Does DISE predict surgical success in TORS multi-level surgery in obstructive sleep apnea?

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Brief running title: DISE in predicting success for TORS in OSA

Keywords: Obstructive sleep apnea, Transoral Robotic Surgery, DISE, NOHL VOTE

No disclosures or conflicts of interest to report

Abstract (250 words max)

Objectives: 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: Pre- and post-polysomnograms were analyzed to assess improvement, success, and cure. Improvement was defined as any decrease in 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: 101 patients were available for analysis. 87% of patient had an improvement in their AHI. 51% met criteria for success, while 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=0.001); 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 that would most benefit 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: OSA, TORS, DISE, VOTE, NOHL

Level of Evidence: 4 (Case series)

Introduction:

Obstructive sleep apnea and hypopnea syndrome (OSAHS) is a common and underdiagnosed disorder characterized by daytime and nocturnal symptoms and findings of an apnea-hypopnea index (AHI) of greater than 5 on 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 30-60% with some individual 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 is 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 OSA undergoing TORS with other multilevel procedures using two different scoring criteria.

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 obstructive sleep apnea 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 post-operative 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 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

Drug-induced sleep endoscopy has been well described in the literature. Briefly, the procedure is performed in to the operating room with the patient under monitored anesthesia using a manual infusion bolus of Propofol (TEVA pharmaceuticals trademark). A BIS monitor (Medtronic, MN USA) 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 following procedures: septoplasty, inferior turbinate reduction, adenoidectomy. uvuloplasty, palate Z-plasty,uvuloplasty, 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.

Transoral Robotic Surgery

We have previously described this 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.

Post-operative care

All patients were admitted to the surgical intensive care unit (SICU). Patients were seen in clinic post-operatively 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

Pre and post-AHI 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 (Vienna, Austria) and Microsoft Excel (Seattle, WA). Fisher's 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 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. 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 pre-operative AHI was 44.9 and decreased to 21.5 post-operatively. **Table 1** details demographic information, pre-operative 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 pre -operative 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 sub-scores. (**Table 2)** 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 sub-scores of the VOTE and NOHL scores to determine if there were 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 3)**. 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 4 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. Since 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 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. While there may be other value in the use of the NOHL and VOTE classification systems, this data supportslimited value of DISE, in isolation, to 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 CPAP 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 hand, 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].

Few studies to date have assessed the predictive value of DISE in surgical outcomes. In a large retrospective study of 1249 patients who underwent preoperative DISE, Vroegop et al suggest that patterns of collapse and success may not correlate with polysomnogrophic 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 less than 30 and AHI less than 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 has shown that while 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 were 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 is the largest study done assessing DISE in isolation and is unable to address this question given its 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 suggests 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 (pre-operative DISE vs no DISE) will help to answer this important question. These studies should incorporate preoperative polysomnographic, radiologic, and anthropometric data in order 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 may have DISE scores that would suggest when surgery should not be performed. Additionally, our data includes patients who had multiple procedures. It may be the case that a certain combination of multilevel surgery based on DISE sub-scores would be more predictive of success. Future studies with multiple cohorts are necessary to answer this question.

Conclusion:

DISE in isolation (as measured by 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.

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Figure text

Figure 1a & 1b: Scatter plots of preoperative AHI and VOTE/NOHL classification systems. No association was found between preoperative AHI and total additive VOTE and NOHL scores.

Figure 2a & 2b: Proportion of patients meeting criteria for improvement, success, and cure compared to total VOTE and NOHL scores.

Figures/Tables:

Table 1:

Patient characteristics	Mean value (SD)
Age	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)
Number 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%

Table 2:

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)

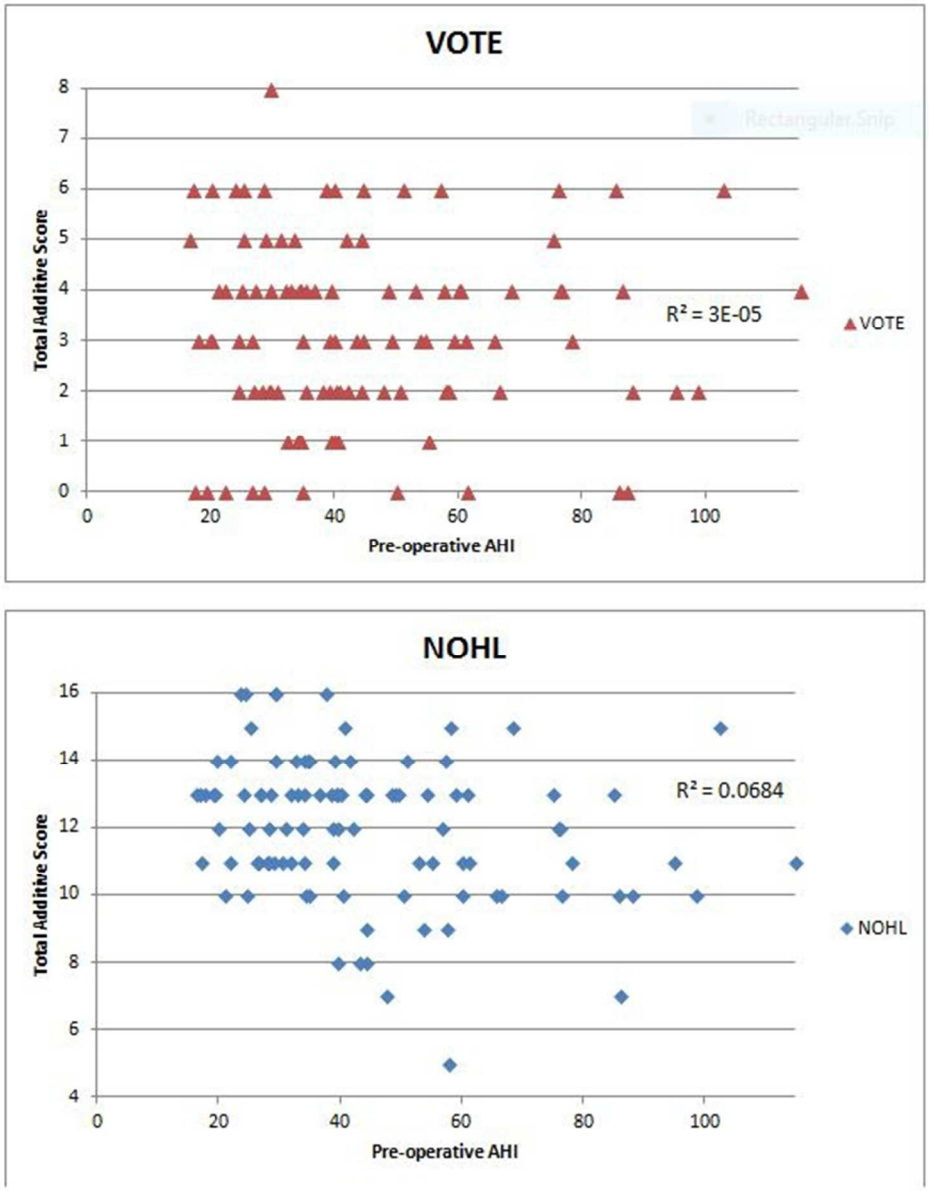

Figure 1a & 1b: Scatter plots of preoperative AHI and VOTE/NOHL classification systems. No association was found between preoperative AHI and total additive VOTE and NOHL scores.

147x188mm (96 x 96 DPI)

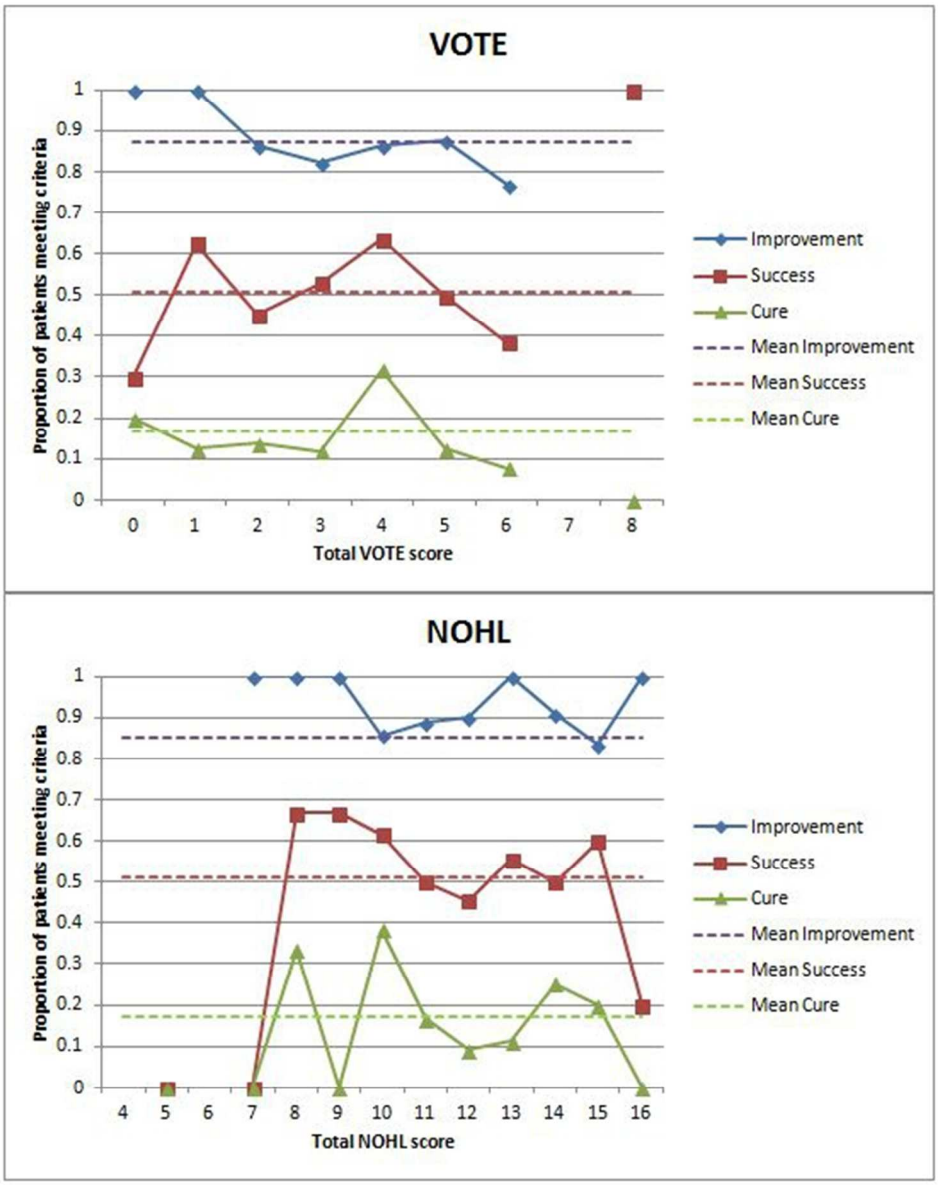

Figure 2a & 2b: Proportion of patients meeting criteria for improvement, success, and cure compared to total VOTE and NOHL scores.

149x186mm (96 x 96 DPI)

Table 3: Associations of NOHL and VOTE classification system subscores with improvement, success and cure.

NOHL:

	N			O			H			L		
	Deg	Dir	Flow	Deg	Dir	Flow	Deg	Dir	Flow	Deg	Dir	Flow
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

VOTE:

	V		O		T		E	
	Deg	Dir	Deg	Dir	Deg	Dir	Deg	Dir
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

Deg – Degree of collapse
Dir – Direction of collapse (anterior/posterior, lateral, concentric)
Flow – Presence or absence of vibration

Table 4: Multivariable Logistic Regression by Tjur's coefficient of discrimination (COD)

	NOHL	VOTE
Improvement	0.12	0.28
Success	0.10	0.07
Cure	0.06	0.15

COD measures the predictive power of which lies between 0 (worst) and 1 (best).