE did not differ significantly among patients with and without pre and post-AT PSG, suggesting that the relationship between pre-AT DISE findings and PSG outcomes is likely generalizable to patients who did not complete pre and post-AT PSG.

Second, this study includes a heterogeneous study population selected based on risk factors for increased risk of AT failure, which may limit the application of these results to the broader population of children with OSA, or any specific subgroup. It is possible that the lack of statistically significant differences across subgroups of PSG testing may have been due to a relatively small sample size, limiting statistical power. As noted above, we did not have sufficient sample size to allow a robust subgroup analysis based on the different inclusion criteria, however, we feel that the inclusion of multiple different risk factors associated with AT failure adds to the potential generalizability of our findings.

Finally, this study focused on the assessment of tonsil and adenoid obstruction by DISE and comparing these to clinic exam with respect to AT outcome. While we did investigate other anatomic levels as part of the SERS ratings, we did not observe significant associations at other anatomic levels (data not shown). This may reflect the limited sample size and the relatively small impact on the change in PSG parameters after AT of obstruction at other anatomic sites. Further prospective studies with larger sample sizes are needed to better determine whether the relationships observed in this study are generalizable to all AT patients or specific subgroups.

CONCLUSION

In our study, preoperative DISE findings, but not clinical assessment of tonsil size, are significantly associated with the outcome of AT. Less severe adenotonsillar obstruction is associated with less polysomnographic improvement. Preliminary data suggests that in this population at high-risk for persistent OSA after AT, assessment of the pattern of dynamic collapse and airway obstruction using DISE may better predict the outcome of AT than tonsil size assessment in clinic and potentially help guide expectations and management of residual OSA.

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Table I.

Cohort Characteristics, Stratified by Polysomnography Testing

Characteristic N (%)	Pre & Post-AT PSG N = 36	No PSG N = 22	Pre-AT PSG only N = 22	Post-AT PSG only N = 7	p-value
Age at time of AT (Years)					
Mean $\pm$ Std Dev	6.8 $\pm$ 4.3	8.1 $\pm$ 4.8	8.7 $\pm$ 4.6	9.4 $\pm$ 3.2	0.33
% Male	25 (69)	14 (64)	12 (55)	3 (43)	0.59
BMI					
Percentile, Median [IQR]	92 [64, 100]	86 [48, 100]	86 [28, 100]	98 [85, 99]	0.89
Obese	16 (44)	9 (41)	9 (41)	4 (57)	0.88
Medical Comorbidities [†]					
Neurologic condition	1 (3)	2 (9)	1 (5)	1 (14)	0.46
Craniofacial anomaly	4 (11)	1 (5)	1 (5)	0 (0)	0.79
Down syndrome	5 (14)	0 (0)	3 (14)	1 (14)	0.24
Prematurity	3 (8)	3 (14)	0 (0)	0 (0)	0.34
Asthma	4 (11)	2 (9)	1 (5)	2 (29)	0.32
Other [*]	9 (25)	6 (29)	2 (9)	2 (29)	0.33
None	19 (53)	12 (55)	17 (77)	2 (29)	0.10
Tonsil Size (Friedman scale) ^{**}					
1 +	3 (9)	0 (0)	5 (23)	1 (14)	0.10
2+	6 (17)	5 (23)	7 (32)	2 (29)	
3+	23 (66)	13 (59)	9 (41)	2 (29)	
4+	3 (9)	4 (18)	1 (5)	2 (29)	
Pattern of AT Obstruction [#]					
Minimal AT Obstruction	16 (44)	11 (50)	11 (50)	4 (57)	0.41
Partial AT Obstruction	13 (35)	11 (50)	8 (36)	2 (29)	
Complete AT Obstruction	7 (19)	0 (0)	3 (14)	1 (14)	

[†] Some patients had more than one comorbidity, so column percentages do not necessarily total 100%

^{*} Includes Arnold-Chiari malformation, spina bifida, neurofibromatosis, developmental delay, eosinophilic esophagitis

AT = Adenotonsillectomy, BMI = Body Mass Index, PSG = Polysomnography, IQR = Interquartile Range

^{**} Based on awake clinical exam

[#] Based on drug-induced sleep endoscopy findings

Table II.

Sleep Endoscopy Rating Scale (SERS) Scores Among Patients with Pre and Post PSG (N = 36)

Anatomic Level	SERS Score
	Mean $\pm$ SD
Nasal Airway	0.97 $\pm$ 0.64
Nasopharynx	0.84 $\pm$ 0.87
Velopharynx	1.27 $\pm$ 0.73
Oropharynx (including tonsils)	1.24 $\pm$ 0.76
Base of Tongue (including epiglottis)	0.59 $\pm$ 0.76
Arytenoids	0.19 $\pm$ 0.46
Total Score	5.17 $\pm$ 1.95

PSG = polysomnography. Scores based on 3 point rating scale: 0 = no obstruction, 1 = partial obstruction, 2 = complete obstruction at each anatomic level

Table III.

Frequency Distribution of Awake Tonsil Scores and SERS Oropharyngeal (OP) Rating

N (%) [*]	Awake Tonsil Score				
	1 +	2+	3+	4+	Total
SERS OP = 0	3 (100)	2 (33)	2 (9)	0 (0)	7 (20)
SERS OP = 1	0 (0)	3 (50)	10 (43)	0 (0)	13 (37)
SERS OP = 2	0 (0)	1 (17)	11 (48)	3 (100)	15 (43)
Total ^{**}	3 (9)	6 (17)	23 (66)	3 (9)	35

^{*} Column percentages,

^{**} Row percentages,

SERS = Sleep Endoscopy Rating Scale, OP = oropharynx, p = 0.005, Fisher's exact test

Table IV.

Polysomnography Parameters Before and After Adenotonsillectomy

Parameter	Pre-AT	Post-AT	Change	p-value
oAHI (events/hr)	23.2 ± 21.7	5.0 ± 4.1	-18.2 ± 21.6	<0.0001
REM AHI (events/hr)	42.7 ± 37.6	14.0 ± 11.2	-28.6 ± 39.3	0.0003
O2 nadir (%)	81.9 ± 8.3	86.8 ± 6.1	4.9 ± 10.2	0.007
ODI (events/hr)	18.6 ± 18.8	4.9 ± 4.8	-13.6 ± 18.2	0.0002
Mean ETCO2 (mmHg)	39.5 ± 9.6	41.2 ± 9.2	1.8 ± 10.9	0.41
Maximal ETCO2 (mmHg)	51.2 ± 5.2	53.2 ± 14.6	2.0 ± 17.4	0.56

Data presented as mean ± standard deviation. oAHI = obstructive apnea-hypopnea index, REM AHI = apnea-hypopnea index during rapid eye movement sleep stage, O2 = oxygen, ODI = oxygen desaturation index, ETCO2 = end-tidal carbon dioxide

Table V.

Change in PSG Parameters after AT Based on Pattern of Obstruction

PSG Parameter (Mean Change from Baseline $\pm$ Std Dev)	Minimal AT Obstruction	Partial AT Obstruction	Complete AT Obstruction	p-value
oAHI (events/hr)	-8.2 ± 11.5	-15.9 ± 14.3	-46.8 ± 31.3	0.0005
REM AHI (events/hr)	-10.2 ± 24.7	-28.0 ± 38.7	-72.9 ± 36.9	0.002
O ₂ nadir (%)	1.8 ± 7.1	4.0 ± 11.7	13.6 ± 9.4	0.03
ODI (events/hr)	-6.2 ± 10.9	-12.8 ± 14.3	-32.3 ± 26.6	0.009

oAHI = obstructive apnea-hypopnea index, REM AHI = apnea-hypopnea index during rapid eye movement sleep stage, O₂ = oxygen, ODI = oxygen desaturation index

Table VI.

Association Between Change in PSG Parameters and Awake Tonsil Score, SERS Ratings

Beta [95%CI] R-squared	oAHI Change	REM AHI Change	O2 nadir Change	ODI Change
Awake Tonsil Score	-8.9 [-20.4, 2.6] 0.08	-22.6 [-45.9, 0.7] 0.12	2.0 [-2.9, 6.8] 0.02	-4.2 [-15.8, 7.4] 0.02
SERS TA	-17.5 [-26.4, -8.5] 0.35	-29.2 [-45.0, -13.4] 0.33	5.3 [1.1, 9.5] 0.16	-12.0 [-19.7, -4.3] 0.26

* **Bold** denotes $p < 0.05$, univariate linear regression. R-squared values indicate the proportion of variance in PSG parameter change attributable to predictor.

oAHI = obstructive apnea-hypopnea index, REM AHI = apnea-hypopnea index during rapid eye movement sleep stage, O2 = oxygen, ODI = oxygen desaturation index, SERS = sleep endoscopy rating scale, TA = combined tonsil and adenoid obstruction.