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# The role of drug-induced sleep endoscopy: predicting and guiding upper airway surgery for adult OSA patients

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## Abstract

**Purpose** Obstructive sleep apnea (OSA) is a common sleep disorder that can be corrected with upper airway surgery. Prior to surgery, drug-induced sleep endoscopy (DISE) is routinely used to evaluate obstruction sites and severity. Evidence suggests that the findings of DISE may relate to the final surgical outcome. Therefore, we evaluated the ability of drug-induced sleep endoscopy to predict the final effect of upper airway surgery and potentially to guide surgical treatment decision-making.

**Methods** A retrospective analysis was conducted on 85 adult patients with OSA (50 men with mean apnea-hypopnea index [AHI] 30 ± 15 events/h) who underwent DISE followed by tonsillectomy, uvulopalatopharyngoplasty (UPPP), or a combination of the two. Surgery outcome was evaluated at follow-up by polysomnography. Success response to surgery was defined as a postoperative value of the AHI< 20 events/h and more than 50% postoperative reduction of AHI.

**Results** Of the 85 patients evaluated, 48 (53%) were responders. DISE revealed significant differences between the two groups. Specifically, complete circumferential collapse at the velum and complete anterior-posterior collapse at the tongue base occurred at higher frequencies in nonresponders. In contrast, the presence of grade 3–4 tonsillar hypertrophy and anterior-posterior mild/partial collapse at the velum were positively associated with responders.

**Conclusions** Our results suggest that DISE may help predict the final outcome of tonsillectomy, UPPP, or a combination of the two in adult patients with OSA. The use of DISE shows potential to guide treatment decisions for individual patients with OSA.

**Keywords** Obstructive sleep apnea · Drug-induced sleep endoscopy · Upper airway surgery · VOTE classification

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## Introduction

Obstructive sleep apnea (OSA) is a common disorder that affects 4% of men and 2% of women [1, 2]. The most frequent symptoms of OSA are snoring, excessive daytime sleepiness, and an altered mental state, due to recurrent upper airway collapse during sleep. If left untreated, OSA may lead to adverse consequences, including poor quality of life, traffic accidents, and cardiovascular morbidities [3].

Continuous positive airway pressure (CPAP) inflates the upper airway with air and is the standard first-line treatment for patients with OSA [4, 5]. However, 30–50% of CPAP users fail to meet the minimum recommended weekly use of at least 4 h/night for five nights [6], prompting them to search for alternative treatments. Such alternative treatments include weight loss, mandibular advancement devices, and upper airway surgery [5, 7, 8]. The most common upper airway surgery performed for mild to moderate OSA is uvulopalatopharyngoplasty (UPPP) which was introduced by Fujita et al. in 1981 [9–11]. Specifically, the UPPP procedure involves tonsillectomy,

removing excess fat and mucosa in the soft palate and uvula, and trimming the posterior and anterior tonsillar pillars.

Currently, polysomnography is the gold standard method for diagnosing and evaluating obstruction severity in patients with OSA [12, 13]. Drug-induced sleep endoscopy (DISE) was proposed by Croft and Pringle in 1991 [14] to assess the airway for anatomical sites of airway narrowing or obstruction. DISE is an endoscopic examination performed during drug-induced sleep to visualize the upper airway collapse. Although DISE has been confirmed to be a dynamic, safe, effective, and easy-to-use method for evaluating the severity of upper airway collapse at different airway levels, investigation of DISE as a tool in preoperative treatment decision-making deserves further study [13, 15, 16].

Because of the controversial effectiveness of upper airway surgery in the management of patients with OSA, the American Academy of Sleep Medicine recommends that strict indications for surgery be present [5, 17]. One method for analyzing these indications is the combination of DISE with a VOTE (velum, oropharynx lateral wall, tongue base, and epiglottis) classification system. VOTE classification focuses on the specific structures that contribute to obstruction at each anatomical level and assists in the comparison of results [18]. The VOTE classification system is the most frequently used method to characterize findings under DISE. Using the VOTE system through DISE could serve as the first step for optimizing treatment for patients who have failed to adapt to CPAP and are potential candidates for upper airway surgery.

Therefore, the purpose of our study was to explore the relationship between DISE findings and the postoperative outcomes of upper airway surgery in adult patients with OSA [19]. We hypothesized that DISE evaluation of tonsil hypertrophy grading and the obstruction structure (VOTE), degree (mild, partial, complete), and configuration (anterior-posterior, lateral, circumferential) would predict the outcome of upper airway surgery, specifically tonsillectomy, UPPP, or both. These results might then guide the design of targeted effective treatment for individual patients with OSA.

## Materials and methods

### Study subjects

In this study, we retrospectively analyzed 85 adult patients who were diagnosed with OSA and underwent propofol-induced sleep endoscopy and upper airway surgery in the Department of Otolaryngology, Head and Neck Surgery of Shandong Provincial QianFoShan Hospital between November 2014 and November 2017. All patients received a routine ENT examination, and the palate classifications were scored with the Friedman tonsillar hypertrophy grading system. Additional inclusion criteria included the following: AHI > 15 events/h measured by full-night polysomnography, no previous upper airway surgery, polysomnography performed every 6 months for 2 years following upper airway surgery, and no subsequent treatment, including CPAP, during the follow-up. The details of our study were approved by the human ethics committee of the hospital.

Basic clinical variables for each subject were evaluated at baseline including age, BMI, gender, and Epworth Sleepiness Scale. The Epworth Sleepiness Scale is a self-administered questionnaire used to evaluate the probability and degree of dozing during eight common situations [19, 20].

### Polysomnography

All patients with OSA received a preoperative and postoperative polysomnograph (Philips Respironic Alice 6 LDE, 1001 Murry Ridge Lane, Murrysville, PA 15668, USA). The full-night parameters were collected from an electroencephalogram, electrooculogram, submental and anterior tibialis electromyogram, and electrocardiogram. The following parameters were also recorded: snoring (detected by a laryngeal microphone attached to the neck), airflow (assessed with a nasal pressure transducer and oral thermistor placed in front of the mouth), arterial oxygen saturation (recorded by a finger pulse oximeter), and respiratory movements (measured by thoracic and abdominal sensors). Ultimately, all variables were recorded using a digital polygraph system [16]. Sleep stages and respiration events were scored using standard criteria [21].

### DISE

All patients underwent DISE in a supine position in the operating room with an operating surgeon and an anesthetist [19, 22]. During the procedure, patients were monitored for oxygen and cardiac rhythms. Propofol was administered by the anesthetist to achieve and maintain induction of accurate medium sedation [23]. The initial infusion rate of propofol was set at 50 μg/kg/min, and the bispectral index was controlled around 60 [15]. Similar sedation was ensured in every patient. When sleep was achieved, a flexible endoscope was inserted into the nasal cavity to sequentially observe the nasal passage, nasopharynx, velum, oropharynx, tongue base, epiglottis, and larynx [1, 17]. After completing the sleep endoscopy, surgery was performed. Surgical videos were recorded and later reviewed by the operating surgeon.

### VOTE classification

The VOTE classification system includes the structures most commonly involved in OSA and provides valuable knowledge for identification of the configuration and degree of upper airway collapse. Moreover, using the universal scoring

**Table 1** The VOTE classification

| Structure | Degree of Obstruction | Configuration | | |
|---|---|---|---|---|
| | | Anterior-Posterior | Lateral | Concentric |
| Velum | | | | |
| Oropharynx lateral wall | | ■ | | ■ |
| Tongue base | | | ■ | ■ |
| Epiglottis | | | | ■ |

system can facilitate scientific assessment and comparison of results between patients. As a result, using the VOTE classification associated with DISE has been recommended by previous reports [24].

DISE findings were characterized using the VOTE classification system, which has been reported previously [19]. Accordingly, findings under the VOTE classification were evaluated by obstruction structure, degree, and configuration (Table 1). The degree of obstruction was categorized into three groups: 0–50% narrowing corresponds to none/mild obstruction; 50–75% narrowing corresponds to partial obstruction, and 75–100% narrowing corresponds to complete obstruction. The configuration of the obstruction could be anterior-posterior (typically anterior structures moving posteriorly against the posterior pharyngeal wall), lateral (lateral structures moving towards the center of the airway), or circumferential (combination of the two) [18].

## Upper airway surgery

All candidates underwent upper airway surgery that included either tonsillectomy, UPPP, or a combination of the two. All UPPP procedures were performed by the same otorhinolaryngology surgeon using a standardized procedure.

In this study, success was defined as a postoperative value of the AHI less than 20 events/h along with more than 50% postoperative reduction of AHI (responders) [25]. Treatment failure was defined as a postoperative AHI ≥ 20 events/h and/or a decrease of AHI from baseline by ≤ 50% (nonresponders).

## Statistical analysis

Statistical analysis was performed using IBM SPSS STATISTICS 22.0 (Chicago, IL, USA). Continuous variables were expressed as mean ± SD. Categorical measures were compared by chi-square test, and all ordinal data were analyzed by Kruskal-Wallis *H* test. The results were considered statistically significant for $p$ values < 0.05 where paired-sample tests were used to compare responders and nonresponders.

# Results

For comparisons in clinical characteristics and polysomnographic results between responders and nonresponders, no statistically significant differences were found (see Table 2).

Among 85 patients with OSA who underwent upper airway surgery from November 2014 to November 2017, 48 (56%) were responders. Postoperative polysomnography data in responders and nonresponders are presented in Table 3. DISE findings of responders and nonresponders are presented in Table 4. Preoperative physical examinations according to the Friedman tonsillar hypertrophy grading system were graded from 1 to 4 (see Table 5) [26].

As shown in Table 4, there were significant differences in the univariate comparisons between DISE findings of

**Table 2** Clinical characteristics and baseline polysomnographic results in responders and nonresponders

| | Responders ($n = 48$) | Nonresponders ($n = 37$) | $p$ value |
|---|---|---|---|
| Age (years) | 44.1 ± 10.7 | 46.7 ± 11.2 | > 0.05 |
| Body mass index (kg/m$^2$) | 26.2 ± 4.3 | 27.5 ± 4.9 | > 0.05 |
| Men (%) | 88 | 86 | > 0.05 |
| Apnea-hypopnea index (events/h) | 38.3 ± 15.4 | 36.9 ± 17.1 | > 0.05 |
| Epworth Sleepiness Scale | 9.3 ± 4.4 | 8.9 ± 3.1 | > 0.05 |
| Minimum oxygen desaturation (%) | 75.2 ± 12.4 | 75.6 ± 10.0 | > 0.05 |

Continuous data are presented as mean ± SD. There was no statistical difference between the clinical variables of responders and nonresponders ($p > 0.05$)

**Table 3** Postoperative polysomnography data in responders and nonresponders

| | Responders ($n = 48$) | Nonresponders ($n = 37$) | $p$ value |
|---|---|---|---|
| Body mass index (kg/m$^2$) | 25.0 ± 4.0 | 25.5 ± 5.1 | >0.05 |
| Apnea-hypopnea index (events/h) | 11.4 ± 6.7 | 19.9 ± 10.2 | <0.05 |
| Epworth Sleepiness Scale | 5.4 ± 4.1 | 6.9 ± 4.5 | >0.05 |
| Minimum oxygen desaturation (%) | 82.5 ± 11.6 | 80.9 ± 10.8 | >0.05 |

All values are mean ± standard deviation unless noted otherwise

responders and nonresponders. At the velum, nonresponders showed a significantly increased proportion of complete collapse (Figs. 1, and 2) (mild anteroposterior vs. partial anteroposterior, $p < 0.05$; mild anteroposterior vs. partial circumferential, $p < 0.05$). Moreover, obstructions at the oropharynx, tongue base, and epiglottis were negatively correlated with success rate. The correlation coefficient between obstruction at the oropharynx and success rate was − 0.356 (mild anteroposterior vs. partial anteroposterior, $p = 0.001$). Similarly, obstruction at the tongue base and success rate were negatively correlated with a correlation coefficient of − 0.630 (mild anteroposterior vs. complete anteroposterior collapse, $p < 0.05$; partial anteroposterior vs. complete anteroposterior collapse, $p < 0.05$). Finally, the correlation coefficient between obstruction at the epiglottis and success rate was − 0.272 (no collapse vs. partial collapse, $p < 0.05$; no collapse vs. complete collapse, $p < 0.05$). In stark contrast, tonsillar hypertrophy grade was positively associated with a success rate (Table 5). Specifically, the correlation coefficient between the degree of tonsil hypertrophy (Fig. 3) and the success rate was 0.765 (grade 1 vs. grade 3, $p < 0.05$; grade 1 vs. grade 4, $p < 0.05$; grade 2 vs. grade 3, $p < 0.05$; grade 2 vs. grade 4, $p = 0.012$).

## Discussion

Previous research has produced insufficient evidence to establish the ability of DISE to predict surgical outcomes successfully and to direct surgical planning. Therefore, we investigated the relationship between obstruction severity, obstruction site, and final outcome. To do so, we compared DISE findings to surgical outcomes of upper airway surgery in 85 patients with OSA with a goal of defining specific indicators of success or failure. We found that treatment failure in nonresponders was associated with complete circumferential collapse at the velum and complete anterior-posterior collapse at the tongue base under DISE. In contrast, surgical success in responders showed a significantly higher occurrence rate of grade 3–4 tonsillar hypertrophy and anterior-posterior mild/partial collapse at the velum. Therefore, we propose that complete circumferential collapse at the velum and complete anterior-posterior collapse at the tongue base predict high failure rates, whereas grade 3–4 tonsillar hypertrophy and anterior-posterior mild/partial collapse at the velum predict satisfactory results of upper airway surgery in patients with OSA.

According to our statistical analysis, the degree of the enlarged tonsils and tongue base had greater relevance to surgical outcome than the oropharynx and epiglottis. Furthermore, our data show negative correlations between success rate and the degree of obstruction at the tongue base, oropharynx, and epiglottis. This finding is consistent with previous studies that concluded that the degree of tongue base collapsibility was positively associated with obstruction severity; the more severe the obstruction, the higher the failure rate. On the contrary, success rate is positively correlated with the degree of tonsillar hypertrophy and mild/partial obstruction at the velum.

Similar to previous reports, our findings indicate that occurrence of complete circumferential collapse at the velum predicts a high failure rate of upper airway surgery. Irrigate et al. founded that circumferential obstruction in the soft palate can predict surgery failure for upper airway surgery and other

**Table 4** Drug-induced sleep endoscopy findings in responders and nonresponders

| | | Responders ($n = 48$) | | | Nonresponders ($n = 32$) | | |
|---|---|---|---|---|---|---|---|
| Site of obstruction | Configuration of obstruction | Complete collapse | Partial collapse | No/mild collapse | Complete collapse | Partial collapse | No/mild collapse |
| Velum | Anteroposterior | 0 (0%) | 18 (100%) | 6 (100%) | 0 (0%) | 0 (0%) | 0 (0%) |
| | Circumferential | 24 (39%) | 0 (0%) | 0 (0%) | 37 (61%) | 0 (0%) | 0 (0%) |
| Oropharynx | Anteroposterior | 0 (0%) | 36 (49%) | 12 (100%) | 0 (0%) | 37 (51%) | 0 (0%) |
| Tongue base | Anteroposterior | 6 (16%) | 12 (100%) | 30 (83%) | 31 (84%) | 0 (0%) | 6 (17%) |
| Epiglottis | Anteroposterior | 12 (40%) | 5 (50%) | 31 (69%) | 18 (60%) | 5 (50%) | 14 (31%) |

**Table 5** Tonsillar hypertrophy grading in responders and nonresponders

| Enlarged tonsils | Responders ($n = 48$) | Nonresponders ($n = 37$) |
|---|---|---|
| 1*# | 0 (0%) | 12 (100%) |
| 2*# | 12 (32%) | 25 (68%) |
| 3 | 30 (100%) | 0 (0%) |
| 4 | 6 (100%) | 0 (0%) |

*$p < 0.05$ versus 3

#$p < 0.05$ versus 4

procedures, such as hypoglossal nerve stimulation [27]. Similarly, Iwanaga et al. found that upper airway surgery is ineffective in solving a circumferential type of collapse [28].

We also observed that complete anterior-posterior collapse at the tongue base predicted failure of upper airway surgery. Koutsourelakis et al. also showed that, although various techniques are available for addressing obstructions at the base of the tongue (radiofrequency ablation, hyoid suspension), total anteroposterior obstruction is a failure factor for all techniques studied [17].

In contrast, we found that a higher success rate for upper airway surgery was predicted by grade 3–4 enlarged tonsils and anteroposterior mild/partial collapse at the velum. Consistent with this observation, Lin et al. concluded that patients with lateral velopharyngeal wall collapse observed during DISE had an aggravated surgical response rate in contrast to those without velopharyngeal wall collapse [29]. Our current research validates these results. Similarly, in a retrospective assessment of UPPP guided by preoperative DISE in 60 patients with OSA, Iwanaga et al. found that success rate varied with obstruction site [28]. Specifically, the overall 60% improvement in AHI could be improved if obstruction site was stratified: tonsils, 76%; soft palate with anteroposterior obstruction, 74%; soft palate with circumferential obstruction, 53%; and soft palate

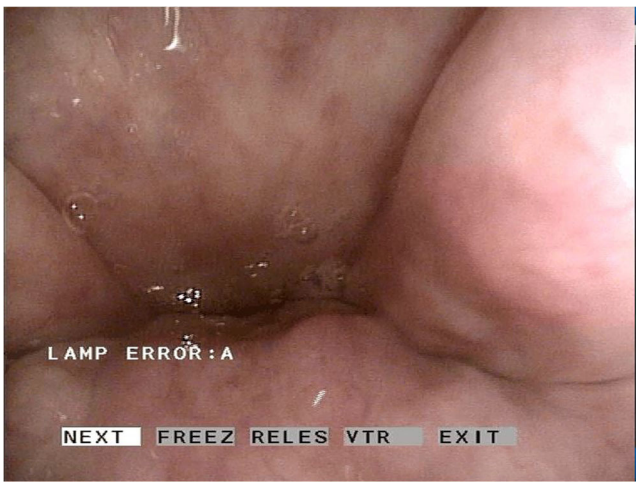


**Fig. 1** Complete anteroposterior collapse at velum (typically anterior structures moving posteriorly against the posterior pharyngeal wall during DISE)

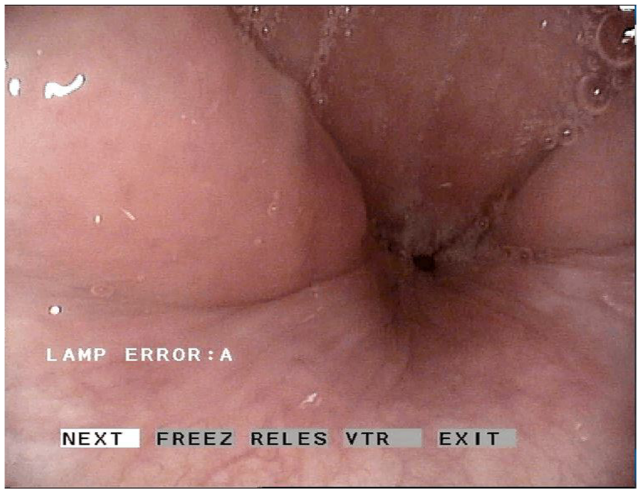


**Fig. 2** Complete circumferential collapse at velum (combination of the anterior-posterior and lateral)

and tongue base, 34%. The surgical procedures and DISE sites assessed in the Iwanaga study were similar to those of the present study and reached consistent conclusions.

In summary, DISE can retrospectively account for certain surgery failures and identify predictive factors of failure [30]. Surgery is generally more effective when indications are based on DISE findings. Specifically, the occurrence of enlarged tonsils, grade 3–4, and anterior-posterior mild/partial collapse at the velum indicates that upper airway surgery may be an appropriate treatment method. In contrast, unsatisfactory final outcomes are predicted for patients with OSA who display total circumferential collapse at the velum or complete anterior-posterior collapse at the tongue base.

Prior to DISE, there was no gold standard method for determining the level and the degree of airway collapse. DISE was proposed and utilized to provide additional clinical information to assess airway function and collapse in addition to awake endoscopy [8]. Previous reports show that DISE altered

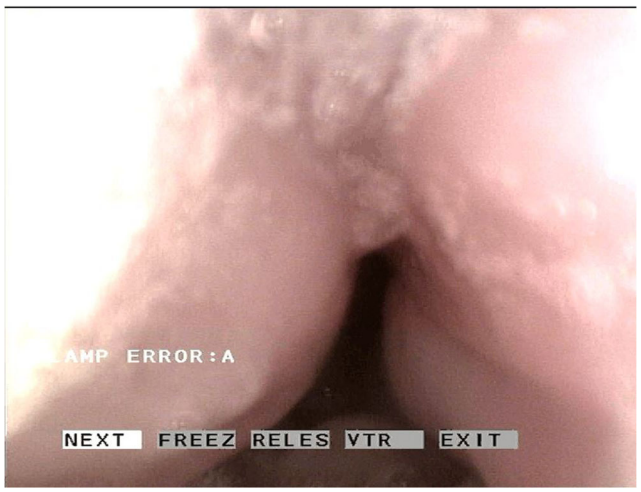


**Fig. 3** Grade 4 tonsillar hypertrophy, according to the Friedman staging system

the surgical plan in 64% of surgery subjects; however, the depth of sedation was not considered. In our study, the bispectral index was used to ensure identical sedation in individuals and to preserve accurate control of propofol to achieve medium sedation [31]. As a result, the surgeon was better able to predict operative effects and make decisions regarding treatment plans at this level of sedation under DISE. We expect that an increased proportion of surgical plans would be altered by DISE findings if these parameters are considered.

Some limitations of our study must be acknowledged and deserve consideration. A primary limitation of our study is the limited sample size and highly selected study population; our study focused on moderate to severe patients with OSA with BMI < 32 kg/m$^2$ and AHI > 15 events/h, which may account for the high coefficient of variation in the data. As a result, our results cannot yet be safely applied to the general population of adult patients with OSA. Moreover, our definition of surgical response using an AHI < 20 and > 50% reduction in AHI, though widely used, constitutes a very generous definition. OSA is a chronic disease and requires lifelong follow-up and management. The follow-up time in our study was only 24 months and, therefore, lacks long-term observation. Furthermore, in the current study, all surgeries were performed by one surgeon, reducing the external validity of our study.

Additional large-scale and long-term follow-up studies are necessary to improve the accuracy and reliability of our conclusions. Moreover, although the reliability of DISE examination is generally acceptable, additional investigation is necessary to standardize DISE techniques, training, and interpretation [15]. In the future, construction of a patient-specific computer model in individual patients with OSA may help guide therapeutic intervention in upper airway surgery [32].

## Conclusion

This study emphasizes the significant role of DISE in decision-making for individual patients with OSA by providing evidence of prospective surgical success or failure. Grade 3–4 tonsillar hypertrophy and anterior-posterior mild/partial collapse at the velum appear to indicate individuals who are very appropriate for upper airway surgery. In contrast, individuals with complete circumferential collapse at the velum and complete anterior-posterior collapse at the tongue base may not be suitable for surgical treatments. Additional large-scale sample populations with long-term follow-up observation are necessary to predict potential influences of obstruction severity and location observed by DISE on surgical outcome.

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## Compliance with ethical standards

**Ethical approval** All studies have been performed in accordance with and approved by the Shandong Provincial QianFoShan Hospital human ethics committee and have, therefore, been performed in accordance with the Declaration of Helsinki and its amendments. For this type of study, formal consent is not required.

**Conflict of interest** The authors declare that they have no conflicts of interest.

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