

# Tonsil Size and Outcome of Uvulopalatopharyngoplasty With Tonsillectomy in Obstructive Sleep Apnea

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**Objectives/Hypothesis:** To investigate the relationship of tonsil volume and grade on outcomes of uvulopalatopharyngoplasty (UPPP) with tonsillectomy in patients with obstructive sleep apnea (OSA).

**Study Design:** Retrospective cohort analysis.

**Methods:** Data of 70 consecutive patients undergoing UPPP with tonsillectomy between 2015 and 2018 were analyzed. Patients with an apnea-hypopnea index (AHI) <10/hr or concomitant surgery other than nasal surgery were excluded. Tonsil volume was measured intraoperatively. Preoperatively and 3 months after surgery we assessed the AHI using respiratory polygraphy, daytime sleepiness using the Epworth Sleepiness Scale (ESS), and a visual analog scale for the snoring index (SI).

**Results:** Tonsil grade and volume both showed a significant correlation with preoperative AHI. Postoperative AHI was not significantly different between grades and volume. The AHI reduction after surgery increased significantly with larger volume and higher tonsil grade. For all grades, the postoperative ESS was significantly reduced compared to the preoperative value, but was not significantly correlated with tonsil volume. Preoperative and postoperative SI was not significantly correlated between tonsil grade or volume. In all grades, SI was significantly reduced after surgery.

**Conclusions:** In our study, we found that large tonsils are responsible for higher preoperative AHI values, and their removal leads to greater reduction of initial AHI. However, the postoperative effect on daytime sleepiness and snoring reduction is not significantly correlated with tonsil size and volume, indicating that these parameters are mainly influenced by other factors. The knowledge of the significance of tonsil size and volume is important for ear, nose, and throat physicians when counseling OSA patients.

**Key Words:** Obstructive sleep apnea, surgical treatment of obstructive sleep apnea, tonsillectomy, palatine tonsil, clinical outcomes/research.

**Level of Evidence:** 2c

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## INTRODUCTION

Obstructive sleep apnea (OSA) affects a large portion of the Western population and is a risk factor for many diseases.<sup>1</sup> Continuous positive airway pressure (CPAP) therapy is the primary nonsurgical treatment of OSA.<sup>2,3</sup> However, 40% to 60% of patients do not tolerate CPAP in the long term.<sup>1</sup> Therefore, therapeutic alternatives are necessary, and uvulopalatopharyngoplasty (UPPP) is the most common procedure for surgical treatment of OSA.<sup>4</sup> UPPP with tonsillectomy (TE) has been shown to reduce apnea-hypopnea index (AHI), daytime sleepiness, and snoring.<sup>5</sup> The efficacy of UPPP is greatly enhanced when a concomitant TE is performed. Maurer showed that the success rate after UPPP is doubled when a TE is performed compared without a TE.<sup>6</sup> The responder rate following

multilevel surgery with UPPP and hyoid suspension is increased sixfold with a TE compared to nonremoval of the palatine tonsils (PTs).<sup>7</sup> Several publications have shown an association between the objective tonsil volume as well as the subjective tonsil grade and the AHI.<sup>2,8,9</sup> PT grade has also been used in the prediction for OSA severity.<sup>10,11</sup>

Removal of the PTs is often recommended to patients with OSA, especially if the PTs are enlarged. However, the significance of tonsil size and tonsil volume on the outcome after UPPP with TE is unknown. Lai et al.<sup>2</sup> and Jara and Weaver<sup>8</sup> point out in their studies that this aspect should be investigated. The aim of the present study was to analyze the effect of tonsil size and tonsil volume on AHI, daytime sleepiness, and snoring following UPPP with TE.

## MATERIALS AND METHODS

All consecutive patients undergoing UPPP with palatine TE and radio frequency ablation (RFA) of the soft palate for OSA between 2015 and 2018 at our institution were included. Patients with an AHI of <10 per hour, incomplete data, or concomitant surgery other than nasal septoplasty were excluded.

All patients underwent routine clinical ear, nose, and throat (ENT) examination before surgery following a structured physical examination chart. This included Friedman tongue position,<sup>10</sup> uvula size, pharyngeal webbing, and PT grade (assessed using the Brodsky grading scale<sup>12</sup>), and the modified Friedman stages of

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OSA.<sup>4,13</sup> In case of asymmetrical PT size, the higher grade was used for this study. Body mass index (BMI) and neck circumference were obtained for all patients.

Preoperatively and at 3 months after surgery, AHI, daytime sleepiness using the Epworth Sleepiness Scale (ESS),<sup>14</sup> and snoring using a snoring index (SI) on a visual analog scale from 1 to 10 were assessed. AHI was measured using respiratory polygraphy. At 3 months postoperatively, patients were asked whether they would undergo the surgery again or recommend it to a friend.

All patients underwent UPPP with a standard TE and a volume reduction of the soft palate using interstitial RFA. A prolonged uvula was shortened upon the decision of the surgeon if it was longer than 10 to 12 mm. The tonsil volume was determined intraoperatively by the Archimedes' principle of water displacement. Each side was measured separately. For statistics the total volume of both tonsils was used. All data were collected prospectively.

As the primary endpoint, postoperative AHI and AHI reduction were analyzed. Secondary endpoints were the reduction of the ESS and SI. For the definition of surgical success for AHI, the Sher criteria were used. Responders were defined as a postoperative AHI  $\leq 20$ /hr and a reduction of the initial AHI of  $\geq 50\%$ .<sup>15</sup> Responders of daytime sleepiness were defined as a postoperative ESS score  $\leq 10$  and a  $\geq 50\%$  reduction of preoperative ESS. Regarding snoring, responders were defined as a postoperative SI of  $\leq 3$  and a reduction of initial SI  $\geq 50\%$ .

Statistical analysis was performed using the Application RStudio Version 1.1.456 (RStudio, Boston, MS) with consultation of the Clinical Trial Unit Basel and using statistical tests as appropriate.  $P < .05$  was considered significant. The local ethics committee approved the study.

## RESULTS

### *Patient Characteristics*

The cohort consisted of 70 patients who met the inclusion criteria. Sixty-five were male, and five were female. All patients underwent UPPP for OSA with palatine TE and RFA of the soft palate (Table I). The patients were divided into four groups according to their clinical tonsil grade (1–4). Only one female patient had grade 4 tonsils. The patient characteristics are summarized in Table I. Tonsil grade 2 was the most common ( $n = 32$ , 45.7%). The median follow-up time was 99.0 days (interquartile range, 90.0–115.8 days). The groups were similar regarding BMI, neck circumference, age, concomitant nasal surgery, configuration of the uvula, pharyngeal webbing, Friedman tongue position, and gender distribution. Uvula length, width, and the degree of pharyngeal webbing had no significant influence on pre and postoperative AHI, ESS, and SI (Spearman's correlation,  $P > .05$ ). Consequently, these parameters were excluded from further statistical analysis. A significant correlation between neck circumference and postoperative ESS was found (Spearman's correlation,  $P = .0059$ ). Postoperative ESS was higher with increased neck circumference. The preoperative and postoperative AHI increased significantly with age (Spearman's correlation,  $P = .027$  and  $P = .036$ , respectively). There were no further significant relationships of neck circumference and age with our endpoints.

A subgroup analysis for BMI was performed by dividing the patients into normal weight (BMI 18.5–25 kg/m<sup>2</sup>,

$n = 14$ ), overweight (BMI 25–30 kg/m<sup>2</sup>,  $n = 32$ ), and obese (BMI 30–35 kg/m<sup>2</sup>,  $n = 22$ ). No patient had a BMI  $< 18.5$  kg/m<sup>2</sup> or  $> 35$  kg/m<sup>2</sup>, and the BMI values of two patients were not available. The three subgroups were similar regarding tonsil size and volume. Pre- and postoperative AHI, ESS, and SI values were not significantly different among the subgroups ( $P > .05$ ).

Tongue position was significantly correlated with postoperative AHI (Spearman's correlation,  $P = .035$ ), but showed only a borderline correlation with preoperative AHI (Spearman's correlation,  $P = .063$ ).

### *Tonsil Grade and Volume*

Tonsil volume and tonsil grade are shown in Figure 1. Significant differences were found between tonsil grades 1 and 3 (Wilcoxon test,  $P < .0001$ ) and tonsil grades 2 and 3 (Wilcoxon test,  $P < .0001$ ), but not for grades 1 and 2 (Wilcoxon test,  $P = .2$ ). Using a linear regression model, tonsil volume increased by 2.52 mL from grade to grade. Mean values and standard deviations are given in Table I.

### *AHI by Grade and Volume*

Preoperative AHI increased significantly with the tonsil grade (Kruskal-Wallis test,  $P = .0041$ ) and tonsil volume (Spearman's correlation,  $P = .043$ ). In a linear regression model, the preoperative AHI was calculated depending on tonsil volume and grade. The model showed that the preoperative AHI increased by 1.46 for every milliliter of additional tonsil volume and by 9.68 for every step up in tonsil grade. Postoperative AHI was not significantly correlated with tonsil volume or grade (Spearman's correlation,  $P > .05$ ). The difference between pre- and postoperative AHI for tonsil grades was significant (Wilcoxon test,  $P < .001$ ), except for grade 1, where the level of significance was not reached (Wilcoxon test,  $P = .10$ ).

AHI reduction after UPPP with TE and RFA significantly increased with increased tonsil volume (Spearman's correlation,  $P = .006$ ) (Fig. 2A) and grade (Kruskal-Wallis test,  $P = .006$ ) (Fig. 2B). AHI responders according to the Sher criteria had significantly larger tonsil volume (Wilcoxon test,  $P = .0034$ ) (Fig. 2C). The AHI responder rate also increased with each tonsil grade ( $\chi^2$  test,  $P = .037$ ) (Fig. 2D).

### *ESS by Grade and Volume*

Preoperative ESS scores were significantly lower in patients with tonsil grade 1 than the other groups (Wilcoxon test,  $P = .023$ ). This is in accordance with the increasing severity of OSA with higher tonsil grade. There was no significant correlation of preoperative ESS with tonsil volume (Spearman's correlation,  $P > .05$ ). In all groups the postoperative ESS was significantly reduced compared to the preoperative value (Wilcoxon test,  $P < .03$ ). The postoperative ESS was similar in all groups (Kruskal-Wallis test,  $P = .23$ ). ESS reduction is given in Table I. Only a tendency of increased ESS responder rates by grade

TABLE I.  
Patient Characteristics by Brodsky Tonsil Grade.

Variables	Grade 1	Grade 2	Grade 3	Grade 4	P Value
No. of patients	23 (33.3%)	32 (46.4%)	14 (20.3%)	1 (1.4%)	
Age, yr	43.6 ± 8.2	48.2 ± 9.9	45.9 ± 14.2	48	.446*
Gender, male	22 (95.7%)	30 (93.8%)	13 (92.9%)	0	.097 <sup>†</sup>
BMI	27.5 ± 3.1	29.2 ± 4.6	26.7 ± 4	24.7	.271*
Nasal surgery	16 (69.6%)	13 (40.6%)	8 (57.1%)	0	.126 <sup>‡</sup>
Neck circumference	40.9 ± 3.5	42.2 ± 3.2	40.9 ± 2.4	NA	.446*
Tonsil volume	4.9 ± 1.9	6.1 ± 2.1	10.9 ± 3.3	8	<.0001*
Apnea-hypopnea index					
No. for AHI	23	32	14	1	.0041*
AHI preoperative	24.7 ± 16.9	31.7 ± 19	42.9 ± 17.8	69.7	.0015*
AHI supine preoperative	37.3 ± 24.7	38.4 ± 14	60.9 ± 18.9	NA	.4364*
AHI postoperative	16.1 ± 9.8	16.6 ± 14.5	17.3 ± 15.4	2.6	
AHI supine postoperative	29.4 ± 23.3	23.6 ± 20.6	26.8 ± 22.9	NA	.4786*
AHI responder	6 (26.1%)	15 (46.9%)	10 (71.4%)	1 (100%)	.0366 <sup>‡</sup>
Epworth Sleepiness Scale					
No. for ESS	17	26	12	1	
ESS preoperative	6.8 ± 4.5	10.4 ± 4.1	10.1 ± 4.5	18	.0088*
ESS postoperative	2.9 ± 3.1	4.8 ± 3.6	3.0 ± 1.8	2	.2273*
ESS responder	11 (64.7%)	13 (50%)	12 (92.3%)	1 (100%)	.0612 <sup>‡</sup>
Snoring index					
No. for SI	16	23	13	1	
SI preoperative	7.9 ± 2	7.9 ± 2.1	8.8 ± 1.7	8	.3168*
SI postoperative	3.1 ± 2.4	3.5 ± 2	2.6 ± 1.6	2	.3223*
SI responder	12 (75%)	11 (47.8%)	10 (76.9%)	1 (100%)	.1744 <sup>‡</sup>

Values are given as mean and standard deviation or as number of observations and percentage.

\*Kruskal-Wallis test.

<sup>†</sup>Fisher exact test.

<sup>‡</sup> $\chi^2$  test.

AHI = apnea-hypopnea index; BMI = body mass index; ESS = Epworth Sleepiness Scale; SI = snoring index.

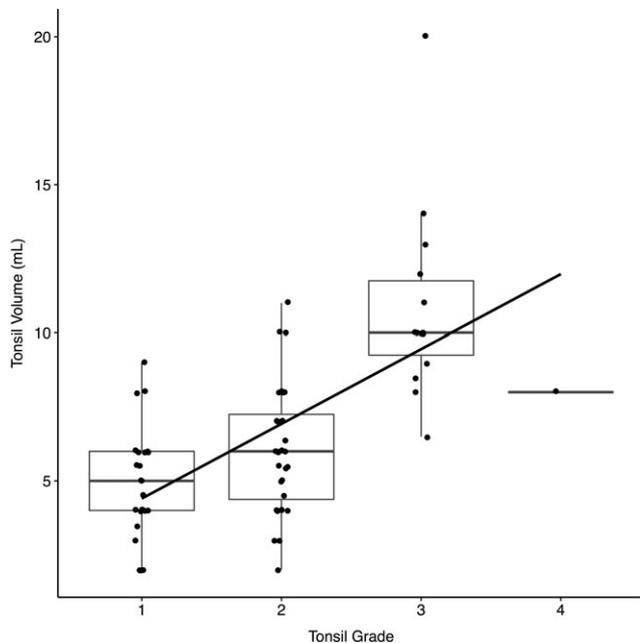


Fig. 1. Relationship between tonsil volume and Brodsky tonsil grade.

( $\chi^2$  test,  $P = .061$ ) and volume (Wilcoxon test,  $P = .17$ ) could be found, but it did not reach significance.

### Snoring by Grade and Volume

There was no significant correlation between tonsil grade or volume and preoperative or postoperative snoring (Spearman correlation,  $P > .05$ ). Also, no significant difference in SI responder rates was found regarding tonsil volume or grade ( $\chi^2$  and Wilcoxon test,  $P > .05$ ). The reduction of SI was highly significant for all tonsil grades (Wilcoxon test,  $P < .0001$ ). SI reduction increased with volume and grade, but this tendency did not reach significance (Kruskal-Wallis test and Spearman's correlation,  $P > .05$ ). SI responder rate was not significantly influenced by tonsil grade and volume (Table I).

### Modified Friedman Staging System of OSA

In our cohort, the modified Friedman stage of OSA did not correlate significantly with pre- or postoperative AHI (Kruskal-Wallis test,  $P > .05$ ). The correlation between absolute AHI reduction and Friedman stage of OSA did not reach the level of significance (Spearman's

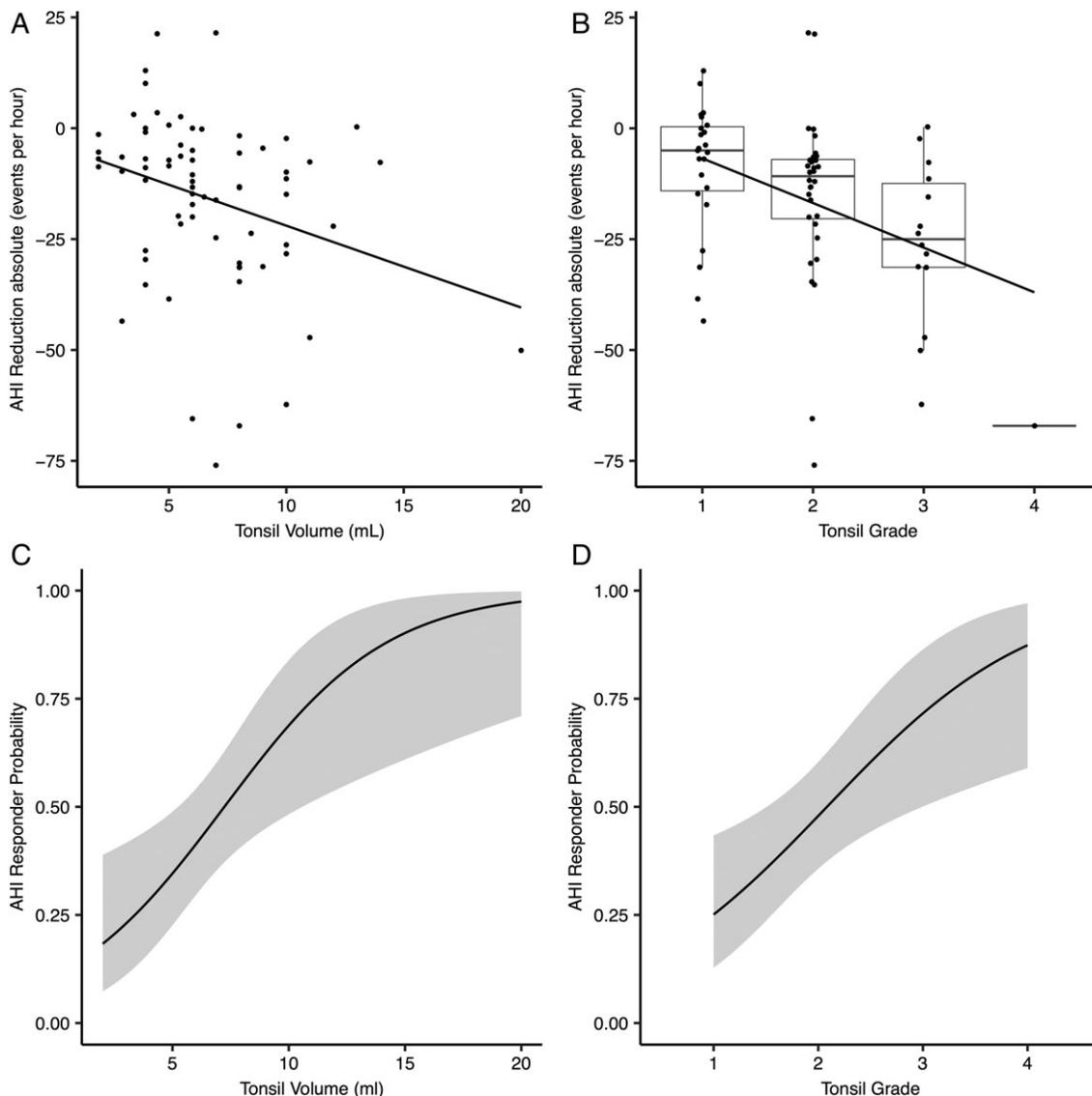


Fig. 2. AHI outcome. AHI reduction versus tonsil volume (A) and versus Brodsky tonsil grade (B). Logistic model of the AHI responder rate (according to Sher) versus tonsil volume (C) and versus Brodsky tonsil grade (D). AHI = apnea-hypopnea index.

correlation,  $P = .07$ ). No correlation was found between responder and Friedman stage of OSA ( $\chi^2$ ,  $P > .05$ ).

### Patient Satisfaction

General satisfaction after UPPP with TE and RFA was very high. Overall, 92.5% of patients reported that they would undergo the surgery again, and 94.3% would recommend it to a friend.

### DISCUSSION

Our patient cohort was predominantly male, moderately overweight, and middle aged. The study group mainly consisted of tonsil grades 1 to 3. Only one patient had grade 4 tonsils in accordance with clinical experience that grade 4 tonsils are rare in adult patients.

Tonsil grade reflected tonsil volume very well. A higher tonsil grade was strongly correlated with larger

tonsil volume. The preoperative AHI increased with tonsil grade. These findings are in accordance with reports in the literature.<sup>8</sup> To the best of our knowledge, our study is the first to show that the reduction of preoperative AHI as well as the responder rate is strongly correlated with tonsil grade and tonsil volume. The authors therefore believe that ENT examination with assessment of the Brodsky tonsil grade is a very meaningful predictor of the outcome of UPPP with TE and RFA.

Interrater variability is an important issue for any clinical staging system. A high interexaminer agreement has been reported for tonsil size and tongue position with an interclass correlation coefficient of 0.89 and 0.93, respectively.<sup>16,17</sup> This is in agreement with the findings of Friedman et al. for the tongue position.<sup>18</sup> Ng et al. showed that interexaminer agreement in evaluating tonsil size using the Brodsky grading scale is very high.<sup>16</sup> In our study, tonsil volume was not statistically different between Brodsky tonsil grades 1 and 2. A different intramural position of

tonsils with low volumes may explain this finding rather than the interexaminer variability.

The Friedman staging of OSA involves tonsil grade, Friedman tongue position, and BMI greater than or less than 40 kg/m<sup>2</sup>. In our cohort no patient had an OSA stage of 4. OSA stage was developed as a predictor for the success of UPPP. In our cohort the postoperative AHI increased with OSA stage, but the trend did not reach significance. AHI responder rates were not significantly different for the OSA stages. In agreement with Friedman et al.,<sup>13</sup> we found a significant correlation of tonsil size and tongue position with postoperative AHI and AHI reduction. In the authors' opinion, a larger patient population is necessary to fully explain these findings.

Preoperative ESS was lower in tonsil grade 1 than in other groups in accordance with a mostly mild degree of OSA. In contrast to AHI, the reduction of ESS was not significantly correlated with tonsil grade or volume. This is in accordance with the literature, which found no correlation between AHI and daytime sleepiness.<sup>19</sup> The causal factors for daytime sleepiness are not yet well established. Individual daytime sleepiness is rather determined in a multifactorial way and cannot be explained by simple measures of the severity of sleep-related breathing disorders such as AHI.

No significant correlation between SI and tonsil volume or grade was found. This might suggest that the perception of snoring is less dependent on physical factors such as tonsil size or AHI. This corresponds with the difficulty to correlate snoring with acoustic parameters, leaving to date the severity of snoring to the subjective assessment by the beholder's ear.<sup>20</sup>

Patients with tonsil grade 1 usually suffer only from mild OSA, and snoring or daytime sleepiness might be chief complaint. Potential benefits need to be carefully weighed against the risks of surgical intervention when counseling these patients.

This study has several limitations. Data were collected prospectively but analyzed retrospectively. Our cohort was predominantly male and included only five female patients limiting the generalizability of our results to this group of patients. Another limitation is that no patient had a BMI  $\leq 18.5$  kg/m<sup>2</sup> or  $\geq 35$  kg/m<sup>2</sup>. Therefore, our results may not apply to these patients. Patients with concomitant nasal septum surgery were included in the study. However, a meta-analysis by Ishii et al. showed that nasal surgery does not affect AHI outcomes.<sup>21</sup> Another weak point of this study is that multiple surgeons clinically evaluated the patients preoperatively. However, as shown above, interrater variability for tonsil size and tongue position is low.<sup>16,17</sup> The great night-to-night variability of AHI is a general challenge in sleep medicine and applies also to our study. Multiple measurements, especially at home, could reduce variability.<sup>22,23</sup>

The exclusion criteria were concomitant procedures other than nasal surgery and AHI values  $<10$ /hr. Therefore, the results might be generalized for all OSA patients undergoing UPPP with TE and RFA.

In our study cohort, UPPP with TE and RFA of the soft palate was performed. Many variations of UPPP procedures have been published. However, the removal of

the palatine tonsils seems to be the most decisive factor for therapeutic success. A comparative study between TE and RFA combined with expansion sphincteroplasty and TE and RFA of the soft palate alone showed similar results.<sup>24</sup> Therefore, our results may also be applied for other modifications of UPPP involving TE and RFA.

Many modifications of UPPP have been proposed. However, tonsil size has mostly not been specified. The neglect of tonsil size and volume may be an important confounder when comparing modifications of UPPP with TE and RFA. The authors believe that tonsil size and volume are key factors of outcome in OSA surgery.

## CONCLUSION

Preoperative AHI, AHI reduction after UPPP with TE and RFA, and the responder rate according to the Sher criteria are strongly correlated with tonsil grade and tonsil volume. Large tonsils are therefore responsible for higher preoperative values, and their removal leads to a greater reduction of initial AHI. However, the postoperative effect on daytime sleepiness and snoring reduction is not significantly correlated with tonsil size and volume, indicating that these parameters are influenced by other factors. The knowledge of the significance of tonsil size and volume is important for ENT physicians when counseling OSA patients about the possible surgical benefit of UPPP with TE and RFA.

## BIBLIOGRAPHY

1. Doherty LS, Kiely JL, Swan V, McNicholas WT. Long-term effects of nasal continuous positive airway pressure therapy on cardiovascular outcomes in sleep apnea syndrome. *Chest* 2005;127:2076–2084.
2. Lai C-C, Friedman M, Lin H-C, et al. Objective versus subjective measurements of palatine tonsil size in adult patients with obstructive sleep apnea/hypopnea syndrome. *Eur Arch Otorhinolaryngol* 2014;271:2305–2310.
3. Lin H-C, Friedman M, Chang H-W, Gurpinar B. The efficacy of multilevel surgery of the upper airway in adults with obstructive sleep apnea/hypopnea syndrome. *Laryngoscope* 2008;118:902–908.
4. Friedman M, Vidyasagar R, Bliznikas D, Joseph N. Does severity of obstructive sleep apnea/hypopnea syndrome predict uvulopalatopharyngoplasty outcome? *Laryngoscope* 2005;115:2109–2113.
5. Sommer JU, Heiser C, Gahleitner C, et al. Tonsillectomy with uvulopalatopharyngoplasty in obstructive sleep apnea. *Dtsch Arztebl Int* 2016;113:1–8.
6. Maurer JT. Update on surgical treatments for sleep apnea. *Swiss Med Wkly* 2009;139:624–629.
7. Tschopp K, Zumbunn T, Knaus C, Thomaser E, Fabbro T. Statistical model for postoperative apnea-hypopnea index after multilevel surgery for sleep-disordered breathing. *Eur Arch Otorhinolaryngol* 2011;268:1679–1685.
8. Jara SM, Weaver EM. Association of palatine tonsil size and obstructive sleep apnea in adults: tonsil size and sleep apnea in adults. *Laryngoscope* 2018;128:1002–1006.
9. Cahali MB, Soares CF de P, Dantas DA da S, Formigoni GGS. Tonsil volume, tonsil grade and obstructive sleep apnea: is there any meaningful correlation? *Clinics* 2011;66:1347–1352.
10. Friedman M, Tanyeri H, La Rosa M, et al. Clinical predictors of obstructive sleep apnea. *Laryngoscope* 1999;109:1901–1907.
11. Sahin M, Bilgen C, Tasbakan MS, Midilli R, Basoglu OK. A clinical prediction formula for apnea-hypopnea index. *Int J Otolaryngol* 2014;2014:1–5.
12. Brodsky L, Moore L, Stanievich JF. A comparison of tonsillar size and oropharyngeal dimensions in children with obstructive adenotonsillar hypertrophy. *Int J Pediatr Otorhinolaryngol* 1987;13:149–156.
13. Friedman M, Ibrahim H, Bass L. Clinical staging for sleep-disordered breathing. *Otolaryngol Head Neck Surg* 2002;127:13–21.
14. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* 1991;14:540–545.
15. Sher AE, Schechtman KB, Piccirilli JF. The efficacy of surgical modifications of the upper airway in adults with obstructive sleep apnea syndrome. *Sleep* 1996;19:156–177.
16. Ng SK, Lee DLY, Li AM, Wing YK, Tong MCF. Reproducibility of clinical grading of tonsillar size. *Arch Otolaryngol Head Neck Surg* 2010;136:159.

17. Fischer Y, Neagos A, Gronau S, Rettinger G. Examiner variability of clinical findings in patients with sleep related breathing disorders [in German]. *Laryngorhinootologie* 2006;85:338–343.
18. Friedman M, Soans R, Gurpinar B, Lin H-C, Joseph NJ. Interexaminer agreement of Friedman tongue positions for staging of obstructive sleep apnea/hypopnea syndrome. *Otolaryngol Head Neck Surg* 2008;139:372–377.
19. Strollo PJ, Gillespie MB, Soose RJ, et al. Upper airway stimulation for obstructive sleep apnea: durability of the treatment effect at 18 months. *Sleep* 2015;38:1593–1598.
20. Hoffstein V, Mateika S, Anderson D. Snoring: is it in the ear of the beholder? *Sleep* 1994;17:522–526.
21. Ishii L, Roxbury C, Godoy A, Ishman S, Ishii M. Does nasal surgery improve OSA in patients with nasal obstruction and OSA? A meta-analysis. *Otolaryngol Head Neck Surg* 2015;153:326–333.
22. Bittencourt LR, Suchecki D, Tufik S, et al. The variability of the apnoea-hypopnoea index. *J Sleep Res* 2001;10:245–251.
23. Stepnowsky CJ, Orr WC, Davidson TM. Nightly variability of sleep-disordered breathing measured over 3 nights. *Otolaryngol Head Neck Surg* 2004;131:837–843.
24. Brumann M, Horvath L, Zehnder J, Tschopp K. Comparison of functional expansion pharyngoplasty with radiofrequency volume reduction of the soft palate in surgery for sleep-related breathing disorders. *J Clin Sleep Med* 2017;4:1073.