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Drug-induced sleep endoscopy in adults with sleep-disordered breathing: Technique and the VOTE Classification system

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Drug-induced sleep endoscopy (DISE) offers an unique evaluation of the upper airway. After pharmacologic induction of unconscious sedation, it is possible to evaluate endoscopically the structures contributing to upper airway obstruction in sleep disordered breathing. The authors describe DISE techniques and the VOTE classification system for reporting of DISE findings. The VOTE classification focuses on the primary structures that contribute to upper airway obstruction and represents a common language to describe the patterns of obstruction during DISE. The latter can facilitate the scientific evaluation of DISE, including its role in directing treatment.

Assessment of the site(s) of obstruction is critical to successful surgical treatment of snoring and obstructive sleep apnea. Multiple evaluation techniques have been developed to examine an individual's pattern of upper airway obstruction; each with important strengths and weaknesses. Obstructive sleep apnea (OSA) surgical evaluation techniques are commonly performed during wakefulness and include largely static observations rather than dynamic assessments. As such, they may not be ideal methods to assess the upper airway during breathing and sleep. The variety and complexity of vibrations and collapse events in the upper airway during sleep depend on multiple factors. Sleep stages, muscle tone, body position, head and neck position, and lung volumes are some of the variables that affect upper airway collapsibility.

Drug-induced sleep endoscopy (DISE) has been performed for decades, in many leading centers in Europe as well as selected centers in other parts of the world. Introduced by Croft and Pringle in 1991, the evaluation requires pharmacologic induction of sedation and flexible fiber optic endoscopy to visualize upper airway obstruction and/or snoring.[1]

We have previously renamed the technique DISE to reflect the 3 key features of this method of assessment: (1) the use of various pharmacologic agents to achieve sedation; (2) the goal of reproducing upper airway behavior similar to that which occurs during natural sleep; and (3) endoscopic upper airway evaluation. Other terms referenced in the literature include sleep endoscopy, sleep nasendoscopy, somnoendoscopy, somnoscopy, sedated endoscopy, and propofol sleep endoscopy.

Although DISE is performed widely, research concerning the technique is remarkably limited. Several studies have examined its safety, feasibility, validity, and reliability.[2-6] Various studies have examined the association between DISE findings and outcomes of palate surgery[7-10] and mandible repositioning appliances.[11,12]

More importantly, essential clinically relevant questions remain unanswered. The diversity of classification systems, ranging from the simple to the complex, has prevented the comparison of results across studies and centers.

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Based on the DISE findings, and combining these findings with those of poly(somno)graphy and clinical assessment, a mandibular repositioning appliance (MRA) or 1 of the many different forms of surgery can be selected.

Indications

DISE is indicated when surgery or MRA therapy is being considered as a treatment option by the patient and physician. Consequently DISE is not necessary if continuous positive airway pressure, weight loss, or positional therapy is being considered, as visualization of the level of obstruction is not mandatory for these treatment modalities. A high American Society of Anesthesiologists (ASA) score ($\geq$3) and propofol or midazolam allergies (albeit rare) are considered contraindications, owing to the high risk. Because of a higher procedure-associated risk and lesser effects on treatment decisions, markedly severe OSA (such as an apnea-hypopnea index (AHI) $>$70 events/h) and severe obesity are relative contraindications.

Prior to DISE, polysomnography must be performed. The results of these examinations are mandatory and at the basis of performing of DISE.

Technique

Patients should have basic cardiorespiratory monitoring (pulse oximetry, blood pressure, electrocardiogram), and it must be possible to administer oxygen if needed. A computerized target-controlled infusion system for propofol (not available in the United States) can be helpful, as well as a bispectral index score system for monitoring the depth of sedation, respectively; neither are compulsory.

Patients should remain nil per os before the DISE, to prevent regurgitation and aspiration. To reduce salivation, atropine or other anticholinergic agents can be administered 30 minutes before starting the procedure.

A topical anesthetic, with or without a decongestant, should be administered to 1 or both nostrils at least 20 minutes before starting the procedure, being careful not to overanesthetize the pharynx, as the risk of aspiration and coughing increases.

The patient should lie in a supine position on an operating table or in a bed. The position should attempt to mimic sleeping habits at home (eg, 1 or 2 pillows, with or without dentures). To gain added value, the body position should be easily changeable, should one want to visualize potential consequences of another position. It is practical to be able to view the film of the flexible endoscopy on a screen and record it. With the help of a microphone, acoustic and visual signals can be recorded simultaneously. The lights should be dimmed and the room quiet to minimize awaking stimuli.

Drugs commonly used for DISE are propofol and/or midazolam. Some use propofol only; others use midazolam only. Others start with midazolam and continue with propofol.[12] If midazolam is used, a flumazenil injection should be readily available in case reversal of the benzodiazepine effect should be necessary.

Table 1 Pharmacologic properties of midazolam and propofol

Midazolam	Propofol
Benzodiazepine derivative	2-6 Disopropylphenol
Large therapeutic range	Small therapeutic range
Active metabolites (accumulation)	No accumulation
Functional half-life 45 min	Functional half-life 4-6 min
Elimination half-life 150 min	Elimination half-life 55 min
Central muscle relaxation	Central breathing depression
Paradoxal reaction in 1%	Hypopharyngeal reflex depression

When propofol is the drug of choice, in an operating theater or in a clinic setting propofol (1.5 mg/kg or continuous infusion) is administered. Propofol, an ultra-short-acting hypnotic, enables greater control of the depth of sedation, albeit limited by a smaller therapeutic/diagnostic range. The pharmacologic properties of both drugs are shown in Table 1. Depending on the organization of the examination, a combined procedure may be useful: commence by administrating midazolam intravenously (3-4 mg) followed by propofol (30-50 mg or continuous infusion), titrated individually.[12]

Subjects with an AHI below 30, or to be more accurate patients with a supine AHI below 30 and with good health (ASA I or II) can undergo midazolam-induced sleep endoscopy in the clinic. Midazolam is administered by the ear, nose and throat surgeon (presence of an anesthetist not obligatory) or by an anesthetist. Sleep is induced by giving midazolam intravenously, slowly titrated up to 0.07 mg/kg per patient, followed by a saline flush.[13,14] If insufficient, a bolus of 1-2.5 mg is given (a maximum of 7.5 mg per patient). Patients who are extremely nervous or who habitually use antidepressants or sedatives may need an extra bolus.

Previous studies reported that propofol did not change the respiratory pattern nor significantly influence the AHI, but did interfere with the sleep architecture, specifically, reduction in rapid eye movement (REM) sleep in patients undergoing propofol-induced sleep endoscopy.[15] Respiratory and somnological parameters did not change significantly during diazepam-induced sleep endoscopy in comparison with natural sleep either, except for a small increase in the apnea index and a minor change in the duration of the longest apnea and REM sleep.[15,16]

Anesthetic depth is of key importance. The target depth of sedation is the transition from consciousness to unconsciousness (loss of response to verbal stimulation). Because individuals have differential susceptibilities to propofol, the required dosage can vary widely. Slow stepwise induction is required to avoid oversedation. Deeper levels of sedation are associated with progressive decreases in upper airway dilator muscle tone and neuromuscular reflex activation that both increase airway collapsibility, and the transition to

unconscious sedation may be a closer approximation to natural sleep. Previous research using propofol has shown that the transition to unconsciousness is associated with changes in upper airway collapsibility (passive critical closing pressure), Bispectral Index Score readings (based on frontal EEG activity), and genioglossus muscle tone; normals have decreases in genioglossus tone to 10% of maximum awake activity, which is one-half to one-third of the level in normals but greater than during REM sleep in normals and OSA.[17] While unconscious sedation under propofol may not a perfect simulation of natural sleep, pharyngeal dilator muscle activity appears to lie somewhere between NREM and REM sleep.

Once the patient has reached a satisfactory level of sedation, a flexible endoscope (eg, 3.5 mm) lubricated and coated with anticondense is introduced into the nasal cavity. The nasal passage, nasopharynx, velum, tongue base, epiglottis, and larynx are observed. The levels of snoring and/or obstruction are assessed.

During the DISE, maneuvers such as a chin lift (a manual closure of the mouth) (Figure 1) or a jaw thrust (or Esmarch maneuver) (Figure 2) should be performed, with reassessment of the airway after each maneuver. A jaw thrust is a gentle advancement of the mandible by up to approximately 5 mm, mimicking the effect of a mandibular repositioning appliance. It is thought that, using DISE, one can predict the likelihood that an appliance would be effective by examining the changes in the airway.[12] Although the effects during sedation may not be identical to those of natural sleep, the distance of protrusion can be measured and can inform decisions about the necessary degree of mandibular repositioning with an appliance.

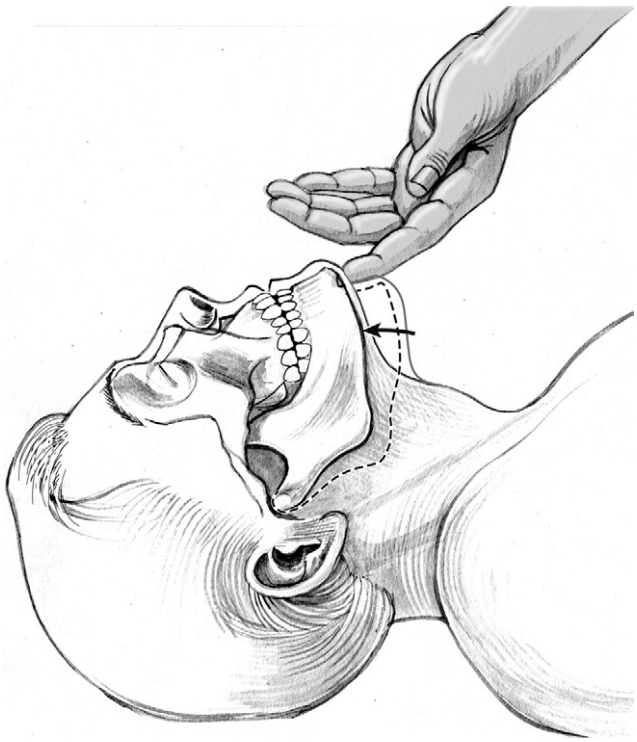

Figure 1 Chin lift, a manual closure of the mouth.

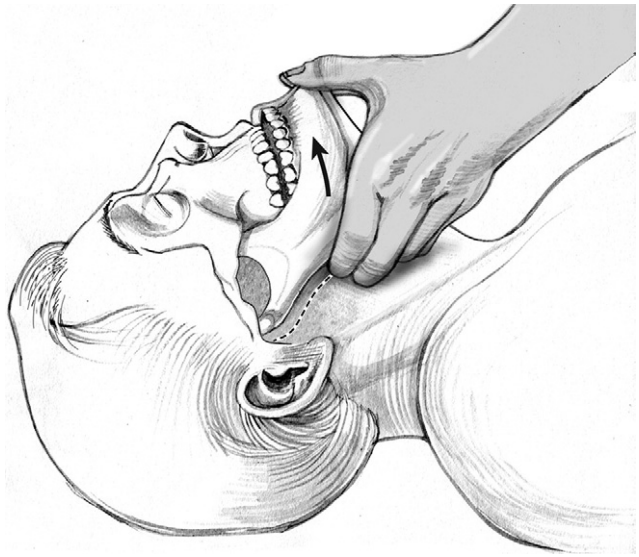

Figure 2 Jaw thrust, or Esmarch maneuver, a gentle advancement of the mandible by up to approximately 5 mm.

In patients with an insufficient effect of an MRA, DISE can be performed without the device both in and out, to assess obstruction site(s) and surgical alternatives.

VOTE Classification

The complex interplay of upper airway structures cannot be explained fully by simple examination of individual structures and their relationship to the airway during DISE.

There is a wide range of systems, ranging from overly simplistic to overly complex. Some exclude the epiglottis; others try to group multiple structures together in various combinations.[18-20]

There is no universally used DISE scoring system—hence one is needed.

We therefore recently proposed the VOTE Classification system for reporting DISE findings, with a focus on the primary structures that contribute to upper airway obstruction, either alone or in combination: the velum, oropharyngeal lateral walls (including the tonsils), tongue, and epiglottis.[21]

The VOTE Classification may be an oversimplification that overlooks some interactions, but we believe it is a foundation for further study of pharyngeal obstruction in OSA and for assessment of the response of upper airway structures to directed interventions. DISE is a qualitative, not quantitative assessment of vibration and obstruction events. It is not possible to assess exact percentages of obstruction, and the 3 (a) none, (b) partial, (c) complete, cutoff points are most realistic and best for clinical use. For quantitative measurements, polysomnography and Pcrit measurements are more suitable. DISE is neither intended for, nor possible to calculate, the rate (or grade) of obstructive events per night.

The shared use of the VOTE Classification can facilitate the scientific evaluation of DISE in individual centers and,

just as importantly, the collection of data across multiple centers and comparison of results across studies. Our experience suggests that a focus on structures enables examination of 2 central questions: treatment selection and the association between DISE findings and treatment outcomes—for surgery, mandibular repositioning appliances, or combined therapy. The VOTE Classification represents a common language to describe the patterns of obstruction during DISE and may ultimately direct treatment interventions (Table 2).

Table 2 The VOTE Classification

Level	Direction		
	A-P	Lateral	Concentric
Velum			
Oropharynx	■		■
Tongue base		■	■
Epiglottis			■

Degree of obstruction: (0) no obstruction (no vibration, <50%); (1) partial obstruction (vibration 50-75%); (2) complete obstruction (collapse, >75%); (x) not visualized.

The most common and well-known sites of obstruction and vibration are located in the soft palate, the lateral pharyngeal walls, including tonsils and the base of tongue. Obstruction at epiglottic level occurs less often but has clinical significance. Previous large series of DISE in patients with OSA reported a majority of multilevel obstruction, a retropalatinal as well as retrolingual obstruction in a large percentage of cases.[1,13,18,19] In general, an unilevel obstruction is more common in patients with mild OSA, while in severe OSA, a multilevel obstruction is more characteristic, being the very reason for the severity of the OSA.[3,22] The subsequent surgical treatment with different, site-specific procedures will not be discussed here.

For many years, surgical evaluation techniques have focused on categorizing patients first according to the Fujita classification system that encompasses the 2 primary regions of pharyngeal upper airway obstruction: the palatal/velopharyngeal and hypopharyngeal/retrolingual regions. However, there are 2 major limitations of a region-based classification. First, there is substantial anatomical overlap between these regions, including the extension of the lateral pharyngeal walls throughout the length of the pharynx and the physical overlap of the tongue and soft palate. Second, a region-based approach may not direct surgical treatment adequately. For example, in patients with hypopharyngeal/

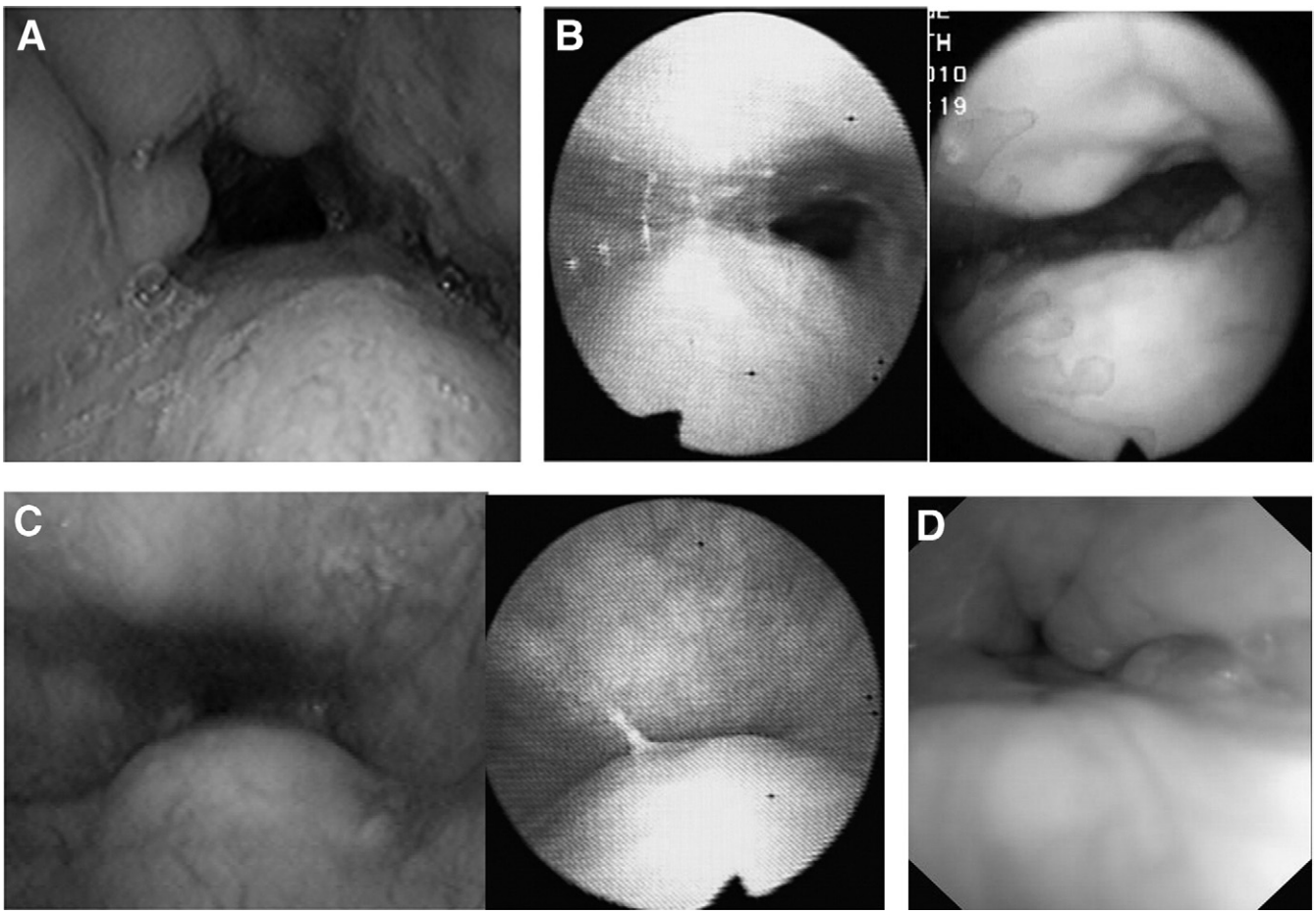

Figure 3 Velum obstruction. (A) No obstruction; (B) total anteroposterior (AP) obstruction; (C) partial AP obstruction; (D) concentric obstruction.

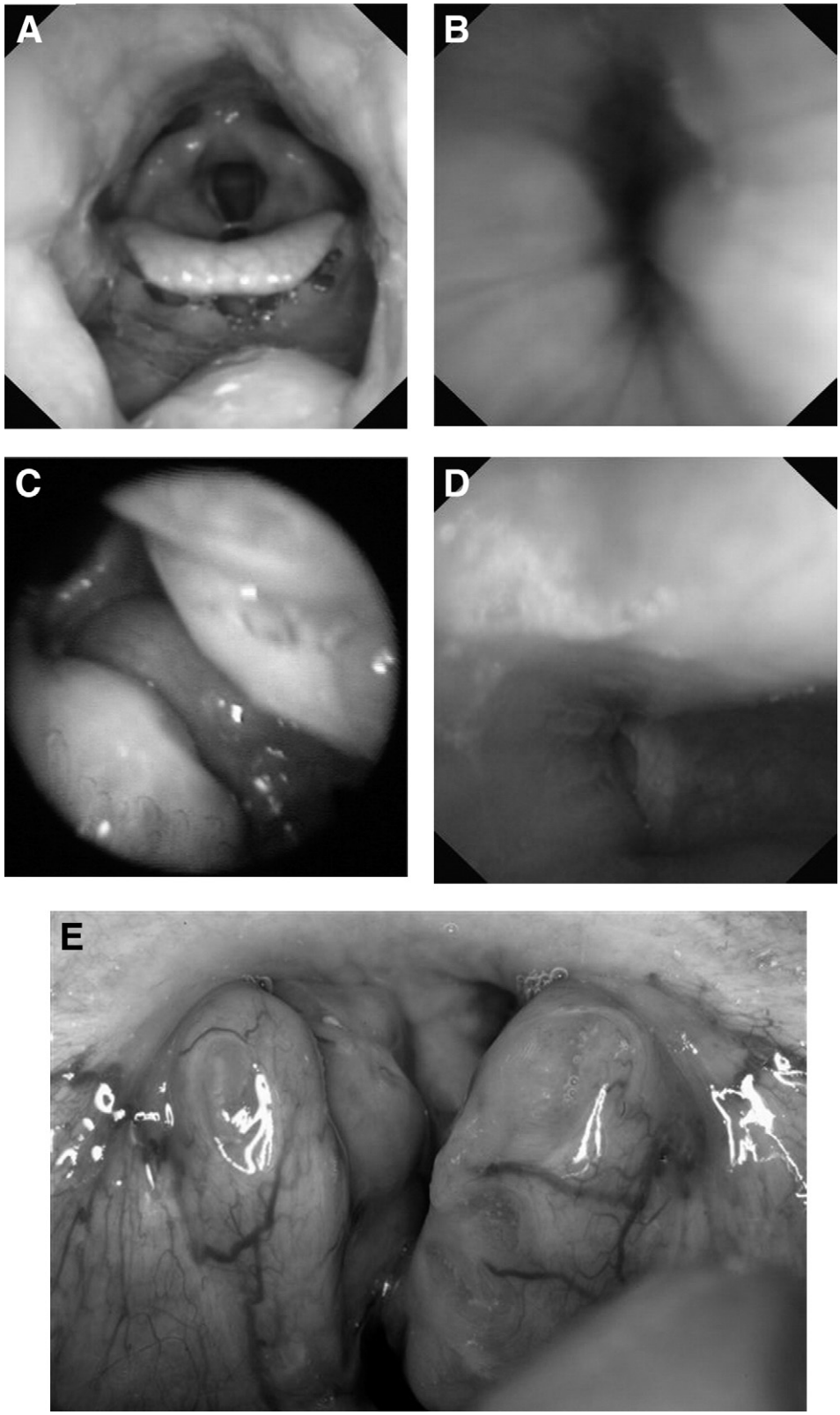

Figure 4 Oropharynx and tonsil obstruction. (A) No obstruction; (B) complete lateral collapse; (C) partial obstruction by tonsils; (D) complete obstruction by kissing tonsils; (E) kissing tonsils view in the oral cavity.

retrolingual obstruction, the oropharyngeal lateral walls, tongue, and epiglottis can each play a more prominent role. Because surgical procedures may exert differential effects on these structures and their contribution to upper airway obstruction, distinguishing between the structural contributions may play a critical role in procedure selection and improvement of outcomes.

Expert opinion suggests that surgical success rates are lower in concentric obstruction. Concentric obstruction is usually related to higher body mass index and in particular to increased

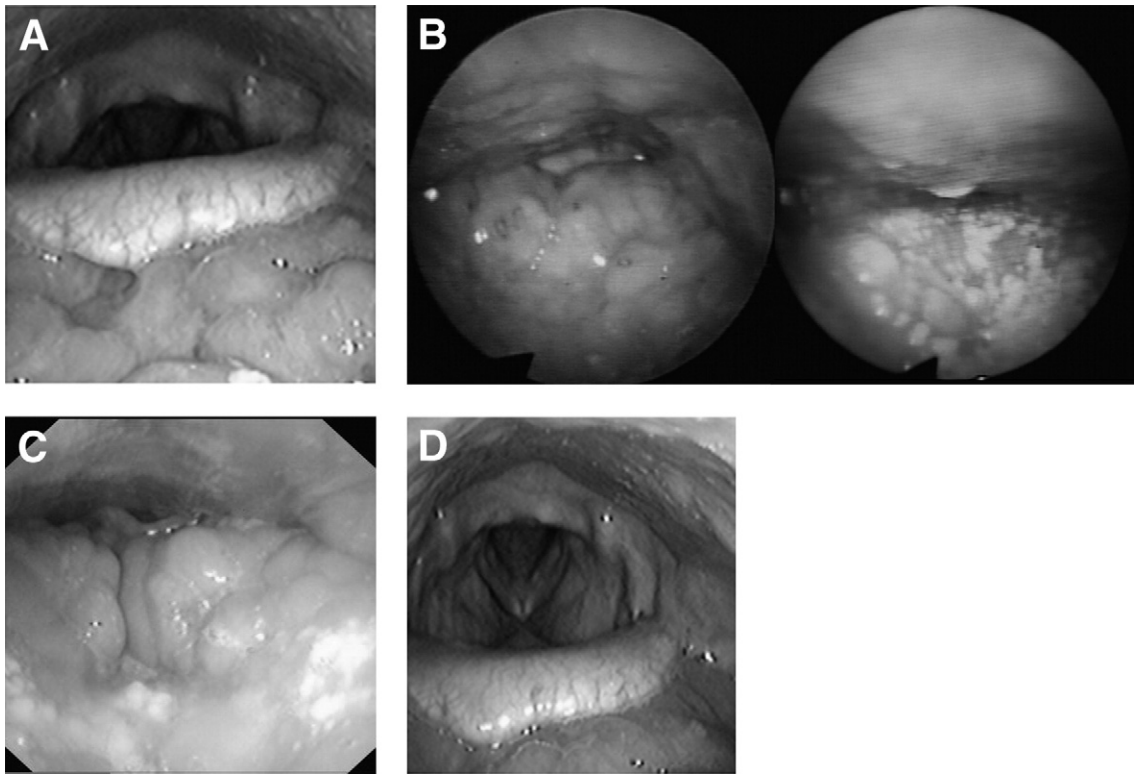

Figure 5 Tongue base obstruction. (A) Partial AP obstruction; (B) complete AP obstruction; (C) hypertrophic lingual tonsils; (D) patient with tongue base obstruction whilst performing a chinlift.

neck circumference. One of the biggest advantages of DISE is the individual analysis, which allows patient-specific and site-specific therapies according to location and amount. Although we have the impression that surgical success rates in patients selected by DISE are better than average, this has to be confirmed in more studies.[12,23]

As opposed to most surgical evaluation techniques, DISE not only uniquely offers a dynamic evaluation of the upper airway during conditions that ideally mimic natural sleep but also enables visualization of specific structures that contribute to upper airway obstruction. This structure-based characterization is the foundation of DISE and must be the core of any classification system. The recording and reporting of structure-specific findings will enable comparison of data across centers and procedures.

The structures of the VOTE acronym

Our experience with over 7500 DISE examinations suggests that a selected group of structures contribute to upper airway narrowing and/or obstruction in sleep disorded breathing, individually or in combination. The VOTE Classification (Table 2) evaluates these structures and the degree of airway narrowing.

Velum. Velopharyngeal obstruction occurs at the level of soft palate, uvula, or lateral pharyngeal wall tissue at the level of the velopharynx. Because these 3 structures are not entirely distinct entities—both anatomically and on DISE—we have grouped them together. Airway closure related to the velum can occur with collapse in an anteroposterior or concentric configuration, but rarely in a lateral configuration (Figure 3A-D).

Oropharyngeal lateral walls including tonsils. The oropharyngeal lateral walls include 2 structures: the tonsils and the lateral pharyngeal wall tissues that include musculature and the adjacent parapharyngeal fat pads. Both structures collapse in a lateral configuration, although this may occur in combination with collapse of other structures, with a resulting concentric pattern. In the presence of lateral wall collapse, it can be difficult (but certainly not impossible) to determine whether the tonsils or lateral walls are playing a significant role, reflecting potential subtypes; importantly, the distinction can have important implications for treatment selection and outcomes. While the VOTE Classification is largely based on DISE findings alone, the examination of tonsil size and lateral pharyngeal wall tissues during routine oral cavity examination can be invaluable in making a determination of potential contributions of each structure. Obstruction related to the oropharynx can occur with collapse in a lateral or concentric configuration, but not in an anteroposterior configuration (Figure 4A-E).

Tongue base. Tongue base obstruction is a common DISE finding, and it results in anteroposterior narrowing of the upper airway. In natural sleep, there is a reduction in muscle tone of the tongue, especially during non-REM and REM sleep that is more pronounced in OSA patients compared to healthy individuals. Airway closure related to the base of

Figure 6 Epiglottis obstruction. (A) Anteroposterior; (B) lateral.

tongue occurs with collapse in an anteroposterior direction (Figure 5A-D).

Epiglottis. Epiglottic collapse occurs in 1 of 2 configurations, anteroposterior (Figure 6A) or lateral (Figure 6B), but not concentric. Anteroposterior collapse can result with folding of the epiglottis with what appears to be decreased structural rigidity of the epiglottis or with an apparent posterior displacement of the entire epiglottis against the posterior pharyngeal wall, with normal epiglottic structural integrity. The second pattern, a lateral folding or involution, is consistent with a central vertically oriented crease of decreased rigidity of the epiglottis. The epiglottis may be underrecognized as a factor in patients with sleep-disordered breathing, and a substantial proportion of patients with OSA do demonstrate a significant epiglottic contribution to airway obstruction during DISE.[3,7,19] DISE may provide a unique assessment of the epiglottis, as its apparent role has not been demonstrated as clearly demonstrated with other evaluation techniques (Fujita, Mallampati/Friedman).

Other structures

Although less common, airway obstruction in sleep-disordered breathing can be related to other structures. In rare cases collapse above the VOTE level, for example, by massive nasal polyps, adenoid hypertrophy or nasopharyngeal neoplasms, or below the VOTE level, for example, vocal cord level, in postradiation edema or vocal cord paralysis, can be visualized. This is usually detected by awake examination already. If indicated, they are noted separately. We do not mean to minimize their potential role but believe the VOTE Classification reflects patterns seen in the large majority of patients.

Degree of airway narrowing

The VOTE Classification involves a qualitative assessment of the degree of airway narrowing, divided into the following:

None (typically with no vibration of the involved structure and less than 50% airway narrowing compared to dimensions during nonapneic state)
Partial (vibration, 50-75% narrowing), or
Complete (obstruction, greater than 75% narrowing, and no airflow). We recognize that differentiating between the 3 categories is not always clear, although the evaluation of degree of obstruction has been demonstrated as having moderate reliability.[7] At 1 level in the upper airway, a partial collapse (vibration, snoring) might be present, while at the other level a complete collapse might be detected.

The VOTE Classification differs slightly from what we independently have developed for use in our practice, as it reflects the most fundamental aspects of the DISE evaluation.[5,18] The VOTE Classification does not exclude addition of center-specific assessments. DISE has the advantage of permitting certain maneuvers, ranging from manual closure of the mouth only (Figure 1), to the Esmarch/jaw thrust

(Figure 2). It goes without saying that multiple, separate tables can be used during a single DISE to record changes in the pattern of collapse that occur after an assessment with jaw thrust or altered body position, for example.

Complications

There are no severe side effects or emergency situations described with DISE in the literature. In more than 7,500 combined endoscopies, endotracheal intubation, tracheostomy, or use of flumazenil was never necessary. In case of oversedation, airway management with the use of positive pressure or, in rare cases, a laryngeal mask airway may be required. In cases with marked oxygen desaturation on sleep study, oxygen insufflation (such as 2-4 L/min via blow by face mask or nasal cannula) may help to prevent undesirable desaturations. Saliva aspiration can occur, but it is rare and usually not dangerous. However, it may compromise the procedure, due to extreme coughing. Laryngospasm is rare. Regurgitation and aspiration acid reflux are theoretically possible and might need specific treatment. The authors did not encounter such cases.

To prevent complications in high-risk patients such as those with body mass index >35 kg/m^2, problematic anatomical features (short neck, modified Mallampati position IV), DISE may be performed concurrent with positive airway pressure administration.

Conclusions

DISE is a valid addition to polysomnography and clinical assessment in an awake patient. Correct technique and performance presumed, it is a reliable and safe tool to detect and analyze the phenomena of the upper airway during sleep visually and acoustically.

The anatomical structures that are involved in sound generation and obstruction of the upper airway can be identified individually. By identifying specific structures that mediate collapse, surgeons may potentially be able to develop targeted, effective treatment plans. Individual therapeutic planning concerning choice and extent of surgical procedures can be optimized. With the help of passive maneuvers the potential efficacy of intraoral devices or other nonsurgical options can be estimated. Various studies have examined the association between DISE findings and outcomes of palate surgery and mandibular repositioning appliances. We hope introduction of the VOTE system will aid comparison between findings, both intra- and interindividually. The shared use of the VOTE Classification can facilitate the scientific evaluation of DISE in individual centers and, just as importantly, the collection of data across multiple centers. With these data we can compare results across studies and increase our knowledge and find supporting evidence whether DISE is indeed beneficial to the outcomes of existing and novel treatments for snoring and OSA.

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