The Laryngoscope

Drug-Induced Sleep Endoscopy for Upper Airway Evaluation in Children With Obstructive Sleep Apnea

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Objectives/Hypothesis: To evaluate sites and characteristics of upper airway obstruction, as detected with drug-induced sleep endoscopy (DISE) in children with obstructive sleep apnea (OSA).

Material and Methods: The medical records of children who underwent DISE were reviewed. Data pertaining to demographics, past medical history, body mass index, tonsil size, adenoid size, polysomnography, and DISE were obtained.

Results: Eighty-two children had DISE and severity of OSA was mild in four patients, moderate in 17, and severe in 61. DISE revealed obstruction at the level of velum in 67 patients, oropharynx/lateral walls in 72 patients, tongue in 10 patients, and epiglottis in 10 patients. Oropharynx/lateral walls were the most common single site of obstruction. The majority of children had obstruction at multiple sites. Combination of velum and oropharynx/lateral walls was the most common multiple sites of obstruction. Prevalence of complete obstruction at velum and oropharynx/lateral walls in children with severe or moderate OSA were greater than those of children with mild OSA. Complete obstruction at oropharynx/lateral walls was documented in 50% of children with grade I tonsils and 64% of children with grade II tonsils.

Conclusion: The oropharynx/lateral walls are the most common site of obstruction in children with single site obstruction. Combined oropharynx/lateral walls and velum obstruction was the most common sites of obstruction in children with multiple site obstruction. Children with grade I and grade II tonsils may suffer from complete airway obstruction. DISE is a useful tool to identify upper airway obstruction sites in addition to adenotonsillar hypertrophy.

Key Words: Drug induced sleep endoscopy, obstructive sleep apnea, children.

Level of Evidence: 4.

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INTRODUCTION

Obstructive sleep apnea (OSA) is characterized by the reduction or complete cessation of breathing and increased respiratory effort in response to repetitive obstruction of the upper airway during sleep.[1] A wide variety of disorders and conditions have been implicated in the pathogenesis of OSA in children. Fixed and/or dynamic upper airway obstruction may occur due to anatomical factors and abnormal upper airway motor tone.[1] Enlarged adenoid and/or tonsils are commonly implicated in the pathogenesis of upper airway obstruction in children with OSA. Hence, tonsillectomy and/or adenoidectomy are performed in children with OSA. However, OSA persists in 21% to 75% of children after tonsillectomy and adenoidectomy.[2–5] Residual OSA after tonsillectomy and/or adenoidectomy corroborates the complex and multifactorial nature of the pathogenesis of upper airway obstruction in children with OSA. Better identification of the degree and site of upper airway obstruction potentially improves management of children with OSA.

Drug-induced sleep endoscopy (DISE) is a safe and cost-effective tool to evaluate multiple levels of upper airway during spontaneous ventilation while the patient is induced into pharmacologically produced unconscious sedation-simulating sleep.[6] DISE has been shown to be a valid and reliable method to evaluate site, degree, and configuration of upper airway obstruction in adults with OSA.[7–12] Furthermore, DISE findings are associated with outcomes of palate surgery.[13–14] In children with OSA, DISE-directed surgery resulted in improvement of OSA.[15] To date, the use of DISE to detect mechanisms and sites of upper airway obstruction in children with OSA has not been systematically studied. The aim of the present study was to evaluate sites and characteristics of upper airway obstruction, as detected with DISE in children with OSA.

MATERIALS AND METHODS

The charts of patients who had undergone DISE for upper airway evaluation as part of a clinical assessment between October 2010 and January 2012 were reviewed retrospectively.

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The study was approved by the Institutional Human Research Review Board. Patients with OSA documented by polysomnogram were included. Patients under the age of 21 years were eligible. Children were not excluded due to craniofacial anomalies, developmental delay, psychiatric illness, immunodeficiency, possible neoplasia, possible posttransplant lymphoproliferative disorder, or other chronic conditions.

An all-night, attended polysomnography was performed in the sleep laboratory using a computerized polygraph; sleep measurements were based on the criteria of the American Academy of Sleep Medicine. The apnea-hypopnea index (AHI) was calculated as the sum of apneas and hypopneas per hour. The severity of obstructive sleep apnea was categorized according to AHI: mild, AHI between 1 and 5; moderate, AHI between 5 and 10; or severe, AHI greater than 10.[16]

The DISE was performed during induction of anesthesia for tonsillectomy and adenoidectomy by the same otolaryngologist in all patients. Each patient was premedicated with oral midazolam (0.5 mg/kg) 20 minutes before inducing general anesthesia. The blood pressure, electrocardiography, pulse oximetry, end-tidal CO_2, and anesthetic concentrations were monitored in all patients. General anesthesia was induced with nitrous oxide 70% in oxygen and 7% sevoflurane via a face mask. After insertion of an intravenous catheter, the sevoflurane was switched off and 1 mcg/kg of dexmedetomidine, together with 4 mcg/kg of glycopyrrolate, were administered while the patient was spontaneously breathing 100% O2. During the following 3 to 5 minutes, the patients were allowed to emerge from sevoflurane anesthesia while being deeply sedated with dexmedetomidine. Following endoscopy, anesthesia was continued with a combined sevoflurane–opiate technique, the patient's trachea was intubated, and tonsillectomy and adenoidectomy was performed.

During the endoscopy procedure, the patient's neck was kept in a neutral position with the chin unsupported. A flexible endoscope with an outer diameter of 3.4 mm was inserted through the right nostril, leaving the other nostril patent. The intranasal cavity, nasopharynx, soft palate, base of tongue, pharyngeal walls, and laryngeal structure were examined while the child was breathing spontaneously. The endoscope was positioned at multiple levels of the upper airway to assess obstruction. DISE findings were analyzed using the previously reported VOTE classification: the location (velum, oropharynx/lateral walls, tongue base, epiglottis), pattern (anterior–posterior, concentric, laterolateral), and degree of obstruction.[17] The degree of obstruction for each structure was further categorized for each structure: 0, no obstruction (no vibration); 1, partial obstruction (vibration); 2, complete obstruction (collapse); X, not visualized. The analysis of DISE findings were performed by a single observer who had no knowledge of the severity of OSA. DISE was recorded on MPEG-1 digital format and were reviewed using software (Nero Platinum, Glendale, CA) allowing frame-to-frame analysis of the video and no objective measurements made of monitor images.

Tonsil size was assessed during oropharyngeal examination performed prior to surgery and was classified as follows: grade 0, limited to tonsil fossa; grade I, tonsils occupy less than 25% of oropharynx; grade II, tonsils occupy more than 25% and less than 50% of oropharynx; grade III, tonsils occupy more than 50% and less than 75% of oropharynx; or grade IV, tonsils occupy more than 75%.[18]

Adenoid size was classified by estimating the percentage of posterior choanae obstruction as follows: grade I, adenoid occluding less than 25% of posterior choanae; grade II, adenoid occluding than 25% and less than 50% of posterior choanae; grade III, adenoid occluding more than 50% and less than 75% of posterior choanae; or grade IV, adenoid occluding more than 75% of posterior choanae.

DISE findings are reported for the entire cohort and for subgroups of children with mild, moderate, and severe OSA. Data pertaining to age, gender, past medical history, comorbid conditions, body mass index (BMI), tonsil size, adenoid size, and findings of polysomnography were obtained from the charts. BMI z-score was calculated using Centers for Disease Control and Prevention growth standards. Children with a BMI z-score greater than 1.65 (95th percentile) were classified as obese.

Statistical comparisons between groups were performed using parametric (one-way analysis of variance) and nonparametric test (Kruskal Wallis one-way analysis of variance), as appropriate. Student-Newman–Keuls method or Dunn's method was used to identify which group or groups differed from the others. Comparisons of prevalence were performed by a chi-square test or Fisher exact test, as appropriate. A P value less than 0.05 deemed statistically significant. Data are presented as mean $\pm$standard deviation.

RESULTS

Eighty-two patients (39 male, 43 female), aged from 1.5 to 17 years (6 $\pm$3.7 years), have undergone DISE with no complications on the day of tonsillectomy and adenoidectomy. Comorbid conditions included asthma in 10 patients, seizure disorder in three patients, Down syndrome in two patients, congenital heart disease in one patient, autism in one patient, sickle cell disease in one patient, chronic lung disease in one patient, and neurofibromatosis in one patient. Of the 82 children, 61 children had severe OSA, 17 children had moderate OSA, and four children had mild OSA. Age and BMI were not significantly different among the groups of children with mild, moderate, and severe OSA (Table I). Children with severe OSA had greater AHI than children with mild OSA and moderate OSA ($P < 0.05$). Children with moderate OSA had greater AHI than children with mild OSA ($P < 0.05$).

The majority of children had grade III and grade IV hypertrophy of tonsils and adenoid (Table I). Of the 82 patients, four patients showed slightly deviated nasal septum. DISE showed obstruction at the level of velum in 67 patients, oropharynx/lateral walls in 72 patients, tongue in 10 patients, and epiglottis in 10 patients. Oropharynx/lateral walls were the most common site of obstruction in children with single- site obstruction (Table II). The majority of children had obstruction at multiple sites of the upper airway. Velum and oropharynx/lateral walls were the most common sites of obstruction in children with multiple-sites airway obstruction. The pattern of obstruction at each site is presented in Table III.

In children with mild OSA, single-site obstruction was documented in the majority of children (Table II). Oropharynx/lateral walls were the most common site of obstruction in children with mild OSA. The majority of children with moderate or severe OSA had obstruction in the multiple sites of upper airway. Velum and oropharynx/lateral walls were the most common sites of airway obstruction in children with moderate and severe OSA (Table II).

TABLE I.
Characteristics and Grading of Tonsil and Adenoid Size of Patients With OSA.

Patient Characteristics	Entire OSA Group (*n* = 82)	Mild OSA (*n* = 4)	Moderate OSA (*n* = 17)	Severe OSA (*n* = 61)
Age (range)	6 ±3.7 (1.5–17 y)	9.5 ±2.8 (7–12y)	6.2 ±3.5 (2–13y)	5.7 ±3.7 (1.5–17y)
Gender	39M, 43F	2M, 2F	7M, 10F	30M, 31F
BMI (kg/m2)	20 ±7	22 ±8	19 ±7	20 ±7
Obese (*n*)	30 (36%)	3 (75%)	3 (18%)	24 (39%)
Non-obese (*n*)	52 (64%)	1 (25%)	14 (82%)	37 (61%)
AHI (events/hr)	28 ±27	3.5 ±1.7	8.4 ±1.4	35.4 ±28.8
Tonsil size				
Grade I	9 (11%)	1 (25%)	2 (12%)	6 (10%)
Grade II	22 (27%)	1 (25%)	6 (35%)	15 (25%)
Grade III	29 (35%)	1 (25%)	6 (35%)	22 (36%)
Grade IV	22 (27%)	1 (25%)	3 (18%)	18 (29%)
Adenoid size				
Grade I	6 (7%)	0	2 (12%)	4 (7%)
Grade II	11 (13%)	1 (25%)	2 (12%)	8 (13%)
Grade III	17 (21%)	1 (25%)	3 (18%)	13 (21%)
Grade IV	48 (59%)	2 (50%)	10 (58%)	36 (59%)

AHI = apnea hypopnea index; BM = body mass index; F = female; M = male; *n* = number; OSA = obstructive sleep apnea; Y = years.

The degree of obstruction at the levels of velum, oropharynx/lateral walls, tongue, and epiglottis are shown in Figures 1 to 4. Prevalence of complete velum obstruction in children with severe OSA and moderate OSA were greater than that of children with moderate OSA and mild OSA ($P < 0.05$). Prevalence of complete oropharynx/lateral walls in children with severe OSA and moderate OSA were greater than that of children with mild OSA ($P < 0.05$).

The degree of oropharynx/lateral wall obstruction for each grade of tonsil size is shown in Figure 5. Complete obstruction of oropharynx/lateral pharyngeal walls was documented in 50% of children with grade I tonsils and 64% of children with grade II. Partial obstruction of oropharynx/lateral walls occurred in 27% of children with grade II. In children with grade III and grade IV, complete obstruction of oropharynx/lateral pharyngeal walls was seen in 69% and 86% of children, respectively. Partial obstruction of oropharynx/lateral walls occurred in 24% of children with grade III and 9% of children with grade IV.

DISCUSSION

Since its introduction in 1991,[6] DISE has been increasingly used to evaluate the site, degree, and configuration of airway obstruction in adults with OSA. Obstruction at multiple levels of airway is documented during DISE. Furthermore, frequency and distribution of the levels of airway obstruction vary in adults with

TABLE II.
Frequency Distribution of Obstruction Sites.

Obstruction site	Entire OSA Group (*n* = 82)	Mild OSA (*n* = 4)	Moderate OSA (*n* = 17)	Severe OSA (*n* = 61)
Single site	29%	75%	24%	27%
Velum	11%	25%	6%	11%
Oropharynx/lateral walls	18%	50%	12%	16%
Tongue base	0%	0%	6%	0%
Epiglottis	0%	0%	0%	0%
Multiple sites	71%	25%	76%	73%
Velum and oropharynx/lateral walls	58%	0%	58%	56%
Velum and epiglottis	1%	25%	0%	0%
Velum and tongue	0%	0%	0%	1%
Velum, oropharynx/lateral walls, and tongue	1%	0%	6%	5%
Velum, oropharynx/lateral walls, and epiglottis	10%	0%	12%	8%
Velum, oropharynx/lateral walls, tongue, and epiglottis	0%	0%	0%	2%
Oropharynx/lateral walls and epiglottis	1%	0%	0%	1%

TABLE III.
Frequency Distribution of Obstruction Pattern.

Obstruction Pattern	Entire OSA Group ($n = 82$)	Mild OSA ($n = 4$)	Moderate OSA ($n = 17$)	Severe OSA ($n = 61$)
Velum				
Anteroposterior	46%	25%	47%	46%
Lateral	2%	25%	6%	0%
Concentric	35%	0%	29%	39%
Oropharynx/lateral walls				
Lateral	77%	50%	100%	89%
Tongue base				
Anteroposterior	4%	0%	12%	2%
Epiglottis				
Anteroposterior	12%	25%	12%	11%
Lateral	0%	0%	0%	0%

OSA.[19–20] Persistent airway obstruction after tonsillectomy and adenoidectomy provides evidence for obstruction at other sites of upper airway in children with OSA. Better identification of the structures contributing to airway obstruction potentially improves the selection and outcomes of surgical procedures in adults and children with OSA.

We used DISE to examine characteristics of upper airway obstruction in sedated spontaneously breathing children with OSA. Obstruction occurred at varying sites along the airway during DISE. Single-site airway obstruction was documented in 29% of children with OSA. The oropharynx/lateral walls were the most common site of obstruction in children with OSA with single-site airway obstruction. The majority of children with OSA had obstruction at multiple sites of airway. Combination of the oropharynx/lateral walls and velum obstruction was the most common sites of obstruction in children with OSA with multiple levels of airway obstruction. Airway obstruction due to the tongue or epiglottis was documented in patients with multiple sites of obstruction. In agreement with previous DISE studies in adults with OSA, our observations provide evidence for a combination of airway structures contributing to obstruction in children with OSA. We believe that DISE can potentially be used as part of OSA surgery planning in children. Caregivers may be notified that DISE findings might indicate the need for additional surgical procedures or care at the time of tonsillectomy and adenoidectomy, particularly in children with advanced OSA or in children with risk factors for residual OSA after tonsillectomy and adenoidectomy.

In adults with OSA, multiple-level airway obstruction, complete collapse of airway, and tongue base collapse have been associated with higher AHI

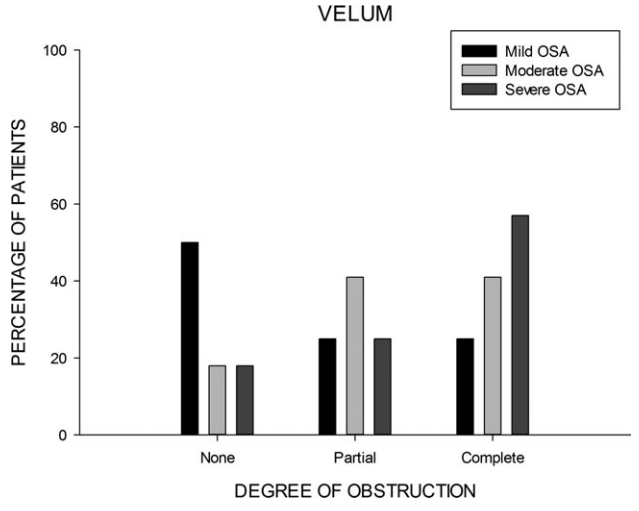

Fig. 1. The prevalence of degree of velum obstruction between children with mild, moderate, and severe OSA. Prevalence of complete velum obstruction in children with severe OSA and moderate OSA were greater than that of children with moderate OSA and mild OSA ($p < 0.05$).

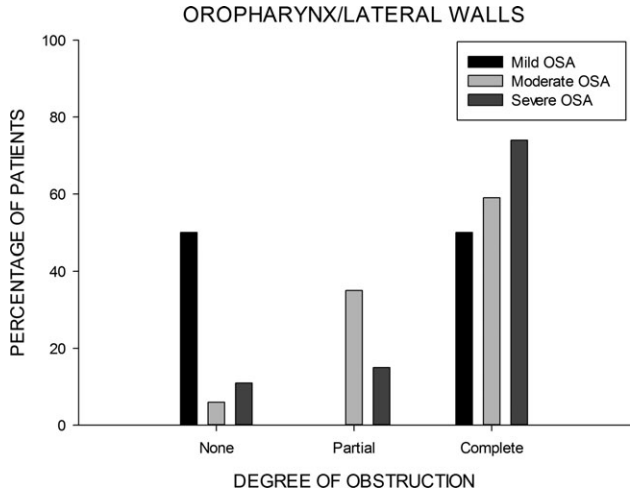

Fig. 2. The prevalence of degree of oropharynx/lateral walls obstruction between children with mild, moderate, and severe OSA. Prevalence of complete oropharynx/lateral walls in children with severe OSA and moderate OSA were greater than that of children with mild OSA ($p < 0.05$).

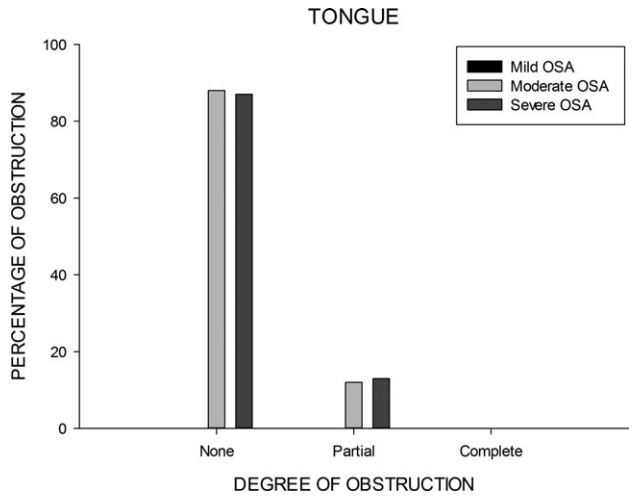

Fig. 3. The prevalence of degree of tongue obstruction between children with mild, moderate, and severe OSA. Prevalence of tongue obstruction was similar between groups.

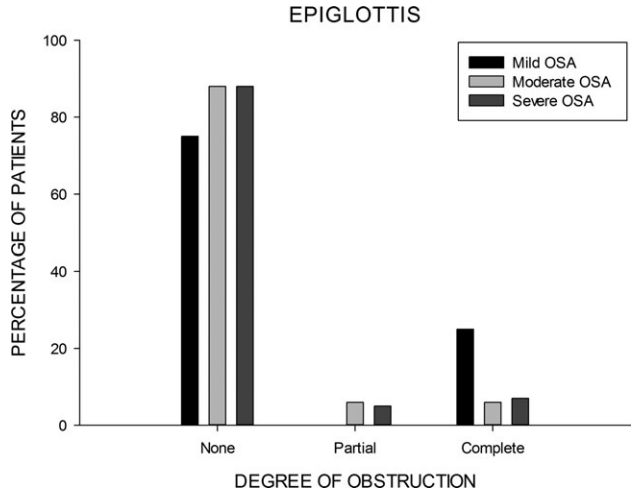

Fig. 4. The prevalence of degree of epiglottis obstruction between children with mild, moderate, and severe OSA. Prevalence of epiglottis obstruction was similar between groups.

values.[6,21] We documented differences in the site of airway obstruction and the degree of collapse among the groups of children with mild, moderate, and severe OSA. The majority of children with mild OSA had single-site obstruction of the airway. A combination of multiple airway structures contributed to the airway obstruction in the majority of children with moderate or severe OSA. As the severity of OSA increased, the prevalence of complete obstruction of velum and oropharynx/lateral walls increased in children with OSA.

The enlargement of tonsils is commonly implicated in the pathogenesis of OSA in children. The size of tonsils is graded based on the percentage of the lateral dimension of oropharynx occupied by tonsils.[17] The lateral dimension of oropharynx is measured between the anterior pillars; however, tonsils extend to the lateral pharyngeal wall. If the majority of a large tonsil is located in the area between the anterior pillar and the lateral oropharyngeal wall, and is occupying a small proportion of the area between anterior pillars, a large tonsil may be graded as grade I or grade II on physical examination. Tonsil grading scale also does not account for the obstruction due to anterior-posterior and superior-inferior dimensions of the tonsil.[22] Enlargement of tonsil in all directions may contribute to upper airway obstruction during sleep. Conceivably, removal of grade I tonsils embedded in tonsillar fossa may alleviate airway obstruction and relieve OSA.

In the present study, we assessed the dynamic airway obstruction due to tonsil and lateral pharyngeal walls during DISE. Complete obstruction at the level of oropharynx/lateral pharyngeal walls was documented in children with grade I and grade II tonsils. Partial obstruction of airway at the level of oropharynx/lateral walls occurred in 27% of children with grade II tonsils. Although we are unable to separate contribution of tonsils and lateral pharyngeal walls to the observed collapse at the level of oropharynx/lateral walls, our findings provide evidence that complete airway obstruction due to grade I tonsils may occur in some children with OSA.

Anatomic level and cause of airway obstruction in children with OSA is routinely assessed based on findings of physical examination and nasopharyngoscopy. As these examinations are performed while the children are awake, information obtained is limited to static observations rather than dynamic assessments. Dynamic assessment of airway obstruction is performed using DISE or magnetic resonance imaging (MRI) sleep studies while pharmacologically inducing the patient into sleep. Cine MRI sleep study is an invaluable tool to evaluate site of airway obstruction in children with OSA.[23] In an effort to avoid giving additional sedation, we performed DISE immediately after the induction of anesthesia prior to tonsillectomy and adenoidectomy. To date, no gold standard technique is identified to determine the site and degree of dynamic airway obstruction, and to lead to more effective surgical treatment options in children with OSA.

We performed DISE after inhalational induction with sevoflurane wore off; and a bolus of dexmedetomidine was administered in order to maintain the pharyngeal musculature tone and a close to normal sleep pattern. Dexmedetomidine is a potent, selective alpha 2-adrenoceptor agonist used for sedation and to enhance postoperative analgesia or opioid consumption in adults. Dexmedetomidine's effects also include anxiolysis, analgesia, and decreased activity of the sympathetic nervous system. Dexmedetomidine does not depress respiratory drive[24] and is associated with a unique type of pharmacological sedation that mimics natural sleep.[25] Dexmedetomidine has been used in children undergoing postoperative mechanical ventilation,

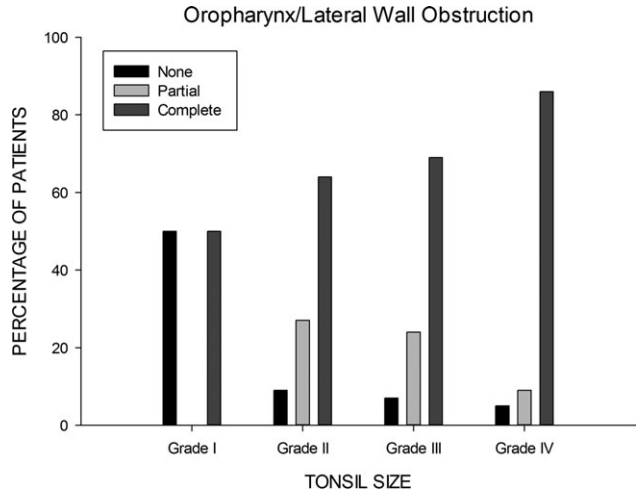

Fig. 5. The degree of oropharynx/lateral wall obstruction for each grade of tonsil size is shown. Complete obstruction of oropharynx/lateral pharyngeal walls was documented in 50% of children with grade I tonsils and 64% of children with grade II. Partial obstruction of oropharynx/lateral walls occurred in 27% of children with grade II. In children with grade III and grade IV, complete obstruction of oropharynx/lateral pharyngeal walls was seen in 69% and 86% of children, respectively. Partial obstruction of oropharynx/lateral walls occurred in 24% of children with grade III and 9% of children with grade IV.

cardiac catheterization, magnetic resonance imaging, endoscopy, and other minor procedures.[26–27] Slow administration of dexmedetomidine (over 10 minutes) results in a decrease in both blood pressure and heart rate,[27] whereas a rapid bolus administration of dexmedetomidine results in a transient increase in systemic and pulmonary pressure and a decrease in heart rate.[28] We administered glycopyrrolate to avoid bradycardia induced by dexmedetomidine in our patients.

Potential limitations of the present study included: the rating of DISE findings by a single observer, the confounding effect of degree of sedation on DISE findings, the classification of severity of OSA, and the small number of subjects in mild OSA group. As DISE findings are subjectively assessed, the evaluation of findings by a single observer potentially leads to biased findings; therefore, DISE findings were evaluated by a blinded observer who did not know the severity of OSA. We did not evaluate interrater reliability of the findings; however, interrater reliability of DISE is reported to be moderate to substantial.[12] The degree of sedation has a confounding effect on DISE findings as excessive sedation decreases upper airway muscle tone and increases pharyngeal critical closing pressure.[19] To date, no uniform nomenclature has been used to report DISE findings. We used VOTE classification to report DISE findings as it recently has been proposed as a useful tool with a potential to compare results across studies and centers.[17] In the present study, severity of OSA was categorized using AHI values reported in a previous study[16]; however, there is no universally accepted AHI value to categorize OSA as mild, moderate, or severe in children with OSA. In addition, few children with OSA had mild OSA, and data from a small number of subjects may produce false positive results; therefore, our conclusions regarding children with mild OSA should be interpreted carefully. It is hoped that the present study findings will be used to design larger confirmatory studies assessing the association between DISE findings and severity of OSA.

CONCLUSION

Obstruction at multiple sites of airway was seen in the majority of children with OSA. A combination of obstruction at velum and oropharynx/lateral walls was the most common site of obstruction. The oropharynx/lateral walls are the most common site of obstruction in OSA children with single-site airway obstruction. Children with grade I and grade II tonsillar hypertrophy may have complete airway obstruction. DISE is a useful tool to identify upper airway obstruction sites, in addition to adenotonsillar hypertrophy.

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