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Does Drug-Induced Sleep Endoscopy Predict Surgical Success in Transoral Robotic Multilevel Surgery in Obstructive Sleep Apnea?

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Objectives/Hypothesis: The aim of this study was to determine if drug-induced sleep endoscopy (DISE) was predictive of success for patients undergoing transoral robotic surgery (TORS) and multilevel procedures for sleep apnea.

Study Design: Retrospective case series of patients who underwent TORS surgery for sleep apnea

Methods: Before and after polysomnograms were analyzed to assess improvement, success, and cure. Improvement was defined as any decrease in apnea-hypopnea index (AHI), success as an AHI <20 with a decrease $>50\%$, and cure as an AHI <5. DISE videos were scored using the NOHL (nose, oropharynx, hypopharynx, larynx) and VOTE (velum, oropharynx, tongue, epiglottis) classification systems.

Results: One hundred one patients were available for analysis. Eighty-seven percent of patients had an improvement in their AHI. Fifty-one percent met criteria for success, whereas 17% were cured. The degree of collapse at individual NOHL and VOTE subsites as well as total additive scores did not predict improvement, success, or cure. Patients with no oropharyngeal lateral collapse in the VOTE classification system were more likely to improve following surgery ($P = .001$); however, this effect did not hold for success or cure. Multivariate analysis of DISE variables was not predictive of success.

Conclusions: In obstructive sleep apnea patients, there is a 51% success rate and a 17% cure rate. DISE, as scored by the NOHL and VOTE system, did not readily identify patients who would benefit most from surgery. Patients with lateral oropharyngeal collapse may be poorer candidates. Prospective, larger studies are required to further evaluate the use of DISE in predicting success following TORS.

Key Words: Obstructive sleep apnea, transoral robotic surgery, drug-induced sleep endoscopy, nose, oropharynx, hypopharynx, larynx, velum, tongue, epiglottis.

Level of Evidence: 4

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INTRODUCTION

Obstructive sleep apnea and hypopnea syndrome is a common and underdiagnosed disorder characterized by daytime and nocturnal symptoms and findings of an apnea-hypopnea index (AHI) >5 on a polysomnogram. The condition is associated with increased cardiovascular morbidity. It is estimated that 13% of men and 6% of women have an AHI $\geq$15.[1] The gold standard treatment is the use of positive air pressure (PAP). However, the compliance rates range from 30% to 60%, with some individuals unable to tolerate daily use of the PAP machines.[2] Alternative treatments include the use of oral appliances and surgical procedures.

Recently, transoral robotic surgery (TORS) was introduced as an alternative treatment for those patients undergoing multilevel surgery after failing PAP therapy. Specifically, TORS is used to access the lingual tonsils, base of tongue, and epiglottis. Previously, these regions have been difficult to treat surgically prior to the use of the robot. Since the original description in 2010 by Vicini et al.,[3] TORS has become an accepted addition in the armamentarium for multilevel sleep surgery.

Drug-induced sleep endoscopy (DISE) is a technique first described as sleep nasendoscopy[4] and involves the use of sedative anesthesia and a flexible fiberoptic laryngoscope to directly visualize the dynamic collapse of the upper airway. It has been shown to be a valid assessment[5] of the upper airway and has been used by some centers to determine both the ideal surgical candidate and surgical technique. The procedure, however, is not without risk, including the need for unplanned intubation or an emergency surgical airway. DISE has been shown to reveal obstruction at the base of tongue and epiglottis that is not seen during awake endoscopy.[6] However, there are little data supporting the use of DISE in predicting the severity of sleep apnea or the ability to predict outcomes following surgical intervention. The objective of this study was to assess if DISE was predictive of success in patients with obstructive sleep apnea (OSA) undergoing TORS with other multilevel procedures using two different scoring criteria.

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MATERIALS AND METHODS

Preoperative Examination

The institutional review board of St. Joseph Mercy Health System approved the study, and a waiver of informed consent was obtained. The medical records of consecutive patients (n = 162) who underwent TORS lingual tonsillectomy and other multilevel procedures for OSA by a single surgeon between December 2010 and February 2015 were reviewed. Patients with a BMI <40 and AHI ≥15 at the time of preoperative evaluation were included in the study (n= 149). Patients were excluded if they previously underwent TORS lingual tonsillectomy (n = 4). Patients were also excluded if a video of the DISE procedure or if the postoperative polysomnogram (PSG) was not available. A total of 101 adult patients with moderate to severe sleep apnea were available for analysis. Demographic information and preoperative examination variables were collected. DISE videos were scored using a committee consisting of two attending otolaryngologists, two otolaryngology residents, and a senior medical student. These individuals were blind to the office examination including body mass index (BMI), palatine tonsil size, occlusion, lingual tonsil size, Friedman stage, and Friedman palate position as well as to the outcome of each patient. All patients were scored using both the VOTE (velum, oropharynx, tongue, epiglottis)[7] and the NOHL (nose, oropharynx, hypopharynx, larynx)[8] classification systems. These two systems have been independently developed to determine the degree of obstruction on DISE. Within the VOTE system, the degree of collapse was collected at each level (0: no obstruction, 1: partial obstruction with vibration, 2: complete obstruction). The direction of collapse was recorded as anterior-posterior, concentric, or lateral. For the NOHL system, three variables were collected at each level. The degree of collapse was scored as % obstruction (1: 0%–25%, 2: 25%–50%, 3: 50%–75%, 4: 75%–100%). The direction of collapse was recorded as anterior-posterior, concentric, or lateral. The presence or absence of vibration was recorded as "flow" (collapse without vibration or vibration present).

DISE

DISE has been well described in the literature. Briefly, the procedure is performed in the operating room with the patient under monitored anesthesia using a manual infusion bolus of propofol (Teva Pharmaceutical Industries Ltd., Petah Tikva, Israel). A bispectral index (BIS) monitor (Medtronic, Minneapolis, MN) was used with a target score of 60 to ensure sufficient sedation to mimic airway collapse during sleep. A fiberoptic laryngoscope was advanced through the nasal cavity with care to visualize areas of obstruction in the nasal cavity, nasopharynx, oropharynx, and larynx. Areas of visualized collapse as well as in-office physical examination were used to plan the surgical procedure including the use of the following procedures: septoplasty, inferior turbinate reduction, adenoidectomy, uvuloplasty, palate Z-plasty, uvulopalatopharyngoplasty (UPPP), tonsillectomy, lateral expansion sphincteroplasty, TORS lingual tonsillectomy, partial midline glossectomy, and epiglottoplasty. All patients underwent TORS lingual tonsillectomy. When indicated, nasal procedures were performed immediately following DISE.

TORS

We have previously described the TORS procedure.[9–11] Briefly, a Davis-Meyer mouth gag was used to obtain access. The robot was equipped with a Maryland dissector and an electrical cautery or laser (thulium or CO_2). The procedure begins with a horizontal incision just posterior to the circumvallate papilla adjacent to the distal end of the tongue blade. This creates an edge that was then grasped by the Maryland retractor, and the incision was then deepened broadly, and a plane of dissection developed toward the vallecula. In a subset of patients, a partial midline glossectomy was performed. For better visualization, it was helpful to divide the lingual tonsil mass vertically along the midline. The tonsil specimens, right and left, were removed separately. A surgical technician measured the volume of tissue removed using a displacement technique. Bleeding was typically minimal. Lingual tonsillectomy was occasionally followed by epiglottoplasty. The upper one-third of the suprahyoid epiglottis was removed. The epiglottis was held with the Maryland dissector and divided vertically along the midline. A right-angle cut was then made to both the right and left, removing the upper portion of the suprahyoid epiglottis. Most patients were extubated in the operating room following surgery and no patients required reintubation or tracheostomy.

TABLE I.
Patient Characteristics.

Characteristic	Mean Value
Age, yr	54.7 (12.2)
% Male	77.2%
% Caucasian	95.0%
ASA	2.2 (0.5)
Angle class	1.0 (0.3)
Laryngeal view	1.6 (0.6)
Friedman stage	2.6 (0.8)
Preoperative AHI	44.9 (21.6)
Postoperative AHI	21.5 (19.3)
BMI	28.5 (4.0)
No. of procedures	3.3 (1.0)
% of patient with improvement in AHI	87.1%
% of patient meeting success criteria	50.5%
% of patient meeting cure criteria	16.8%

Data are presented as mean (standard deviation) or percentages.
AHI = apnea-hypopnea index; ASA = American Society of Anesthesiologists; BMI = body mass index.

Postoperative Care

All patients were admitted to the surgical intensive care unit. Patients were seen in the clinic postoperatively 2 weeks and 3 months following the procedure. Patients underwent repeat PSG to assess response to therapy. The median number of days for PSG following the procedure was 98.

Statistical Analysis

Before and after AHI scores were compared to determine response to surgical therapy. Improvement was defined as any decrease in AHI, success as an AHI <20 with a >50% decrease, and cure as an AHI <5. DISE variables were used individually as well as a sum to determine they predicted improvement, success, or cure. Statistical analysis was done using R (The R Foundation for Statistical Computing, Vienna, Austria) and Microsoft Excel (Microsoft Corp., Redmond, WA). Fisher exact test was used for the univariate analysis. Multivariable logistic regression was done using NOHL and VOTE variables separately as main effects only. In addition, classification trees were

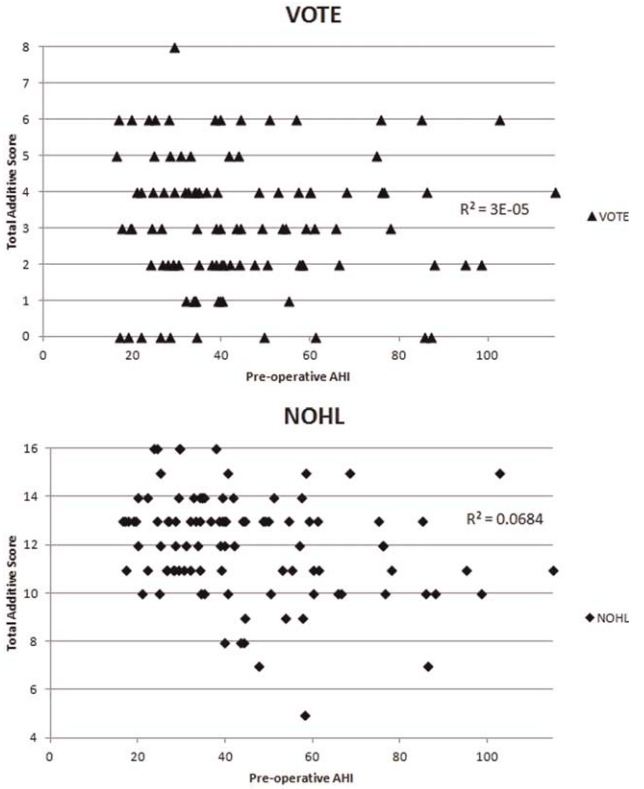

Fig. 1. (A, B) Scatter plots of preoperative AHI and VOTE/NOHL classification systems. No association was found between preoperative AHI and total additive VOTE and NOHL scores. AHI = apnea-hypopnea index; NOHL = nose, oropharynx, hypopharynx, larynx; VOTE = velum, oropharynx, tongue, epiglottis.

also used to predict the outcome, allowing for the possibility of interactions among DISE variables.

RESULTS

The study population consisted of 78 males and 23 females, with a mean age of 54.7 years. The average number of procedures performed was 3.3. All patients underwent TORS lingual tonsillectomy. Other common procedures were palatine tonsillectomy (45% of patients), epiglottoplasty (44% of patients), UPPP (34% of patients), lateral expansion pharyngoplasty (27% of patients), and uvuloplasty (13% of patients). The average preoperative AHI was 44.9 and decreased to 21.5 postoperatively. Table I details demographic information, preoperative data, and proportion of patients meeting criteria for improvement, success, and cure. There were 87% of patients who had an improvement in AHI, 51% met the criteria for success defined as AHI <20 and AHI decrease by 50%, and 17% met the criteria for cure defined as AHI <5. These results are similar to those we have previously reported.[10]

We first wanted to determine if the severity of preoperative obstructive sleep apnea could be predicted by the NOHL or VOTE classification system. Figure 1A and 1B show total VOTE and NOHL scores plotted against preoperative AHI. No correlation was seen in the severity of preoperative sleep apnea and the NOHL or VOTE classification system.

The degree of collapse in the VOTE and NOHL system were then compared between patients who met criteria for success (AHI <20 and AHI decrease by 50%). We compared both aggregate scores within the classification system as well as individual subscores (Table II). There were no correlations between the VOTE and NOHL classifications systems and the ability to predict success. Figure 2A and 2B show total VOTE and NOHL scores, respectively, plotted against the proportion of patients who had improvement, success (AHI <20 and AHI decrease by 50%), or cure (AHI <5). There was no correlation with the proportion of patients who had improvement, success or cure and the total NOHL or VOTE score.

We then sought to perform a univariate analysis to compare the subscores of the VOTE and NOHL scores to determine if there was correlation to improvement, success, and cure. The absence of lateral collapse in the oropharynx, tongue, and epiglottis was associated with an improvement in AHI (Table III). These findings were not associated with success or cure. Additionally, given the multiplicity of hypothesis tests performed, we remain skeptical even of the statistically significant results in the improvement group.

Table IV shows the result of the multivariate logistic regression analysis as summarized by Tjur's coefficient of discrimination (COD),[12] which lies between 0 (worst) and 1 (best) and measures the predictive power of a model. For the six models fit (one for each combination of dependent variable [improvement, success, or cure] and predictor variables [VOTE or NOHL]), the values of Tjur's COD are low, suggesting little predictive value across any of the DISE variables. Because these logistic regression models contained main effects only, we also fit classification trees[13] to predict improvement, success, and cure, allowing for arbitrary interactions between VOTE and NOHL variables. The trees again

TABLE II.
Aggregate Scores and Subscores Within the Classification System.

DISE Classification System	Success	Did Not Have Success
Total VOTE score	3.3 (1.8)	3.0 (1.9)
V degree of collapse	0.9 (0.7)	0.8 (0.7)
O degree of collapse	0.5 (0.6)	0.5 (0.7)
T degree of collapse	0.9 (0.8)	0.8 (0.8)
E degree of collapse	1.0 (0.8)	0.8 (0.8)
Total NOHL score	12.0 (1.9)	11.8 (2.9)
N degree of collapse	2.9 (1.1)	3.0 (1.2)
O degree of collapse	2.0 (1.0)	2.1 (1.2)
H degree of collapse	3.5 (0.8)	3.5 (0.9)
L degree of collapse	3.6 (0.8)	3.4 (1.0)

Data as Mean (SD); DISE = drug-induced sleep endoscopy; NOHL = nose, oropharynx, hypopharynx, larynx; VOTE = velum, oropharynx, tongue, epiglottis.

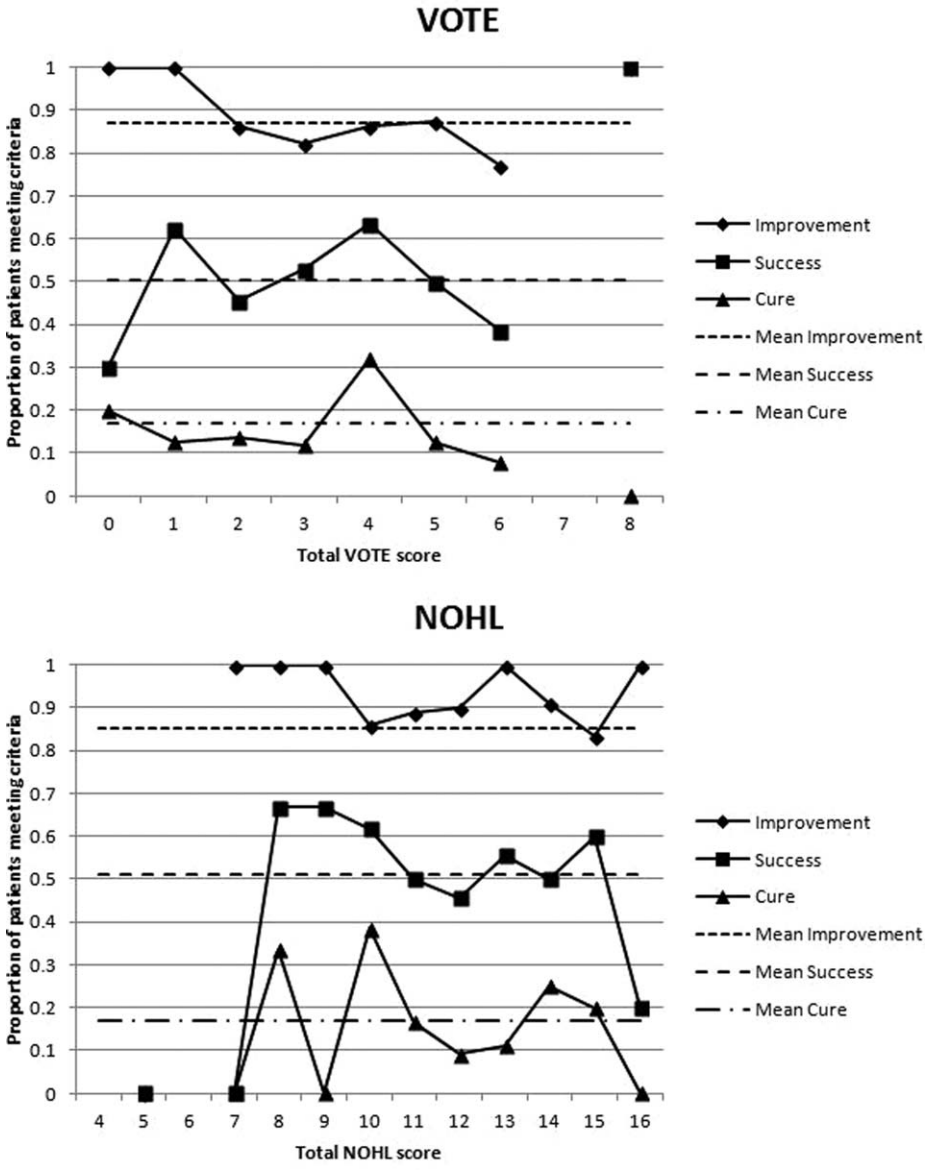

Fig. 2. (A, B) Proportion of patients meeting criteria for improvement, success, and cure compared to total VOTE and NOHL scores. NOHL = nose, oropharynx, hypopharynx, larynx; VOTE = velum, oropharynx, tongue, epiglottis.

showed minimal predictive ability among the DISE variable (data not shown).

DISCUSSION

In this study, we investigated whether DISE (as measured by the NOHL and VOTE classification systems) was predictive of success for patients undergoing TORS lingual tonsillectomy with other multilevel procedures in the treatment of moderate to severe sleep apnea. Our results shows that DISE scores in both the VOTE and NOHL scoring system do not predict which patients will ultimately go on to succeed following the procedure. Although there may be other value in the use of the NOHL and VOTE classification systems, these data support a limited value of DISE, in isolation, to predict surgical success.

The ultimate goal of any surgical procedure, new or old, is to provide both the surgeon and the patient the confidence for a successful outcome. The surgical treatment of a complex, multifactorial disease such as OSA is a difficult proposition. Competing treatment modalities such as continuous positive airway pressure offer a high degree of short-term success, but struggle with patient acceptance and tolerance. Because of the morbidity associated with the surgical treatment of OSA, surgeons and patients seek predictors of success; this remains an elusive task. The advent of sleep endoscopy and its ability to identify areas of obstruction in the upper airway has been a promising technique offering a possibility of predicting surgical success or failure.

Many studies have shown that DISE is able to identify sites of obstruction not seen during office examination.[14] In experienced hands, DISE reporting is reproducible.[15,16] Viana et al. performed a comprehensive systematic review of the DISE literature in 2015, and concluded that DISE is an important tool in identifying multilevel obstruction and is particularly useful in identifying retrolingual and laryngeal collapse.[17]

TABLE III.
Associations of NOHL and VOTE Classification System Subscores With Improvement, Success, and Cure.

	N			O			H			L		
	Deg	Dir	Flow	Deg	Dir	Flow	Deg	Dir	Flow	Deg	Dir	Flow
NOHL												
Improvement	1.00	0.90	0.71	0.24	0.80	0.79	0.76	1.00	0.19	0.22	1.00	0.44
Success	0.64	0.59	1.00	0.65	0.13	0.40	0.98	0.18	0.51	0.10	0.66	0.60
Cure	0.29	0.48	0.39	0.54	0.38	0.40	0.62	1.00	0.77	0.76	0.76	0.51

	V		O		T		E	
	Deg	Dir	Deg	Dir	Deg	Dir	Deg	Dir
VOTE								
Improvement	0.85	0.13	0.20	<0.001	0.34	0.028	0.40	0.015
Success	0.80	0.51	0.34	0.55	0.94	1.00	0.58	0.75
Cure	0.14	0.26	0.33	1.00	0.94	0.25	0.67	0.64

P-values listed. Deg = Degree of collapse; Dir = direction of collapse (anterior/posterior, lateral, concentric); Flow = (presence or absence of vibration); NOHL = nose, oropharynx, hypopharynx, larynx; VOTE = velum, oropharynx, tongue, epiglottis.

Few studies to date have assessed the predictive value of DISE in surgical outcomes. In a large retrospective study of 1,249 patients who underwent preoperative DISE, Vroegop et al. suggest that patterns of collapse and success may not correlate with polysomnographic or anthropometric data.[18] DISE is able to predict a poor outcome in patients undergoing hypoglossal nerve stimulation when concentric collapse is identified in the velum.[19] To date there have been no studies looking at the ability of DISE to predict outcomes in multilevel surgery, with the exception of Lin et al. who have developed a scoring system that incorporates both DISE, AHI, and BMI.[20] In this study the presence or absence of lateral velopharyngeal collapse was an important isolated predictor of success (67%), and when combined with BMI <30 and AHI <60 predicted a surgical response (AHI <15 and 50% reduction) of 86.7%.

DISE is used by many clinicians for surgical planning of specific procedures, and its lack of predictive ability does not disqualify its use in clinical practice. Our previous data have shown that although patients who have a BMI <30 or with Friedman II or III anatomy see greater success with a surgical approach, no correlation on the number of procedures was seen with improvement, success, or cure following surgery.[10] Thaler et al., however, have recently shown that patients undergoing multilevel surgery, including TORS, have a greater success rate (56%) if they have not had previous pharyngeal surgery for OSA (56%) compared to patients who have undergone previous surgery (30%).[21]

In light of the results presented here, the important question is whether DISE should continue to be performed. Our data are the results of the largest study done assessing DISE in isolation and are unable to address this question given our study's retrospective design and selection criteria. Although it is a safe procedure done in the operating room with an attending anesthesiologists and otolaryngologists, loss of airway can result requiring emergency intubation or other life-saving measures. DISE also adds significant cost of the health system, requiring the use of the operating room to perform the procedure. Patients require an additional visit and time off from work to undergo the DISE procedure.

Our data suggest that DISE in isolation may not be predictive of success; however, when incorporating additional clinical data as demonstrated by Lin et al., DISE may prove to be an essential component of a pretreatment algorithm that will assure both the patient and the surgeon of a successful surgical outcome. Certal et al. conducted a systematic review of awake examination versus DISE and found DISE changed surgical planning in 50% of the cases but without clear evidence of improved outcome.[22] Similarly, Golbin et al. found that patients who underwent DISE prior to undergoing TORS multilevel surgery showed no improvement in outcome compared to a group of patients who did not undergo DISE. The group that did not undergo DISE did not, however, undergo TORS.[23] Further studies, including prospective randomized trials (preoperative DISE vs. no DISE) will help to answer this important question. These studies should incorporate preoperative polysomnographic, radiologic, and anthropometric data

TABLE IV.
Multivariable Logistic Regression by Tjur's Coefficient of Discrimination.

	NOHL	VOTE
Improvement	0.12	0.28
Success	0.10	0.07
Cure	0.06	0.15

Tjur's coefficient of discrimination measures the predictive power of which lies between 0 (worst) and 1 (best).
NOHL = nose, oropharynx, hypopharynx, larynx; VOTE = velum, oropharynx, tongue, epiglottis.

to determine the correct and most cost-effective treatment algorithm.

There are limitations to our study. In this retrospective analysis, we do not have data on patients who underwent DISE and subsequently did not undergo surgery. It is possible that within this cohort of patients there may be DISE scores that would suggest when surgery should not be performed. Additionally, our data include patients who had multiple procedures. It may be the case that a certain combination of multilevel surgery based on DISE subscores would be more predictive of success. Future studies with multiple cohorts are necessary to answer this question.

CONCLUSION

DISE in isolation (as measured by the NOHL and VOTE classification systems) does not identify patients that would most benefit from surgery. Prospective studies and larger sample sizes are required to further evaluate the use of DISE in predicting success following TORS.

BIBLIOGRAPHY

1. Peppard PE, Young T, Barnet JH, Palta M, Hagen E, Hla KM. Increased prevalence of sleep-disordered breathing in adults. *Am J Epidemiol* 2013;177:1006–1014.
2. Weaver TE, Sawyer AM. Adherence to continuous positive airway pressure treatment for obstructive sleep apnoea: implications for future interventions. *Indian J Med Res* 2010;131:245–258.
3. Vicini C, Dallan I, Canzi P, Frassineti S, La Pietra MG, Montevecchi F. Transoral robotic tongue base resection in obstructive sleep apnoea-hypopnoea syndrome: a preliminary report. *ORL J Otorhinolaryngol Relat Spec* 2010;72:22–27.
4. Croft CB, Pringle M. Sleep nasoendoscopy—a technique of assessment in snoring and obstructive sleep-apnea. *Clin Otolaryngol* 1991;16:504–509.
5. Berry S, Roblin G, Williams A, Watkins A, Whittet HB. Validity of sleep nasendoscopy in the investigation of sleep related breathing disorders. *Laryngoscope* 2005;115:538–540.
6. Fernandez-Julian E, Garcia-Perez MA, Garcia-Callejo J, Ferrer F, Marti F, Marco J. Surgical planning after sleep versus awake techniques in patients with obstructive sleep apnea. *Laryngoscope* 2014;124:1970–1974.
7. Kezirian EJ, Hohenhorst W, de Vries N. Drug-induced sleep endoscopy: the VOTE classification. *Eur Arch Otorhinolaryngol* 2011;268:1233–1236.
8. Vicini C, De Vito A, Benazzo M, et al. The nose oropharynx hypopharynx and larynx (NOHL) classification: a new system of diagnostic standardized examination for OSAHS patients. *Eur Arch Otorhinolaryngol* 2012; 269:1297–1300.
9. Glazer TA, Hoff PT, Spector ME. Transoral robotic surgery for obstructive sleep apnea perioperative management and postoperative complications. *JAMA Otolaryngol Head Neck Surg* 2014;140:1207–1212.
10. Hoff PT, Glazer TA, Spector ME. Body mass index predicts success in patients undergoing transoral robotic surgery for obstructive sleep apnea. *ORL J Otorhinolaryngol Relat Spec* 2014;76:266–272.
11. Spector ME, Glazer TA, Hoff PT. Addressing the retrolingual space in obstructive sleep apnea: outcomes stratified by Friedman stage in patients undergoing transoral robotic surgery. *ORL J Otorhinolaryngol Relat Spec* 2016;78:1–8.
12. Tjur T. Coefficients of determination in logistic regression models-a new proposal: the coefficient of discrimination. *Am Stat* 2009;63:366–372.
13. Breiman L, Friedman J, Olshen R, Stone C. Classification and Regression Trees. Belmont, CA: Wadsworth; 1984.
14. Campanini A, Canzi P, De Vito A, Dallan I, Montevecchi F, Vicini C. Awake versus sleep endoscopy: personal experience in 250 OSAHS patients. *Acta Otorhinolaryngol Ital* 2010;30:73–77.
15. Kezirian EJ, White DP, Malhotra A, Ma W, McCulloch CE, Goldberg AN. Interrater reliability of drug-induced sleep endoscopy. *Arch Otolaryngol Head Neck Surg* 2010;136:393–397.
16. Rodriguez-Bruno K, Goldberg AN, McCulloch CE, Kezirian EJ. Test-retest reliability of drug-induced sleep endoscopy. *Otolaryngol Head Neck Surg* 2009;140:646–651.
17. Viana AD, Thuler LCS, de Araujo-Melo MH. Drug-induced sleep endoscopy in the identification of obstruction sites in patients with obstructive sleep apnea: a systematic review. *Braz J Otorhinolaryngol* 2015;81:439–446.
18. Vroegop AV, Vanderveken OM, Boudewyns AN, et al. Drug-induced sleep endoscopy in sleep-disordered breathing: report on 1,249 cases. *Laryngoscope* 2014;124:797–802.
19. Ravesloot MJL, de Vries N. One hundred consecutive patients undergoing drug-induced sleep endoscopy: results and evaluation. *Laryngoscope* 2011;121:2710–2716.
20. Lin HS, Rowley JA, Folbe AJ, Yoo GH, Badr MS, Chen W. Transoral robotic surgery for treatment of obstructive sleep apnea: factors predicting surgical response. *Laryngoscope* 2015;125:1013–1020.
21. Thaler ER, Rassekh CH, Lee JM, Weinstein GS, O'Malley BW. Outcomes for multilevel surgery for sleep apnea: obstructive sleep apnea, transoral robotic surgery, and uvulopalatopharyngoplasty. *Laryngoscope* 2016;126: 266–269.
22. Certal VF, Pratas R, Guimaraes L, et al. Awake examination versus DISE for surgical decision making in patients with OSA: a systematic review. *Laryngoscope* 2016;126:768–774.
23. Golbin D, Musgrave B, Succar E, Yaremchuk K. Clinical analysis of drug-induced sleep endoscopy for the OSA patient. *Laryngoscope* 2016;126: 249–253.