Article published online: 2023-04-28

The Effect of Tonsillectomy and Adenoidectomy on Upper Airway Obstruction Patterns in Children with Obstructive Sleep Apnea

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Int Arch Otorhinolaryngol 2023;27(2):e211–e217.

Abstract

Introduction Alterations in upper airway flow dynamics and sites of airway obstruction immediately after tonsillectomy and adenoidectomy (TA) have not been assessed. Identification of the changes in airway obstruction patterns after TA potentially improves the surgical management of children with obstructive sleep apnea (OSA).

Objective To evaluate the effect of TA on upper airway obstruction patterns detected with drug-induced sleep endoscopy (DISE).

Methods The medical records of patients who underwent pre-TA DISE during the induction of anesthesia and post-TA DISE at the end of TA were reviewed. Data pertaining to polysomnography and DISE findings were analyzed.

Results Twenty-seven patients (15 male and 12 females aged between 2 and 18 years old) were identified. All patients had obstruction at multiple sites of the upper airway. Prior to TA, airway obstruction was at the level of the velum in 27 patients, of the oropharynx/lateral walls in 27, of the tongue in 7, and of the epiglottis in 4. After TA, airway obstruction was at the level of the velum in 24 patients, of the oropharynx/lateral walls in 16, of the tongue in 6, and of the epiglottis in 4. The degree of obstruction at the levels of the velum and oropharynx/lateral walls after TA was significantly decreased.

Conclusions Drug-induced sleep endoscopy performed prior to TA revealed that most of the sites of airway obstruction persisted after TA in OSA children with multiple sites of airway obstruction. Further studies in larger group of children with OSA are needed to establish the value of DISE findings in predicting residual OSA after TA, surgical planning, determining the need for post TA sleep study, and counseling caregivers.

Keywords
- airway obstruction
- drug-induced sleep endoscopy
- obstructive sleep apnea
- tonsillectomy

received December 3, 2020
accepted May 24, 2021

DOI https://doi.org/10.1055/s-0043-1768207.
ISSN 1809-9777.

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Introduction

Children with obstructive sleep apnea (OSA) have single or multiple sites of airway obstruction.[1] Tonsillectomy and adenoidectomy (TA) is performed as the first-line treatment because enlarged tonsils and adenoids are commonly encountered in children with OSA. The rate of residual OSA after TA ranges from 21 to 75%.[2–5] Identification of the sites of airway obstruction in surgically naïve children has potential to aid in tailoring individual surgical treatments, reducing the incidence of residual OSA after TA, and minimizing the need for additional airway surgery and general anesthesia. In cases in which caregivers may prefer staged sleep surgery, airway obstruction sites identified at the time of TA may be used to plan additional sleep surgery in children with residual OSA after TA.

Drug-induced sleep endoscopy (DISE) is used to evaluate upper airway obstruction patterns and surgical planning prior to or after TA in children with OSA.[1,6–12] Upper airway flow dynamics and sites of airway obstruction prior to TA may be altered after TA. Plausibly, DISE findings obtained prior to TA may not be useful to plan surgical management of residual OSA after TA. Better understanding of the changes in airway obstruction patterns after TA potentially improves the surgical management of children with OSA. Our aim was to evaluate the effect of TA on upper airway obstruction patterns detected with DISE in children with OSA.

Materials and Methods

The present study was approved by the local institutional human research review board and informed consent was waived. The charts of patients who had undergone DISE between June 2016 and June 2018 were reviewed retrospectively. Patients were identified using an electronic medical record system. Patients who were < 18 years old and underwent DISE before and after surgery at the time of TA were included in the study. Documentation of OSA with preoperative polysomnography (PSG) was the second inclusion criteria. Patients with a history of craniofacial anomalies, developmental delay, psychiatric illness, neoplasia, post-transplant lymphoproliferative disorder, and a previous history of upper airway surgery including tonsillectomy, adenoidectomy, palatoplasty, pharyngoplasty, turbinate reduction, septoplasty, supraglottoplasty, and tracheostomy were excluded.

The patients underwent an all-night, attended PSG in a sleep laboratory of a tertiary care children hospital. American Academy of Sleep Medicine criteria were used to determine sleep measurements. The obstructive apnea hypopnea index (oAHI) was defined as the sum of obstructive apneas and hypopneas per hour. The severity of OSA was classified according to the oAHI: mild, AHI between 1 and 5; moderate, AHI between 5 and 10; or severe, AHI > 10.[2]

The DISE was performed during induction of anesthesia for TA and after completion of TA by the senior author in all patients using the previously reported DISE technique.[1] All patients received nitrous oxide 70% in oxygen and 7% sevoflurane via a face mask during induction of general anesthesia. The sevoflurane was switched off after insertion of an intravenous catheter. While the patient was spontaneously breathing 100% O2, 1 mcg/kg of dexmedetomidine and 4 mcg/kg of glycopyrrolate were administered. Then, the patients were allowed to emerge from sevoflurane anesthesia while being deeply sedated with dexmedetomidine. After performing endoscopy, a combined sevoflurane-opiate technique was used to maintain anesthesia. The trachea of the patient was intubated, and TA were performed. Upon completion of TA and with the patient awake but still sedated, the trachea was extubated, and endoscopy was performed to evaluate the airway obstruction during emergence from anesthesia. The intranasal cavity, the nasopharynx, the soft palate, the base of tongue, the pharyngeal walls, and the laryngeal structure were examined while the child was breathing spontaneously. The endoscope was positioned at multiple levels of the upper airway to assess obstruction.

Recordings of DISE were analyzed by the authors, who had no knowledge of the patient identity and of the severity of the OSA. Postoperative DISE recordings were analyzed without the knowledge of the preoperative DISE findings. The DISE procedures were recorded on MPEG-1 digital format and were reviewed using Nero Platinum software (Glendale, CA, USA, Nero), allowing frame-to-frame analysis of the video, and measurements were made of the images.

The sites of airway obstruction and degree of airway obstruction were measured at the levels of the velum, of the oropharynx/lateral pharyngeal walls, of the tongue, and of the epiglottis. The most and least obstructed points in the respiratory cycle were used to evaluate the degree of site-specific airway obstruction based on single dimension measurement.[12] The degree of site-specific airway obstruction was assessed based on diameter. Cross-sectional area measurement was not performed. Anteroposterior obstruction was evaluated at the levels of the velum, of the tongue, and of the epiglottis. Lateral obstruction was evaluated at the level of the oropharynx/lateral walls. At the level of the oropharynx/lateral walls, invisible palatine tonsils and unobstructed view of tongue base were considered no obstruction. At the level of the velum, no obstruction was defined as complete view of the tongue base and/or of the larynx. Complete view of the vallecula in the absence of lingual tonsil hypertrophy was considered no obstruction at the level of the tongue. At the level of the epiglottis, unobstructed view of the glottis was considered no obstruction. Image (National Institutes of Health, Bethesda, Maryland, USA), an open-source image processing software, was used to measure airway obstruction on the still images.[13] The percentage of airway obstruction was calculated at the level of the velum while the endoscope was positioned at the level of the nasopharynx, and it was calculated at the levels of the oropharynx/lateral pharyngeal walls, of the base of the tongue, and of the epiglottis while the endoscope was positioned at the level of the tip of the uvula.

Data pertaining to age, gender, body mass index (BMI), past medical history, past surgical history, and PSG results were obtained from medical charts. The BMI percentile was calculated according to Centers for Disease Control and

Prevention growth standards. The patients were categorized into obese and nonobese groups based on the BMI percentile. The obese group included children with a BMI > 95th percentile. Children in the nonobese group were further categorized into 3 subgroups: overweight (85th < BMI < 95th percentile), normal weight (5th < BMI < 85th percentile), and underweight (BMI < 5th percentile). Patients were categorized into the following age groups: toddler (1 to 3 years old), preschooler (3 to 5 years old), middle childhood (6 to 11 years old), and teenager (12 to 18 years old).[5] The effects of age, obesity, comorbidity, and severity of OSA on airway obstruction patterns were assessed.

Statistical comparisons between pre- and post- TA percentage of airway obstruction at the velum, the oropharynx/lateral pharyngeal walls, the tongue, and the epiglottis were performed using parametric (Student *t*-test) and nonparametric (Mann-Whitney U test) tests, as appropriate. Comparisons of rate of resolution of airway obstruction at the level of the velum, of the oropharynx/lateral pharyngeal walls, of the tongue, and of the epiglottis were performed by a chi-squared test or by the Fisher exact test, as appropriate. A p-value < 0.05 was deemed statistically significant. Data are presented as mean ± standard deviation (SD).

Results

Twenty-seven patients (15 male, 12 females) aged between 2 and 18 years old (7 ± 4 years old) underwent pre- and postsurgery DISE with no complications on the day of TA (►**Table 1**). The distribution of age groups of patients was 4 toddlers, 10 preschoolers, 10 middle childhood, and 3 teenagers. Of the 27 patients, 7 had comorbidities; 4 had asthma, 2 had a history of seizure, and 1 had hypothyroidism. The BMI percentile ranged from 14.7 to 99.9% (mean, 78; median, 94.7; mean z-score = 1.43). Sixteen patients were obese, and 11 patients were nonobese. The oAHI ranged from 1.8 to 154 events/hr (22.5 ± 33; median = 14.5). The severity of OSA was mild in 6 patients, moderate in 6, and severe in 15. The preoperative oAHI was not significantly different amongst the age, comorbidity, and weight subgroups.

The DISE showed obstruction at the level of the velum in all patients, of the oropharynx/lateral walls in all patients, of the tongue in 7 patients, and of the epiglottis in 4 patients before TA (►**Fig. 1**, ►**Table 2**). All patients had obstruction at multiple sites of the upper airway (►**Table 2**). The obstruction sites were the velum and the oropharynx/lateral walls in 18 patients, the velum/oropharynx/lateral pharyngeal walls/tongue in 5, the velum/oropharynx/lateral walls/epiglottis in 2, and the velum/oropharynx/lateral walls/tongue/epiglottis in 2. After TA, airway obstruction was at the level of the velum in 24 patients, of the oropharynx/lateral pharyngeal walls in 16, of the tongue in 6, and of the epiglottis in 4 (►**Table 2**). Most of the airway sites had a resolution or decrease in the obstruction after TA. The rate of resolution of obstruction at the level of the oropharynx/lateral pharyngeal walls (44%) was higher than that of at the level of the velum (14%), of the tongue (14%), and of the epiglottis (25%) ($p = 0.03$). The rate of resolution of obstruction was not significantly different amongst the age, comorbidity, weight category, and severity of OSA subgroups ($p > 0.05$). Caregivers reported subjective improvement of snoring in all children.

The percentage of obstruction at the level of the velum (60 ± 6%) and of the oropharynx/lateral pharyngeal walls (25 ± 5%) after TA was significantly lower than that of before TA (80 ± 3%; 83 ± 3%) ($p = 0.004$; $p < 0.001$) (►**Table 3**). The degree of obstruction at the levels of the tongue and of the epiglottis after TA (14 ± 2%, 4 ± 2%) was similar to that of before TA (14 ± 4%, 8 ± 4%; $p = 0.8$; $p = 0.2$).

Discussion

In-depth evaluation of upper airway obstruction is critical to better understand the characteristics of the airway obstruction and to develop effective surgical treatment plans in children with OSA. Drug-induced sleep endoscopy has been

Table 1 Characteristics of patients with obstructive sleep apnea

Patient Characteristics	Entire Group (*n* = 27)	Mild OSA (*n* = 6)	Moderate OSA (*n* = 6)	Severe OSA (*n* = 15)
Age (years old)	7 ± 4	7 ± 2	6 ± 5	7 ± 4
Toddler (n)	4	0	1	3
Preschooler (n)	10	2	3	5
Middle childhood (n)	10	4	1	5
Teenager (n)	3	0	1	2
Gender	15M, 12F	5M,1F	5M,1F	5M,10F
BMI percentile	78 ± 30	93 ± 7	72 ± 40	76 ± 3
Obese (n)	16	2	4	10
Nonobese (n)	11	4	2	5
Comorbidity absent (n)	20	3	5	12
Comorbidity present (n)	7	3	1	3
oAHI (events/hr)	22 ± 33	3 ± 0.8	7 ± 0.7	36 ± 39

Abbreviations: BMI, body mass index; F, female; M, male; oAHI, obstructive apnea hypopnea index; OSA, obstructive sleep apnea; y, year.

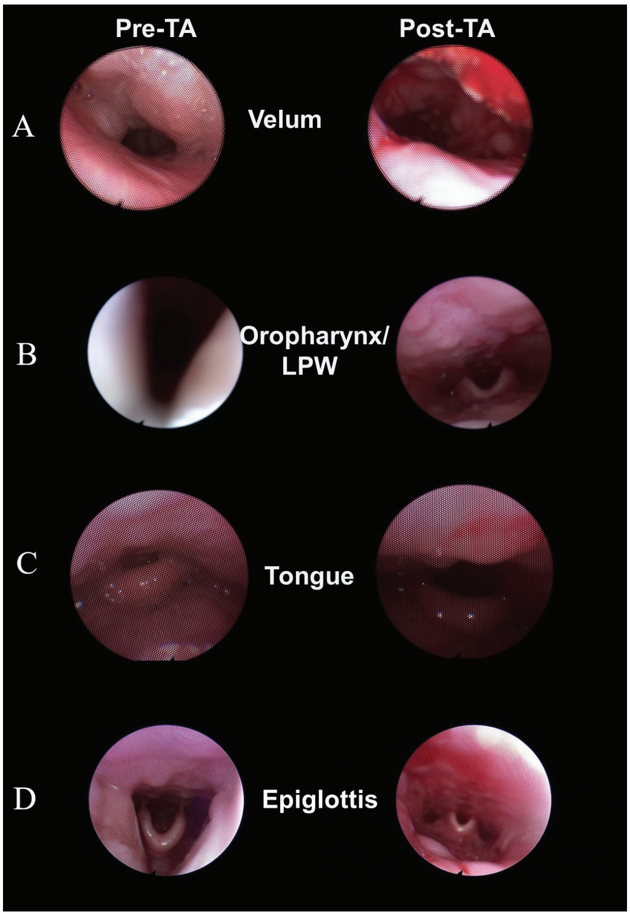

Fig. 1 Representative images showing the obstruction at the levels of the velum, oropharynx/lateral pharyngeal wall (LPW), tongue and epiglottis pre-and post-tonsillectomy.

increasingly used to assess upper airway obstruction in children with OSA; however, the role of systematic use of DISE in the routine work-up of children with OSA is not yet established.[14] The use of DISE prior to TA in surgically naïve children with OSA has potential to identify additional surgical targets that could be addressed at the time of TA or during a second stage procedure.[15–17] However, DISE prior to TA is not widely used because TA may alter upper-airway flow dynamics.[14] The present study is the first report on how TA alters upper airway obstruction patterns in children with OSA.

By performing DISE both before and after TA, we determined that while airway obstruction improved at both the velum and oropharynx/lateral pharyngeal walls after TA, there was no statistically significant change in the airway obstruction at the tongue and epiglottis. Therefore, airway obstruction noted at the tongue and epiglottis during a DISE done before TA can be presumed to still be present after TA. Thus, DISE findings obtained prior to TA may still be useful when planning post-TA management of residual OSA in children. Similar to our findings, previous studies documented upper airway obstruction due to the tongue or epiglottis in surgically naïve children with OSA as well as in children with residual OSA.[18,19]

Drug-induced sleep endoscopy facilitates targeted surgical approaches and individualized surgical treatments while avoiding failures after TA.[18,20–25] The use of DISE at the time of TA in surgically naïve infants and children with OSA altered the surgical decision making in 35% of infants and in 24% of older children. Instead of TA, these children had tonsillectomy alone, adenoidectomy alone, medical treatment, or orthodontic treatment.[25] Drug-induced sleep endoscopy findings prior to TA in children with risk factors for residual OSA resulted in an intervention other than TA in 58% of surgically naïve children.[21] As performing DISE prior to TA improves surgical outcomes and potentially better predicts TA failures in surgically naïve children, pre-TA DISE is recommended in the presence of high risk for residual OSA after TA or uncertainty about the optimal surgical treatment.[21,23–25]

Findings of DISE performed at the time of TA in surgically naïve children may be used to discuss treatment options for children with residual OSA after TA, thus obviating the need for a second diagnostic procedure under general anesthesia.[25] In the present study, residual upper airway obstruction was documented after TA. Caregivers reported subjective improvement of snoring after TA; however, the intensity, duration, and frequency of snoring and OSA symptoms were not systematically documented before and after TA. We could not evaluate the role of our findings in predicting residual OSA due to limited availability of postoperative PSG. However, DISE-directed surgery at the time of TA in surgically naïve children resulted in in reducing oAHI in 79% of subjects [21]. Prospective studies investigating predictive value of pre-TA DISE findings in detecting residual OSA are needed in larger groups of children with varying degrees of OSA.

The optimal use of pre-TA DISE findings in decision-making and surgical planning is not established. Changes in therapeutic decisions and surgical intervention at the time of TA have been reported in surgically naïve children with OSA. Outcomes of altered surgical intervention were similar to outcomes of TA.[25] In children with multiple levels of upper airway obstruction, step-by-step surgery was recommended due to the increased risk of complications associated with surgery at multiple levels. The timing of additional procedures identified by the DISE procedure should be decided on a case-by-case basis.

The limitations of our study included the small number of patients in age subgroups and OSA severity, the methodology used to quantify the airway obstruction, and effect of depth of anesthesia at the time of TA and after TA.

Preschooler and middle childhood children were predominant in the present study. Small numbers of toddlers and teenagers were included. Most children had severe OSA, and few children had mild OSA or moderate OSA. The disproportionate representation of subgroups of age and severity of OSA may influence the outcomes of comparisons; therefore, our results regarding the rate of resolution of obstruction amongst the age and severity of OSA subgroups should be interpreted carefully.

The ability to quantify obstruction at the culprit anatomic sites would be of paramount value. An ideal methodology to quantify the airway obstruction observed during DISE in

Table 2 Pre- and postsurgery sites and degree of airway obstruction at the time of tonsillectomy and adenoidectomy

Patient	Velum		Oropharynx/Lateral Walls		Tongue		Epiglottis	
	Presurgery	*Postsurgery*	*Presurgery*	*Postsurgery*	*Presurgery*	*Postsurgery*	*Presurgery*	*Postsurgery*
1	80%	80%	80%	80%	60%	50%	0%	0%
2	100%	0%	70%	30%	20%	30%	40%	50%
3	80%	80%	100%	0%	0%	0%	0%	0%
4	100%	50%	100%	50%	0%	0%	0%	0%
5	50%	30%	100%	0%	0%	0%	50%	30%
6	90%	40%	80%	20%	0%	50%	0%	0%
7	60%	0%	60%	40%	0%	0%	0%	0%
8	100%	0%	100%	60%	0%	0%	0%	0%
9	70%	80%	80%	70%	50%	50%	0%	0%
10	90%	100%	80%	0%	50%	0%	0%	0%
11	100%	0%	100%	0%	0%	0%	0%	0%
12	100%	80%	100%	30%	0%	0%	0%	0%
13	80%	80%	100%	50%	0%	0%	0%	0%
14	70%	90%	60%	0%	0%	0%	0%	0%
15	30%	70%	40%	0%	0%	0%	80%	0%
16	90%	100%	100%	50%	0%	0%	0%	0%
17	90%	20%	90%	20%	70%	0%	0%	0%
18	50%	70%	100%	0%	0%	0%	0%	0%
19	100%	80%	100%	50%	0%	0%	0%	0%
20	100%	80%	80%	0%	0%	0%	0%	0%
21	90%	80%	100%	20%	0%	0%	0%	0%
22	50%	20%	50%	0%	0%	0%	50%	40%
23	100%	20%	100%	0%	0%	0%	0%	0%
24	80%	50%	50%	0%	50%	50%	0%	0%
25	80%	80%	50%	20%	80%	80%	0%	0%
26	80%	70%	100%	80%	0%	0%	0%	0%
27	100%	50%	80%	0%	0%	0%	0%	0%

children has not been identified. Cross-sectional area, volume, and single dimension measurements can be used to evaluate the airway obstruction. The utility of varying quantification methods in the assessment of airway obstruction as detected with DISE merits further investigation.

The effect of a variety of anesthetics has been evaluated in adults and in children.[26] We used dexmedetomidine to perform DISE prior to TA because dexmedetomidine preserves spontaneous respiration and has minimal effect on respiratory control and on upper airway crosssectional area.[1] After TA, we performed DISE during emergence from anesthesia. Emergence is a passive process with the gradual return of consciousness. The ideal depth of sedation was critical in accurately identifying the anatomical segment obstructing the upper airway. We performed DISE while a stable pattern of light sedation, characterized by

Table 3 Comparison of pre- and postsurgery degree of airway obstruction at the time of tonsillectomy and adenoidectomy

	Velum	Oropharynx/Lateral Walls	Tongue	Epiglottis
Presurgery	$80 \pm 3\%$	$83 \pm 3\%$	$14 \pm 4\%$	$8 \pm 4\%$
Postsurgery	$60 \pm 6\%$	$25 \pm 5\%$	$14 \pm 2\%$	$4 \pm 2\%$
***p*-value**	0.004	< 0.001	0.8	0.2

transitioning from consciousness to unconsciousness, was maintained. We ensured a uniform assessment of the upper airway obstruction by observing three repeated cycles of snoring and airway obstruction while oxygenation was monitored. The potential for false positives with varying degrees of sedation between pre- and post-TA DISE cannot be eliminated. The difference in upper airway muscle activity and tone before and after TA potentially influenced airway obstruction. Plausibly, exaggerated dynamic airway collapse due to the level of anesthesia influenced our findings of residual obstruction as well as increased the percentage of obstruction. Nevertheless, we observed a reduction of the obstruction at the level of the velum and of the oropharynx/lateral pharyngeal walls in most children with OSA in spite of possible residual effects of anesthesia on the airway muscular tone.

An ideal study to determine the effect of TA on upper airway dynamics would require that airway obstruction be assessed at the same level of anesthesia depth before and after DISE TA and under nearphysiologic conditions, with avoidance of significant airway collapse, respiratory depression, and cardiovascular effects.

Conclusions

Drug-induced sleep endoscopy performed prior to TA revealed that most of the sites of airway obstruction persisted after TA in this group of OSA children with multiple sites of airway obstruction. Tonsillectomy and adenoidectomy resulted in the resolution or reduction of the obstruction at the levels of the velum and of the oropharynx/lateral pharyngeal walls in most of the children with OSA. Further studies with larger groups of children with OSA are needed to assess the association between DISE findings obtained at the time of TA and post-TA PSG results to establish the value of DISE findings in predicting residual OSA after TA, surgical planning, determining the need for post TA sleep study, and counseling caregivers.

Financial Disclosure
The authors have no financial relationships to declare.

Conflict of Interests
The authors have no conflicts of interest to declare.

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