Curr Otorhinolaryngol Rep (2013) 1:1–7
DOI 10.1007/s40136-012-0005-2

SLEEP APNEA (SL ISHMAN, SECTION EDITOR)

The Utility of Sleep Endoscopy in Adults with Obstructive Sleep Apnea: A Review of the Literature

J. Peter van Maanen · Madeline J. L. Ravesloot · Faiza Safiruddin · Nico de Vries

Published online: 4 January 2013

Abstract Since history and physical examination alone cannot reliably diagnose obstructive sleep apnea (OSA), the gold standard for the diagnosis of OSA is polysomnography. When an oral device or surgery is considered, it is of utmost importance to examine an individual's pattern, degree and site(s) of upper airway obstruction. This article tries to evaluate recent literature published on the use of (drug-induced) sleep endoscopy in evaluating the individually tailored treatment. Different techniques, interrater reliability, test–retest reliability and currently available data on the relationship with treatment outcome are reviewed.

Keywords Sleep endoscopy · Sleep apnea · Diagnosis · Drug induced sleep endoscopy

Abbreviations

AHI	Apnea hypopnea index
ASA	American Society of Anesthesiologists
BIS	Bispectral index monitoring
BMI	Body mass index
DISE	Drug-induced sleep endoscopy
OPDA	Outpatient department assessment
OSA	Obstructive sleep apnea
PSG	Polysomnography

J. P. van Maanen (✉) · M. J. L. Ravesloot · F. Safiruddin · N. de Vries
Department of Otorhinolaryngology, Head and Neck Surgery, St. Lucas Andreas Hospital, Jan Tooropstraat 164, 1061 Amsterdam, The Netherlands
e-mail: p.vanmaanen@slaz.nl

J. P. van Maanen · M. J. L. Ravesloot
Department of Otorhinolaryngology, Head and Neck Surgery, Academic Medical Center, Amsterdam, The Netherlands

Introduction

Obstructive sleep apnoea (OSA) is characterized by periods of cessation (apnea) and reduction (hypopnea) of the oronasal airflow during sleep accompanied by desaturations of blood oxygen. This sleep-related breathing disorder is a result of abnormal anatomy (crowding of the upper airway) superimposed on physiological or excessive reduction of muscle tone during sleep. Clinical symptoms are snoring, restless sleep, daytime fatigue, diminished intellectual ability and changes in personality. If OSA remains untreated, patients are at higher risk of developing cardiovascular diseases [1–6]. Furthermore, in the case of an apnea hypopnea index (AHI) >40/h the risk of being involved in a traffic accident increases [7].

For many years, treatment for OSA has been based on low levels of evidence. A systematic review by Wright et al. [8] drew attention to the need for evidence on the efficacy of its main treatment: continuous positive airway pressure (CPAP). Since then, evidence has been collected on the impact of OSA on quality of life and health as well as the efficacy of various treatment modalities [9, 10]. CPAP is regarded as the gold standard in OSA treatment in many countries. However, it is a clinical reality that the use of CPAP is often cumbersome. CPAP patients are considered compliant when CPAP is used ≥4 h per night as an average over all nights observed. We recently analyzed CPAP compliance using the above-mentioned criteria and found this to be true in <60 % of a group of 232 CPAP users [11]. Furthermore, it has been proposed that using an AHI value whilst truly using CPAP does not reliably reflect the full overnight situation and it would be better to report mean AHI data in patients using CPAP therapy [12].

Because of the limited number of high quality (i.e., level one or two) evidence articles on the effects of surgery for

OSA some authors deny that there is any role for surgery in the treatment of OSA [13]. A more recent systematic review addressed the limitations of surgical studies of OSA patients and the differences compared to studies concentrating on more conservative treatment options. They identified 12 randomized controlled trials studying palatal implants, radiofrequency surgery, maxillomandibular advancement and uvulopalatoplasty and concluded that high quality trials studying surgical treatment are feasible and can lead to recommendations with high levels of evidence [14]. Other authors concluded in a systematic review that, in a certain percentage of OSA patients who either fail or are unwilling to pursue CPAP therapy, multilevel OSA surgery offers a chance to control their OSA [15].

In some countries, like The Netherlands, oral devices and surgery are considered as primary treatment options in well-selected patients with snoring or mild to moderate OSA. Obviously, patient selection and assessment of the site(s) of obstruction is paramount to successful treatment with an oral device or surgery. The gold standard for diagnosing OSA is polysomnography (PSG), preferably the attended overnight polysomnogram [16], since history and physical examination alone cannot reliably diagnose OSA [17, 18].

Multiple evaluation techniques have been developed to examine an individual's pattern and site(s) of upper airway obstruction [19]. Ideally, this evaluation technique should be anatomically and physiologically sensible, with findings that correlate with objective indices of OSA like AHI, and should be proven to improve the results of surgery. Good measurement characteristics include accuracy, low test–retest variability and low interrater variability. Sleep endoscopy in the naturally asleep patient was introduced in 1978 by Borowiecki et al. [20] and in the asleep or sedated patient by Croft and Pringle [21]. The evaluation requires pharmacologic induction of sedation and flexible fiberoptic endoscopy to visualize the upper airway obstruction and/or snoring.

The purpose of this article is to systematically review recently published data on sleep endoscopy as part of the diagnostic work-up in adult OSA patients in whom surgery or oral device therapy is being considered.

Materials and Methods

Literature Query and Data Selection

The MEDLINE and EMBASE databases were systematically searched on 22 September 2012 by two researchers (J.v.M. and M.R.) using synonyms for DISE and OSA (see Appendices 1 and 2). The search was limited to articles with adult, human study subjects, written in the English language, accompanied by an abstract, and articles published between January 2007 and September 2012. In addition, the reference lists of included articles were screened for additional relevant citations. Conclusions were evaluated according to the Oxford Centre for Evidence-Based Medicine levels of evidence (Table 1) [54]. All abstracts, or full text articles if abstracts provided too little information, were reviewed by two researchers (J.v.M. and M.R.).

Table 1 Oxford Centre for Evidence-Based Medicine levels of evidence [54]

Level	Diagnosis
1a	Systematic review of level 1 diagnostic studies
1b	Validating cohort study with good reference standards
1c	Absolute SpPins and SnNouts[a]
2a	Systematic review of level >2 diagnostic studies
2b	Exploratory cohort study with good reference standards
3a	Systematic review of level >3b studies
3b	Non-consecutive study; or without consistently applied reference standards
4	Case–control study
5	Expert opinion

[a] An absolute SpPin is a diagnostic finding whose specificity is so high that a positive result rules-in the diagnosis. An absolute SnNout is a diagnostic finding whose sensitivity is so high that a negative result rules out the diagnosis

Results

DISE: Sedation Methods, Contraindications and Complications

The DISE technique has been extensively reported previously [22••]. Different sedation methods have been described, but there does not seem to be a standardized protocol for sedation methods [22••, 23–27]. Drugs most commonly reported for use with DISE are propofol and/or midazolam. Some use propofol only; others use midazolam only. Others start with midazolam and continue with propofol [28, 29]. A computerized target-controlled infusion (TCI) system for propofol can be helpful and has been shown to be more accurate, stable and safe than a manual bolus injection [30]. Earlier, Berry et al. [27] demonstrated that TCI using propofol caused 100 % of snorers to snore, while 100 % of non-snorers did not snore.

Subjects with an AHI below 30/h, or, to be more accurate, patients with a supine AHI below 30/h and with good health (ASA I or II), can undergo midazolam-induced sleep endoscopy in the clinic [23, 31]. Patients with a higher ASA score and/or more severe OSA should have DISE performed in the operating room.

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 different susceptibilities to propofol, the required dosage can vary widely. Slow stepwise induction is required to avoid oversedation. Recently, bispectral index monitoring (BIS) during DISE has been introduced to determine the level of sedation required for assessment of snoring and/or obstruction [28, 32]. Once the patient has reached a satisfactory level of sedation, a flexible endoscope 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 DISE, maneuvers such as a chin lift (a manal closure of the mouth) or a jaw thrust (or Esmarch maneuver) should be performed, with reassessment of the airway after each maneuver.

A recent prospective study by Rabelo et al. [33••] showed no significant differences in AHI and mean oxygen saturation between two diurnal polysomnograms with and without the use of propofol. Since the main respiratory parameters evaluated in OSA treatment did not significantly change between polysomnograms, they concluded that sedation with propofol permits respiratory evaluation. Earlier, Sadaoka et al. [34] had also demonstrated that respiratory and somnological parameters did not significantly change during diazepam-induced sleep endoscopy in comparison with natural sleep, except for a small increase in the apnea index and a minor change in the duration of the longest apnea and REM sleep.

Several studies have shown the discrepancies between awake endoscopy and endoscopy in the (drug-induced) sleeping patient. Campanini et al. [35] showed, in a retrospective analysis of 250 patients, identical sites of obstruction during awake and sleep endoscopy in only 25 % of patients, as measured by the Nose Oropharynx Hypopharynx Larynx (NOHL) staging system, introduced by the same authors. Hewitt et al. [36] performed a prospective, blinded, cohort study in 94 consecutive, snoring patients and compared outpatient department assessment (OPDA), consisting of examination of ear, nose, mouth, endoscopy (with and without simulated snoring and in combination with Müller's maneuver), to drug-induced sleep endoscopy (DISE) using midazolam (0.05 mg/kg) and propofol (1.5 mg/kg) titrated individually and maintained with boluses of propofol. During DISE, the jaw was lifted 3–5 mm to simulate the effect of an oral device. Based on the OPDA, a palatal intervention was recommended in 74.4 % ($n = 70$) of patients; based on DISE, only 38 (54 %) of these patients were recommended a palatal intervention. In a prospective analysis by Eichler et al. [37••], 97 patients underwent an OPDA, consisting of examination of the ears, nose, mouth, endoscopy and maximum possible protrusion of the mandible, followed by a theoretical treatment plan. A second ENT specialist conducted a DISE (using midazolam starting with 0.03 mg/kg and adding 1 mg every 5 min until the patient fell asleep deeply enough to snore and show obstructions), also with jaw thrust maneuver, and independently recommended a second therapy without knowing the first one. Based on DISE, 76 (78.4 %) patients would have received a different therapy compared to OPDA. Furthermore, they found tongue base surgery and oral device treatment to have the highest rate of change, whereas the indications for tonsil surgery were comparable between DISE and OPDA. Soares et al. [38] retrospectively analyzed 53 patients with OSA and compared OPDA (endoscopy with and without Müller's maneuver) to DISE (with propofol titration of 50/75 mcg/kg/min, the target level of sedation was that of light sleep with arousal to tactile but not vocal stimulation) in diagnosing the presence of severe (>75 % collapse) level-specific upper airway collapse. OPDA and DISE did not differ significantly regarding the presence of severe retropalatal collapse, but did significantly differ in the incidence of severe retrolingual collapse (DISE 84.9 %, OPDA 35.8 %). In Friedman I and II tongue positions [39] the greatest difference was found (DISE 88.9 %, OPDA 16.7 %). Gillespie et al. [32] prospectively studied a group of 38 patients and found a change in surgical plan after DISE in 23 (62 %) patients compared to awake endoscopy. A high ASA (≥3) score and propofol or midazolam allergies (albeit rare) are considered contraindications. Because of a higher procedure-associated risk and lesser effects on treatment decisions, extremely severe OSA (AHI > 70/h) and severe obesity are relative contraindications. No severe side effects or emergency situations with DISE have been described in the literature. Endotracheal intubation or tracheostomy was never necessary [22••].

Conclusions

Drug-induced sleep endoscopy permits respiratory evaluation of the sleeping patient and yields different levels of upper airway collapse and consequently different therapeutic options compared to endoscopy in the awake patient

Level of evidence 3a.

DISE: Scoring

Different methods for assessment of level and type of upper airway collapse have been described in the literature. Vicini et al. [40] introduced the nose, oropharynx, hypopharynx and larynx (NOHL) classification and have been using this system since 1996. It is an extensive classification system, grading the degree of obstruction as (1) (0–25 % obstruction), (2) (25–50 %), (3) (50–75 %) or (4) (75–100 %) and defining the pattern of collapse as transversal, anterior-posterior or concentric. Additionally, possible laryngeal obstruction can be graded as positive/negative and supraglottic/glottic. Bachar et al. [41] recently

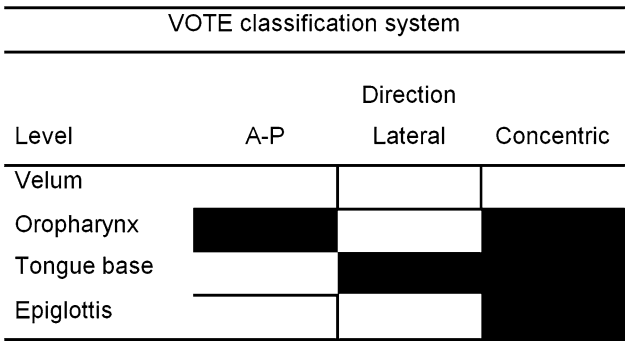

Fig. 1 VOTE classification system [22••, 42, 43]. Degree of obstruction: 0, no obstruction (no vibration, <50 %); 1, partial obstruction (vibration, 50–75 %); 2, complete obstruction (collapse, >75 %); x, not visualized. *A–P* anteroposterior

introduced a novel grading system which allows the user to document collapsibility of the upper airway based on five possible anatomical sites: (1) nose and nasopharynx, (2) palatine plane, uvula and tonsils, (3) tongue base, (4) larynx, and (5) hypopharynx. Obstructions can be categorized as being complete (defined as complete blockage of the airway passage for at least 10 s) or partial (defined as narrowing or intermittent collapse). However, the classification system that has been studied the most is the VOTE system (Fig. 1) [29, 30, 42, 43, 44••]. Velum, oropharynx (including tonsils), tongue base and epiglottis are evaluated. Distinction in configuration is made between anteroposterior, lateral or concentric, depending on the level of obstruction. The degree of airway narrowing is defined as either none (0) (0–50 % obstruction), partial (1) (50–75 % obstruction) or complete (2) (>75 % obstruction). During DISE, a chinlift and a jaw thrust is performed and the different VOTE levels are assessed once again to evaluate whether an oral device is a viable treatment option.

Conclusions

To this point, there has been no gold standard for type(s) of sedative(s) during sleep endoscopy. Target-controlled infusion has proven to be more accurate than a manual bolus injection and seems to be the way to go when it comes to infusion of sedative. Bispectral index monitoring could be an adjunct to the assessment of DISE, although this has not yet been studied thoroughly. For upper airway obstruction using DISE, the VOTE system has been studied the most and seems easily applicable.

Level of evidence 3a.

DISE: Interrater and Test–Retest Reliability

Rodriguez-Bruno et al. [45] prospectively studied 32 patients undergoing 2 separate DISE examinations. Both examinations were evaluated by one unblinded surgeon and one blinded surgeon (with only knowledge of whether or not the patient had undergone prior tonsillectomy). These two DISE examinations were reviewed twice by each surgeon (2–6 weeks apart) resulting in 8 evaluations per patient, using a three-tiered method for DISE examination grading: (1) dichotomous (yes or no) assessment of obstruction at palatal and hypopharyngeal levels, (2) degree of palatal and hypopharyngeal obstruction, and (3) specific structures in palatal and hypopharyngeal region contributing to obstruction. They found a good test–retest reliability (range 50–80 %), particularly in the evaluation of the hypopharyngeal airway. Using this same three-tiered method for DISE examination grading, Kezirian et al. [46••] prospectively studied 108 patients undergoing DISE. One unblinded surgeon performed all DISE examinations. The video images were later reviewed concurrently but independently by two surgeons (the unblinded surgeon and the blinded surgeon with only knowledge of whether or not the patient had undergone prior tonsillectomy). The interrater reliability for the presence of obstruction at the palate and hypopharynx (κ values, 0.76 and 0.79, respectively) was higher than for the degree of obstruction (weighted κ values, 0.60 and 0.44). The interrater reliability for evaluation of the hypopharyngeal structures was higher than for those of the palate region. Overall, interrater reliability of DISE seemed to be moderate to substantial. Gillespie et al. [29] recently evaluated interrater and test–retest reliability by prospectively evaluating 38 patients using DISE index scores. Test–retest reliability was evaluated by comparing the original intraoperative examination of the DISE index score to the DISE index score assigned on blind review of the DISE recording. Interrater reliability was determined, in a blinded and randomized fashion, by three otolaryngologists trained in DISE examinations. Test–retest reliability was good ($\kappa = 0.61$). Interrater reliability also showed good results ($\kappa = 0.65$) ($\kappa = 0.62$ between observer pairs).

Conclusions

Interrater and test–retest reliability for DISE have shown to be moderate to good. Interrater and test–retest reliability of VOTE need further investigation.

Level of evidence 3a.

DISE: Findings in Relation to Clinical and Sleep Parameters and Therapeutical Outcome

Several studies have evaluated the relation of level(s) of obstruction and AHI. Ravesloot and de Vries [43] prospectively analyzed 100 DISE examinations (mean AHI = 21.3/h) scored using the VOTE system and found multilevel

obstruction (which was present in 76 patients) to be statistically significantly related to a higher AHI compared to patients with a unilevel obstruction. They found that the majority of patients had a palatal obstruction (83 %), followed by tongue base (56 %) and epiglottis obstruction (38 %). Patients suffering from a complete concentric collapse of the velum were statistically significantly more likely to have a higher AHI and BMI, whereas an anteroposterior velar collapse was significantly associated with a lower BMI. Furthermore, AHI was found to be statistically significantly higher in patients with a complete anteroposterior collapse of the tongue. Observation of a tongue base or epiglottis obstruction was more common in positional OSA patients; however, this difference was not statistically significant ($P = 0.058$). As an alternative to the qualitative VOTE system for assessing upper airway collapsibility, Borek et al. [47] recently quantified the collapse seen at multiple levels of the upper airway in 37 OSA patients (mean AHI = 42.9/h). Using cross-sectional areas of captured images during DISE, they also showed that upper airway collapse occurs at multiple levels. Mean reductions in airway cross-sectional area were found to be 84.1 % for retropalatal, 39.3 % for retroglossal and 44.6 % for retroepiglottic region which is in line with the previously mentioned article [43].

Koutsourelakis et al. [44••] retrospectively analyzed 49 DISE examinations (scored using the VOTE system) of OSA patients (mean AHI = 30.9/h) who had undergone surgery (palatal surgery, and/or radiofrequent ablation of tongue base, and/or hyoid suspension). Multivariate logistic regression analysis revealed the presence of a complete circumferential collapse at the velum or a complete anteroposterior collapse at tongue base to be independent predictors of upper airway surgery failure. Earlier studies have shown that subjects with palatal obstruction alone versus multilevel obstruction on DISE had better outcomes after palate surgery [48, 49].

Johal et al. [36, 50, 51] showed that the resolution of airway obstruction with manual mandibular advancement under sedation is associated with improved outcomes with treatment using oral devices. More recently, titration of oral device therapy has been investigated by Vanderveken et al. [52], who recently introduced the technique of a simulation bite to be used during DISE and to predict treatment outcome with oral device therapy possibly leading to even more successful treatment of OSA with oral device therapy.

Conclusions

DISE findings (either qualitatively or quantitatively scored) correlate well with AHI and allow for better selection of type of surgery or titration of oral device therapy.

Level of evidence 3a.

DISE: Conclusion and Future Perspectives

DISE is a valid, dynamic, safe and easy-to-perform examination when surgery or oral device treatment is considered. Adequate assessment of the site(s) of obstruction, with use of both DISE and the VOTE classification, targets improvement of OSA treatment success. Furthermore, the shared use of a universally used DISE scoring system 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.

Target-controlled infusion has proven to be more accurate than a manual bolus injection. However, the target depth of sedation is still to be found. BIS monitoring could be of added value.

Increase in the number of DISE examinations is to be expected, not only because of the growing OSA awareness but, perhaps in the near future, also to cut healthcare system costs by means of CPAP titration during DISE instead of during a costly overnight in-hospital polysomnography [53].

Whilst the gold standard investigation to evaluate level(s) of obstruction is yet to be defined, we believe that DISE provides the clinician with an accurate assessment of the obstruction site(s) as to be able to provide a site(s)-specific treatment.

Disclosure

J.P. van Maanen: none; M.J.L. Ravesloot: none; F. Safiruddin: none; N. de Vries: member of the Medical advisory board of MSD, ReVent Medical and NightBalance, is investigator for Inspire, has had honoraria payments from MSD, is consultant for Philips and has stock options in ReVent Medical.

Appendix 1: Syntax MEDLINE

(sleep[tiab] OR asleep[tiab] OR sedated[tiab] OR "drug induced"[tiab] OR drug-induced[tiab] OR DISE[tiab]) AND ("Endoscopy"[Mesh] OR endoscopy[tiab] OR endoscopies[tiab] OR nasendoscopy[tiab] OR nasendoscopies[tiab] OR telescopy[tiab] OR videoendoscopy[tiab] OR videoendoscopies[tiab]) AND ("Sleep Apnea, Obstructive"[Mesh] OR OSA[tiab] OR OSAS[tiab] OR apnoea[tiab] OR apnea[tiab] OR hypopnea[tiab] OR hypopnoea[tiab] OR apneic[tiab] OR "sleep disordered"[tiab] OR SDB[tiab] OR sleep-disordered[tiab]) AND ("2007/1/1"[Date - Publication]: "3000"[Date - Publication]).

Appendix 2: Syntax EMBASE

(sleep or asleep or sedated or dise or drug-induced or "drug-induced").ab,ti and (endoscopy or endoscopies or nasendoscopy or nasendoscopies or telescopy or videoendoscopy or videoendoscopies).ab,ti. and (OSA or OSAS or apnoea or apnea or hypopnea or hypopnoea or apneic or "sleep disordered" or SDB or sleep-disordered).ab,ti.

limit: yr="2007-current".

References

Papers of particular interest, published recently, have been highlighted as:

•• Of major importance

1. Dyken ME, Somers VK, Yamada T, et al. Investigating the relationship between stroke and obstructive sleep apnea. Stroke. 1996;27:401–7.
2. Marin JM, Carrizo SJ, Vicente E, Agusti AG. Long-term cardiovascular outcomes in men with obstructive sleep apnoea–hypopnoea with or without treatment with continuous positive airway pressure: an observational study. Lancet. 2005;365:1046–53.
3. Peppard PE, Young T, Palta M, Skatrud J. Prospective study of the association between sleep-disordered breathing and hypertension. N Engl J Med. 2000;342:1378–84.
4. Phillipson EA. Sleep apnea—a major public health problem. N Engl J Med. 1993;328:1271–3.
5. Shahar E, Whitney CW, Redline S, et al. Sleep-disordered breathing and cardiovascular disease: cross-sectional results of the Sleep Heart Health study. Am J Respir Crit Care Med. 2001; 163:19–25.
6. Shamsuzzaman ASM, Gersh BJ, Somers VK. Obstructive sleep apnea, implications for cardiac and vascular disease. JAMA. 2003;290:1906–14.
7. George CF, Smiley A. Sleep apnea and automobile crashes. Sleep. 1999;22:790–5.
8. Wright J, Johns R, Watt I, et al. Health effects of obstructive sleep apnoea and the effectiveness of continuous positive airways pressure: a systematic review of the research evidence. BMJ. 1997;7084:851–60.
9. Lim J, Lasserson TJ, Fleetham J, Wright JJ. Oral appliances for obstructive sleep apnoea. Cochrane Database Syst Rev. 2006;1: CD004435.
10. Giles TL, Lasserson TJ, Smith BJ, et al. Continuous positive airways pressure for obstructive sleep apnoea in adults. Cochrane Database Syst Rev. 2006;3:CD001106.
11. Richard W, Venker J, den Herder C, et al. Acceptance and long-term compliance of nCPAP in obstructive sleep apnea. Eur Arch Otorhinolaryngol. 2007;264:1081–6.
12. Ravesloot MJL, de Vries N. Reliable calculation of the efficacy of non-surgical treatment of obstructive sleep apnea revisited. Sleep. 2011;34:105–10.
13. Sundaram S, Lim J, Lasserson TJ. Surgery for obstructive sleep apnoea. Cochrane Database Syst Rev. 2005;4:CD001004.
14. Sommer JU, Maurer JT, Hörmann K, Stuck BA. Randomized controlled trials in the surgical treatment of obstructive sleep apnea. HNO. 2012;60:294–9.
15. Lin HC, Friedman M, Chang HW, Gurpinar B. The efficacy of multilevel surgery of the upper airway in adults with obstructive sleep apnea/hypopnea syndrome. Laryngoscope. 2008;118:902–8.
16. Kushida CA, Littner MR, Morgenthaler T, et al. Practice parameters for the indications for polysomnography and related procedures: an update for 2005. Sleep. 2005;28:499–521.
17. Dreher A, de la Chaux R, Klemens C, et al. Correlation between otorhinolaryngologic evaluation and severity of obstructive sleep apnea syndrome in snorers. Arch Otolaryngol Head Neck Surg. 2005;131:95–8.
18. Hessel NS, Laman M, van Ammers VC, et al. Diagnostic work-up of socially unacceptable snoring. History or sleep registration. Eur Arch Otorhinolaryngol. 2002;259:154–7.
19. Stuck BA, Maurer JT. Airway evaluation in obstructive sleep apnea. Sleep Med Rev. 2008;12:411–36.
20. Borowiecki B, Pollak CP, Weitzman ED, et al. Fibro-optic study of pharyngeal airway during sleep in patients with hypersomnia obstructive sleep-apnea syndrome. Laryngoscope. 1978;88: 1310–3.
21. Croft CB, Pringle M. Sleep nasendoscopy: a technique of assessment in snoring and obstructive sleep apnoea. Clin Otolaryngol Allied Sci. 1991;16:504–9.
22. •• Hohenhorst W, Ravesloot MJL, Kezirian EJ, de Vries N. Drug-induced sleep endoscopy in adults with sleep-disordered breathing: technique and the VOTE classification system. Oper Tech Otolaryngol Head Neck Surg. 2012;23:11–8. *A nicely illustrated and detailed article on DISE and VOTE techniques.*
23. Hessel NS, de Vries N. Diagnostic work-up of socially unacceptable snoring. Sleep endoscopy. Eur Arch Otorhinolaryngol. 2002;259:158–61.
24. Kezirian EJ. Drug-induced sleep endoscopy. Oper Tech Otolaryngol Head Neck Surg. 2006;17:230–2.
25. Hamans E, Meeus O, Boudewyns A, et al. Outcome of sleep endoscopy in obstructive sleep apnoea: the Antwerp experience. B-ENT. 2010;6:97–103.
26. Abdullah VJ, Wing YK, van Hasselt CA. Video sleep nasendoscopy: the Hong Kong experience. Otolaryngol Clin North Am. 2003;36:461–71.
27. Berry S, Roblin G, Williams A, et al. Validity of sleep nasendoscopy in the investigation of sleep related breathing disorders. Laryngoscope. 2005;115:538–40.
28. Babar-Craig H, Rajani NK, Bailey P, Kotecha BT. Validation of sleep nasendoscopy for assessment of snoring with bispectral index monitoring. Eur Arch Otorhinolaryngol. 2012;269: 1277–9.
29. Johal A, Hector MP, Battagel JM, Kotecha BT. Impact of sleep nasendoscopy on the outcome of mandibular advancement splint therapy in subjects with sleep-related breathing disorders. J Laryngol Otol. 2007;121:668–75.
30. De Vito A, Agnoletti V, Berrettini S, et al. Drug-induced sleep endoscopy: conventional versus target controlled infusion techniques—a randomized controlled study. Eur Arch Otorhinolaryngol. 2011;268:457–62.
31. Den Herder C, van Tinteren H, de Vries N. Sleep endoscopy versus modified Mallampati score in sleep apnea and snoring. Laryngoscope. 2005;115:735–9.
32. Gillespie MB, Reddy RP, White DR, et al. A trial of drug-induced sleep endoscopy in the surgical management of sleep-disordered breathing. Laryngoscope. 2013;123:277–82.
33. •• Rabelo FA, Braga A, Küpper DS, et al. Propofol-induced sleep: polysomnographic evaluation of patients with obstructive sleep apnea and controls. Otolaryngol Head Neck Surg. 2010;142:218–24. *This article compares polysomnographical parameters during normal sleep to polysomnographical parameters whilst under propofol sedation.*
34. Sadaoka T, Kakitsuba N, Fujiwara Y, et al. The value of sleep nasendoscopy in the evaluation of patients with suspected sleep-

related breathing disorders. Clin Otolaryngol Allied Sci. 1996;21: 485–9.
35. Campanini A, Canzi P, De Vito A, et al. Awake versus sleep endoscopy: personal experience in 250 OSAHS patients. Acta Otorhinolaryngol Ital. 2010;30:73–7.
36. Hewitt RJD, Dasgupta A, Singh A, et al. Is sleep nasendoscopy a valuable adjunct to clinical examination in the evaluation of upper airway obstruction? Eur Arch Otorhinolaryngol. 2009;266: 691–7.
37. •• Eichler C, Sommer JU, Stuck BA, et al. Does drug-induced sleep endoscopy change the treatment concept of patients with snoring and obstructive sleep apnea? Sleep Breath 2012. doi: 10.1007/s11325-012-0647-9. *This article very systematically evaluates whether or not DISE-based treatment recommendations are different to those made after clinical basic ENT examination.*
38. Soares D, Folbe AJ, Yoo G, et al. Drug-induced sleep endoscopy vs awake Müller's maneuver in the diagnosis of severe upper airway obstruction. Otolaryngol Head Neck Surg. 2013;148: 151–6.
39. Friedman M, Ibrahim H, Bass L. Clinical staging for sleep-disordered breathing. Otolaryngol Head Neck Surg. 2002;127: 13–21.
40. Vicini C, De Vito A, Benazzo M, et al. The nose oropharynx hypopharynx and larynx (NOHL) classification: a new system of diagnostic standardized examination of OSAHS patients. Eur Arch Otorhinolaryngol. 2012;269:1297–300.
41. Bachar G, Nageris B, Feinmesser R, et al. Novel grading system for quantifying upper-airway obstruction on sleep endoscopy. Lung. 2012;190:313–8.
42. Kezirian EJ, Hohenhorst W, de Vries N. Drug-induced sleep endoscopy: the VOTE classification. Eur Arch Otorhinolaryngol. 2011;268:1233–6.
43. Ravesloot MJL, de Vries N. One hundred consecutive patients undergoing drug-induced sleep endoscopy: results and evaluation. Laryngoscope. 2011;121:2710–6.
44. •• Koutsourelakis I, Safiruddin F, Ravesloot M, et al. Surgery for obstructive sleep apnea: sleep endoscopy determinants of outcome. Laryngoscope. 2012;122(11):2587–91. *A retrospective analysis focussing on DISE findings using the VOTE system in relation to treatment outcome. A-P palatal collapse is more favourable than concentric collapse, partial is better than complete collapse (as expected).*
45. Rodriguez-Bruno K, Goldberg AN, McCulloch CE, Kezirian EJ. Test-retest reliability of drug-induced sleep endoscopy. Otolaryngol Head Neck Surg. 2009;140:646–51.
46. •• Kezirian EJ, White DP, Malhotra A, et al. Interrater reliability of drug-induced sleep endoscopy. Arch Otolaryngol Head Neck Surg. 2010;136:393–7. *A nicely setup article on interrater reliability of DISE and the first article written on this subject.*
47. Borek RC, Thaler ER, Kom K, et al. Quantitative airway analysis during drug-induced sleep endoscopy for evaluation of sleep apnea. Laryngoscope. 2012;122(11):2592–9.
48. Iwanaga K, Hasegawa K, Shibata N, et al. Endoscopic examination of obstructive sleep apnea syndrome patients during drug-induced sleep. Acta Otolaryngol Suppl. 2003;550:36–40.
49. Hessel NS, de Vries N. Increase of the apnoea-hypopnoea index after uvulopalatopharyngoplasty: analysis of failure. Clin Otolaryngol Allied Sci. 2004;29:682–5.
50. Johal A, Battagel JM, Kotecha BT. Sleep nasendoscopy: a diagnostic tool for predictin treatment success with mandibular advancement splints in obstructive sleep apnoea. Eur J Orthod. 2005;27:607–14.
51. Johal A, Conaghan C. Maxillary morphology in obstructive sleep apnea: a cephalometric and model study. Angle Orthod. 2004;74: 648–56.
52. Vanderveken OM, Vroegop AVM, Van de Heyning PH, et al. Drug-induced sleep endoscopy completed with a simulation bite approach for the prediction of the outcome of treatment of obstructive sleep apnea with mandibular repositioning appliances. Oper Tech Otolaryngol. 2011;22:175–82.
53. Civelek S, Emre IE, Dizdar D, et al. Comparison of conventional continuous positive airway pressure to continuous positive airway pressure titration performed with sleep endoscopy. Laryngoscope. 2012;122:691–5.
54. OCEBM Levels of Evidence Working Group. The Oxford 2011 Levels of Evidence. Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=5653. Accessed 22 Sept 2012.