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Drug-Induced Sleep Endoscopy and Hypoglossal Nerve Stimulation Outcomes: A Multicenter Cohort Study

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Abstract

Objectives: To determine the association between findings of blinded reviews of preoperative drug-induced sleep endoscopy (DISE) and outcomes of hypoglossal nerve stimulation for obstructive sleep apnea (OSA).

Study Design: Retrospective, multicenter cohort study

Setting: Academic medical centers

Subjects and Methods: 343 adults were included from 10 centers. Preoperative DISE videos were scored by 4 blinded reviewers using the VOTE Classification and evaluation of a possible primary structure contributing to airway obstruction. Consensus DISE findings were examined for an association with surgical outcomes based on therapy titration polysomnogram (tPSG). Treatment response was defined by a decrease of ≥50% in the apnea-hypopnea index (AHI) to <15 events/hour.

Results: Study participants (76% male, 60.4±11.0 years old) had a BMI of 29.2±3.6 kg/m^2. AHI decreased (35.6±15.2 to 11.0±14.1 events/hour; p<0.001) on the tPSG, with a 72.6% response rate. Complete palate obstruction (vs. none) was associated with the greatest difference in AHI improvement (−26.8 ± 14.9 vs −19.2 ± 12.8, p=0.02). Complete (vs. partial/none) tongue-related obstruction was associated with increased odds of treatment response (78% vs. 68%, p=0.043). Complete (vs. partial/none) oropharyngeal lateral wall-related obstruction was associated with lower odds of surgical response (58% vs. 74%, p=0.042).

Conclusions: DISE findings of primary tongue or velum contributions to airway obstruction were associated with better outcomes, whereas the opposite was true for the oropharyngeal lateral

walls. This study suggests that the role for DISE in counseling candidates for hypoglossal nerve stimulation extends beyond solely for excluding complete concentric collapse related to the velum.

Keywords

hypoglossal nerve stimulation; upper airway stimulation; drug-induced sleep endoscopy; obstructive sleep apnea

INTRODUCTION

Hypoglossal nerve stimulation (HNS) is FDA-approved for treatment of positive airway pressure therapy (PAP)-intolerant moderate-severe obstructive sleep apnea (OSA) patients. Contraindications to HNS include a number of clinical, polysomnographic and drug-induced sleep endoscopy (DISE) criteria, largely carried over from the Stimulation Therapy for Apnea Reduction (STAR) trial.[1] Drug-induced sleep endoscopy (DISE) was incorporated as a mandatory component of the pre-operative evaluation after Vanderveken et al. demonstrated that complete concentric collapse at the velopharynx portended to worse outcomes in a small number of patients.[2]

As with all surgical interventions for OSA, improving patient selection is of critical importance to improving outcomes. Certain variables such as older age, female gender, therapeutic PAP pressure less than 8cmH2O and lower oxygen desaturation index have demonstrated associations with better response rates to HNS.[3–5] In small studies, preoperative DISE findings have not demonstrated consistent associations with HNS outcomes.[6–9]

The aim of this study was to determine the association between findings of blinded reviews of preoperative DISE and outcomes of HNS in a large multicenter cohort.

METHODS

This was a retrospective cohort study of adults undergoing HNS for OSA. Inclusion criteria were age >21, diagnosed OSA on a preoperative sleep study, absence of prior pharyngeal surgery beyond palatine tonsillectomy, video recorded preoperative DISE, successful implantation of the Upper Airway Stimulation™ (Inspire Medical Systems, Inc., Maple Grove, MN, USA) system, and post-operative titration polysomnography (tPSG) with or without home sleep apnea test (HSAT) performed after the tPSG.

Methods were similar to a previous study of DISE and upper airway surgery (excluding HNS).[10] Study participant data included age at system implantation, gender, body mass index (BMI) at time of implantation, postoperative sleep studies, and tonsil size according to Brodsky[11] or Friedman classifications.[12] De-identified DISE videos and study participant data were submitted to a HIPAA-compliant, cloud-based database (Box.com) maintained through the Keck School of Medicine of USC. DISE videos were reviewed and scored by four physicians blinded to outcomes (P.H., D.T.K., M.A.D'A., and E.J.K.) according to the VOTE classification.[13] The VOTE classification involves scoring the overall degree (absent, 0; partial, 1; or complete, 2) and configuration (anteroposterior, lateral, or concentric) of

airway structures (Velum, Oropharyngeal lateral walls, Tongue, and Epiglottis) collapsing during DISE. In addition, an assessment was made of the primary structure (of the four VOTE structures) contributing to airway obstruction. If at least two reviewers felt they were unable to review the DISE video due to poor technical quality, the study participant was excluded.

A priori criteria for reconciling DISE scoring disagreements to obtain consensus scores were established. For each VOTE structure degree and configuration, agreement of at least 3/4 reviews was considered the consensus score. In cases without such agreement, the mean score was used for degree (rounding down to the nearest integer) and no configuration was assigned. Similarly, primary structure was assigned only if there was agreement among at least 3/4 reviews; otherwise there was no consensus primary structure.

The tPSG was a type 1 sleep study wherein the sleep technologist remotely adjusts stimulation parameters in an attempt to objectively identify optimal settings. The HSAT was a type 3 sleep study without device titration. All sleep studies were scored per institution standards, and there was no re-review of sleep study raw data for this study. Surgical response was defined as a ≥50% decrease in the AHI to a level <15 events/hour on the tPSG or on the HSAT, when available. A ≥50% decrease in the AHI to a level <15 events/hour on the tPSG was used for analyses of surgical response unless specifically stated otherwise.

Data analysis was performed using Stata/IC 10.1 (StataCorp, College Station, TX, USA) and SAS 9.4 (SAS Institute, Cary, NC, USA). Categorical variables were reported as frequency and percentage; continuous variables were reported as mean and standard deviation. Associations between individual DISE findings and surgical outcomes were tested. DISE findings that were examined included: degree of obstruction (none vs. partial vs. complete), complete vs. partial/none, complete vs. none (excluding partial), and any (complete/partial) vs. none. The specific finding of complete concentric collapse related to the velum vs. absence was also considered. Comparisons made for continuous variables were made using the independent 2-sample or paired t-tests and for categorical variables using the 2-sided Pearson χ^2 test.

Logistic regression evaluated the independent association between DISE findings and surgical response, with and without adjustment for potential confounders age, gender and BMI. For each VOTE structure, the DISE finding most clearly associated with outcomes in the univariate analyses was used, with a default of including each structure as a dichotomous variable of complete vs. partial/none obstruction. P-values <0.05 were considered statistically significant.

A generalized linear mixed model based weighted kappa (κ_{ma}) was used to test the interrater reliability for each VOTE structure's degree of obstruction. Fleiss' Kappa was used to assess the interrater reliability for the velum and epiglottis structure's configuration along with the primary site. Both kappa statistics range from 0 to 1, where values ≤0 indicate poor, 0-0.20 indicate slight, 0.21-0.40 indicate fair, 0.41-0.60 indicate moderate, 0.61-0.80 indicate substantial, and 0.81-1.0 indicate almost perfect agreement. Institutional review board approval was obtained from each participating center.

RESULTS

The cohort included 343 adults from 10 centers (Table 1) who underwent treatment with HNS. Table 2 presents baseline and post-treatment findings in the overall cohort (post-treatment findings on tPSG) and in the subgroup with postoperative HSAT. The cohort primarily included middle-aged and older adults (inter-quartile range 53-69 years) who were overweight or with Class I obesity (BMI inter-quartile range 27.0–31.7 kg/m^2). No subject had palatine tonsils with marked enlargement (3+ or 4+ on Brodsky or Friedman classification).

Postoperative sleep studies were performed at 4.1±4.1 months (tPSG) and 16.5±10.8 (HSAT) following implantation. AHI improved in the overall cohort (tPSG) and the subgroup with HSAT (Table 2). Response rates were higher when the postoperative AHI was determined from the tPSG than the HSAT. Using the Sher criteria[14] (≥50% decrease in the AHI and to <20 events/hour), the response rates were 78% and 63%, according to the tPSG and HSAT, respectively.

Consensus ratings of DISE findings are presented in Table 3. Compared to the entire cohort, the subgroup with HSAT had a higher proportion of subjects with concentric (vs. anteroposterior) velum-related obstruction (19%,vs. 6%, p = 0.002), a greater degree of oropharyngeal lateral wall-related obstruction (p = 0.028), and a lesser degree of tongue-related obstruction (p<0.001). There was fair inter-rater reliability for the degree of velum-related obstruction, otherwise there was moderate to substantial inter-rater reliability (Table 4).

Univariate analyses for the association between individual DISE findings and change in tPSG AHI and tPSG surgical response rates are presented in Tables 5 and 6, respectively. In isolation, most DISE findings were not associated with HNS outcomes. For the velum, complete obstruction was associated with a greater decrease in AHI but not a greater odds of surgical response. In contrast, complete oropharyngeal lateral wall-related obstruction and complete tongue-related obstruction were both associated with a greater odds of surgical response but no difference in AHI changes.

Post-hoc analysis revealed that the associations were limited to those with preoperative BMI greater than the median in this cohort (29.5 kg/m^2). Among this subgroup, there were associations between complete (vs. partial/none) oropharyngeal lateral wall-related obstruction and a lower odds of surgical response (53% vs. 74%, p=0.049) and between complete (vs. partial/none) tongue-related obstruction and a greater odds of surgical response (81%, 56/69 vs. 65%, 66/101; p=0.025). There were no statistically significant associations between these DISE findings and outcomes in those in the subgroup with lower preoperative BMI (76%, 59/78 vs. 72%, 68/95; p=0.55).

Elevated BMI was found to be associated with concentric collapse (partial and complete) but no other DISE findings; 69% (22/32) of those with partial or complete concentric collapse related to the velum were in the high BMI subgroup, compared to 47% (124/265) of those with an anteroposterior configuration for velum-related obstruction and 38% (9/24) with no

velum-related obstruction (p=0.035). There was no association between epiglottis-related obstruction and outcomes.

Similar patterns were seen with definition of surgical response based on the HSAT (data largely not shown), although most results were not statistically significant. Of note, complete oropharyngeal lateral wall-related obstruction (vs. partial/none) was associated with a decrease in surgical response according the definition requiring AHI <15 events/hour (11% vs. 61%, p = 0.003). Complete tongue-related obstruction (vs. partial/none) was not associated with HSAT outcomes based on this definition of surgical response (61% vs. 56%; p=0.64).

Among the 14 study participants with complete concentric collapse related to the velum, the surgical response rate was 57% (8/14) and 36% (5/14) for the definitions using tPSG and threshold values of AHI <15 events/hour and <5 events/hour, respectively; both values were not statistically different from study participants without this DISE finding.

Consensus scores for primary structure associated with obstruction are presented for the entire cohort and the HSAT subgroup in Table 7, along with surgical response (≥50% decrease in the AHI to a level <15 events/hour). Overall, there were differences in odds of surgical response according to primary structure. Specifically, for tPSG results, study participants with a primary structure as the tongue had greater odds of surgical response than with a primary structure of the oropharyngeal lateral walls (p=0.028). Those with a primary structure of the velum (p=0.016) and tongue (0.002) both had better odds of surgical response than those with the epiglottis. For HSAT results, both the velum (p=0.002) and tongue (p=0.048) had greater odds of surgical response than for the oropharyngeal lateral walls.

Multivariate logistic regression results are reported in Table 8. There were no statistically-significant associations in adjusted or unadjusted analyses, but the point estimates were consistent with results of analyses of DISE findings in isolation.

DISCUSSION

This is the largest study examining the association between DISE findings and outcomes with HNS and the only study incorporating blinded DISE reviews from a large number of centers.

Overall, the response rate HNS on the tPSG was similar to previous post-market studies, although this study primarily utilized a more stringent definition of response (AHI <15 events/hour and ≥50% decrease) than those employing the Sher criteria (AHI <20 events/hour and ≥50% decrease). Compared to tPSG response, HSAT response rates were notably lower, highlighting the importance of evaluating response over a full night without titration of settings. The lower surgical response rate on the HSAT may reflect a selection bias if study participants who did not have clinical success were more likely to undergo HSAT or if it were solely related to differences in DISE findings for those who underwent HSAT (lower odds of complete tongue-related obstruction; higher odds of concentric palate and oropharyngeal lateral wall obstruction). The direct comparison of tPSG and HSAT outcomes

in those with HSATs suggests that this is unlikely to explain the findings entirely. This concern about the tPSG as defining optimal therapy has been noted clinically in other studies and publications.[15] The effectiveness HSAT may also always yield higher residual AHI figures if the patient utilizes the pause feature or does not adhere to therapy for the full study duration and is therefore untreated for portions of the night. Since our study began, the manufacturer of this hypoglossal nerve stimulation technology has altered the post-implant protocol to include at least a 3-month period of acclimation after activation but before titration to enhance readiness for the tPSG and to decrease adjustments made during the tPSG (to enable longer periods of assessments at target settings). It is yet to be seen whether this translates to improved success rates on tPSG and in the long term.

Tongue-related obstruction has the clearest association with increasing the odds of response to hypoglossal nerve stimulation, whether in the tPSG response rates for complete tongue-related obstruction (Table 6) or when the tongue was identified as the primary structure contributing to obstruction (Table 7). Given that this therapy specifically is designed to move the tongue anteriorly, this finding is important but not surprising

The association between complete tongue-related obstruction and response rate was seen largely in those with higher preoperative BMI. These post-hoc analyses of complete (vs. partial/none) tongue-related obstruction and preoperative BMI subgroups showed that those with complete tongue-related obstruction in the higher-BMI subgroup had the greatest odds of response (81%). Based on the association between increasing BMI and fat deposition in the tongue,[16] these individuals may have OSA largely due to tongue enlargement and HNS provides pharyngeal dilator muscle augmentation at the level of the tongue directly addressing a key mechanism for their OSA. For those without complete-tongue related obstruction in the higher BMI subgroup and lower response rate (65%), their OSA may be due to anatomic or non-anatomic factors that do not respond as clearly to this therapy.

Oropharyngeal lateral wall obstruction was associated with poorer outcomes, whether for complete (vs. partial/none) obstruction (Table 6) or as the primary structure contributing to airway obstruction (Table 7). Similar to the tongue base findings, post-hoc analyses showed that the association was seen primarily with BMI greater than the median in this cohort. This finding is consistent with our previous study showing that oropharyngeal lateral-wall obstruction was associated with poorer outcomes for upper airway surgery (excluding HNS)[10] as well as a smaller study of HNS and mandibular advancement.[9] HNS has been shown to improve the transverse width of the hypopharyngeal airway (presumably due to lateral displacement and/or stabilization of the oropharyngeal lateral walls) during wakefulness and DISE.[17] However, the effect on the oropharyngeal lateral walls is also indirect, reflecting the connections between the lateral pharyngeal soft tissues and the tongue (glossopharyngeal coupling). These indirectly transmitted forces might not be as great as direct forces, perhaps explaining why complete oropharyngeal lateral wall obstruction had an association with poorer outcomes not seen for partial obstruction. Conversely, the presence of these indirect forces may explain why partial oropharyngeal lateral wall obstruction does not compromise outcomes of HNS, whereas both partial and complete oropharyngeal lateral wall obstruction are associated with poorer outcomes after other

upper airway surgeries (that lack this indirect effect of glossopharyngeal coupling seen with HNS).[10]

Velum-related obstruction responded well to HNS with notable improvements in AHI and in some cases showing that greater degrees of velum-related obstruction had greater improvements in AHI (Table 5). There was no clear association between response rates and velum-related degree or configuration (Table 6). Interestingly, the velum as the primary structure contributing to airway obstruction was associated with high tPSG and HSAT response rates, including the highest on HSAT (Table 7). This is consistent with reports of favorable outcomes in isolated retropalatal collapse.[7] The presence of palatoglossal coupling remains the current explanation for this improvement in the retropalatal space despite no direct innervation to the palatal musculature from the hypoglossal nerve.[18,19] Gentle mandibular advancement (Esmarch Maneuver) and/or tongue manipulation have been proposed to assess for palatoglossal coupling, but a recent paper with a relatively small sample size showed that mandibular advancement was not clearly associated with hypoglossal nerve stimulation outcomes.[9]

There was no statistically-significant association between outcomes and complete concentric collapse related to the velum, although there were relatively few (n=14) participants with this DISE finding. DISE is currently a required preoperative evaluation for determining candidacy for HNS to exclude individuals with complete concentric collapse related to the velum from undergoing treatment with this modality. This has been incorporated into indications from the US Food and Drug Administration and other governmental bodies because of this use of DISE in the STAR Trial.[1] That major role in procedure selection was based on an early, small study of this technology showing poorer outcomes in individuals with complete concentric collapse of the velum,[2] even though there were potential confounders, including a change in implant technique between subgroups, moving from placement of the stimulation lead on a proximal to distal portion of the hypoglossal nerve (i.e., stimulating both protrusor and retrusor muscles of the tongue vs. protrusor muscles preferentially). Complete concentric collapse related to the velum is a relatively common DISE finding associated with OSA severity, non-positional OSA and obesity.[20,21] We believe that while this study is small (although there are no published studies with larger samples having this finding), it suggests that some patients with this DISE finding will respond well, even if the response rates are lower (58% with vs. 73% without). It is worth noting that this figure is similar or higher than response rates seen with other DISE findings, specifically the oropharyngeal lateral walls and epiglottis.

Epiglottis-related obstruction was associated with the lowest response rates, especially in those with the epiglottis as the primary structure contributing to airway obstruction. Future studies are needed to clarify the role of HNS in patients with isolated epiglottic collapse.

This study has important limitations. First, we used AHI reported by the sleep center as the primary measure of outcomes because it was recorded universally, but we did not evaluate other potential objective and subjective measures: AHI scored by review of raw sleep study data, oxygen desaturation index,[15] Epworth Sleepiness Scale, and Functional Outcomes of Sleep Questionnaire, to name just a few. The inter-rater reliability demonstrated a

range of fair to substantial agreement on VOTE and primary site scoring, reflecting the known subjectivity of DISE. To overcome this, we used conservative criteria for developing consensus scores and used only those. We also intentionally did not exclude outlier scoring to improve the external validity of these results. Even in the largest study of its kind, the sample sizes for specific DISE findings were small, in many cases, solely because these patterns are less common or because individuals with these findings were generally excluded from treatment (complete concentric collapse related to the velum).

CONCLUSIONS

DISE is required for preoperative evaluation prior to hypoglossal nerve stimulation in order to exclude those with complete concentric collapse related to the velum. Certain other findings are associated with surgical outcomes, suggesting a wider role for DISE in treatment selection.

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Table 1.

Distribution of study participants across centers

Center	No. Study Participants (n=343)	Percent of Total Cohort
MCW	43	12.5
MSH	14	4.1
MUN	35	10.2
TJUH	42	12.2
UC	32	9.6
UPMC	90	26.2
USC	18	5.3
VUMC	27	7.9
WCM	28	8.2
WSU	13	3.8

Table 2.

Patient characteristics.

	Baseline (n=343)	tPSG (n=343)	HSAT Subgroup Baseline (n=110)	HSAT (n=110)
Age at surgery, years	60.4 ± 11.0		59.3 ± 10.4	
Male gender	258 (76.1%)		91 (82.7%)	
BMI, kg/m^2	29.2 ± 3.6	28.5 ± 3.6*	29.6 ± 3.5	28.4 ± 3.6*
AHI	35.6 ± 15.2	11.0 ± 14.1*	35.6 ± 14.3	15.9 ± 16.0*
OSA severity				
None (AHI <5)	0 (0%)	146 (42.6%)	0 (0%)	30 (27.3%)
Mild (AHI 5- <15)	7 (2.0%)	112 (32.7%)	0 (0%)	41 (37.3%)
Moderate (AHI 15- <30)	134 (39.1%)	61 (17.8%)	43 (39.1%)	22 (20.0%)
Severe (>30)	202 (58.9%)	24 (7.0%)	67 (60.9%)	17 (15.5%)
Response rate 15 (≥50% decrease in the AHI to <15 events/hour)		249 (72.6%)		63 (57.3%)
Response rate 5 (≥50% decrease in the AHI to <5 events/hour)		151 (44.0%)		30 (27.3%)

SD = standard deviation, tPSG = titration in lab polysomnogram, eHSAT = efficacy home sleep apnea test, BMI = body mass index, AHI = apnea hypopnea index, OSA = obstructive sleep apnea.

* $p < 0.05$, comparing preoperative to postoperative values

Table 3.

DISE findings: VOTE Classification and primary structure for overall cohort

Structure	Configuration[§]		Degree of Obstruction (0/1/2)	Primary structure
Velum [*]	Anteroposterior 0/138/127	Concentric 0/18/14	24/169/150	67
Oropharynx lateral walls			220/90/33	39
Tongue			74/122/147	154
Epiglottis	Anteroposterior 0/28/12	Lateral 0/5/4	294/33/16	9

[§] In some cases, there was no agreement on configuration, making the total amounts based on configuration findings differ from those for degree of obstruction.

[*] There was no lateral velum-related obstruction

Table 4.

Interrater reliability VOTE classification findings and primary site.

Structure	Degree of obstruction			Configuration		
	κ_{ma}	SE	95% CI	Fleiss Kappa	SE	p-value
Velum	0.30	0.06	0.19-0.42	0.42	0.02	<0.001
Oropharynx lateral walls	0.48	0.08	0.33-0.63			
Tongue	0.59	0.02	0.54-0.63			
Epiglottis	0.85	0.01	0.83-0.87	0.63	*	*
Primary Site	-	-	-	0.41	0.01	<0.001

* Unable to calculate due to substantial missing data (no configuration identified because no obstruction related to the epiglottis)

CI = confidence interval; SE = standard error.

Table 5.

Change in AHI on titration PSG associated with DISE findings

DISE Finding		Mean change in AHI ± SD	p-value
V	None vs partial vs complete	−19.2 ± 12.8 vs −23.5 ± 18.5 vs 26.8 ± 14.9	
	Complete vs partial/none	**−27.0 ± 14.9 vs −23.0 ± 17.8**	**0.04**
	Complete vs partial *	−26.8 ± 14.9 vs −23.5 ± 18.5	0.09
	Any vs none	−25.0 ± 16.9 vs −19.2 ± 12.8	0.10
	CCC presence vs absence	−23.6 ± 13.3 vs −24.7 ± 16.8	0.80
	Complete vs none	**−26.8 ± 14.9 vs −19.2 ± 12.8**	**0.02**
O	None vs partial vs complete	−23.8 ± 16.6 vs −26.9 ± 17.1 vs −24.4 ± 15.8	
	Complete vs partial/none	−24.4 ± 15.8 vs −24.7 ± 16.8	0.94
	Any vs none	−26.2 ± 16.8 vs −23.8 ± 16.6	0.19
	Complete vs none	−24.4 ± 15.8 vs −23.8 ± 16.6	0.83
T	None vs partial vs complete	−23.4 ± 18.7 vs −26.5 ± 16.7 vs −23.8 ± 15.5	
	Complete vs partial/none	−23.8 ± 15.5 vs −25.3 ± 17.5	0.40
	Any vs none	−25.0 ± 16.1 vs −23.4 ± 18.7	0.47
	Complete vs none	−23.8 ± 15.5 vs −23.4 ± 18.7	0.87
E	None vs partial vs complete	−24.6 ± 16.7 vs −25.0 ± 14.3 vs −25.0 ± 21.6	
	Complete vs partial/none	−25.0 ± 21.6 vs −24.6 ± 16.5	0.93
	Any vs none	−25.0 ± 16.8 vs −24.6 ± 16.7	0.87
	Complete vs none	−25.0 ± 21.6 vs −24.6 ± 16.7	0.92

Bold values indicate statistically significant findings.

* In some cases, there was no consensus on configuration, making the total amounts based on configuration findings differ from those for degree of obstruction.

DISE = drug induced sleep endoscopy, AHI = apnea hypopnea index, V = velopharynx, CCC = complete concentric collapse, O = oropharyngeal lateral walls, T = tongue, E = epiglottis

Table 6.

Surgical response (≥50% decrease in AHI to <15 events/hour) on tPSG and association with DISE findings

DISE finding		N (%)	p-value
V	None vs partial vs complete	19 (79.2%) vs 116 (68.6%) vs 114 (76.0%)	0.29
	Complete vs partial/none	114 (76.0%) vs 135 (69.9%)	0.22
	Complete vs partial *	114 (76.0%) vs 116 (68.6%)	0.17
	Any vs none	230 (72.1%) vs 19 (79.2%)	0.64
	Complete vs none	114 (78.0%) vs 19 (79.2%)	1.00
	Complete concentric collapse: presence vs absence	8 (57.6%) vs 241 (73.0%)	0.22
O	None vs partial vs complete	163 (74.1%) vs 67 (74.4%) vs 19 (57.6%)	0.13
	Complete vs partial/none	**19 (57.8%) vs 230 (74.2%)**	**0.042**
	Any vs none	86 (69.9%) vs 163 (74.1%)	0.41
	Complete vs none	**19 (57.8%) vs 163 (74.1%)**	**0.049**
T	None vs partial vs complete	48 (64.9%) vs 86 (70.5%) vs 115 (78.2%)	0.09
	Complete vs partial/none	**115 (78.2%) vs 134 (68.4%)**	**0.043**
	Any vs none	201 (74.7%) vs 48 (64.9%)	0.09
	Complete vs none	**115 (78.2%) vs 48 (64.9%)**	**0.033**
E	None vs partial vs complete	216 (73.5%) vs 24 (72.7%) vs 9 (56.3%)	0.32
	Complete vs partial/none	9 (56.3%) vs 240 (73.4%)	0.13
	Any vs none	33 (67.3%) vs 216 (73.5%)	0.37
	Complete vs none	9 (56.3%) vs 216 (73.5%)	0.13

Bold values indicate statistically significant findings.

* In some cases, there was no consensus on configuration, making the total amounts based on configuration findings differ from those for degree of obstruction.

DISE = drug induced sleep endoscopy, V = velum, CCC= complete concentric collapse, O = oropharyngeal lateral walls, T = tongue, E = epiglottis

Table 7.

Surgical response according to DISE primary structure contributing to airway obstruction.

	tPSG (N, %)*	Success tPSG	HSAT (N, %)*	Success HSAT
V	67 (25%)	49/67 (73.1%)	39 (45%)	29/39 (74.4%)
O	39 (14%)	24/39 (61.5%)	14 (16%)	4/14 (28.6%)
T	154 (57%)	121/154 (78.6%)	30 (34%)	18/30 (60.0%)
E	9 (3%)	3/9 (33.3%)	4 (5%)	2/4 (50.0%)
		p=0.007		p=0.025

tPSG = in lab titration study, eHSAT = efficacy home sleep apnea test

*Total N does not match cohort or subgroup total because some study participants did not have consensus primary structure contributing to obstruction

Table 8.

Logistic regression analyses for odds ratios reflecting association between surgical response (tPSG) and specific DISE findings (complete vs. partial/none structure-related obstruction).

	Unadjusted (n=275)		Adjusted (n=258)	
	Odds Ratio	**95% CI**	**Odds Ratio**	**95% CI**
Velum	1.49	(0.67, 3.34)	1.51	(0.67, 3.40)
Oropharynx lateral walls	0.52	(0.24, 1.12)	0.57	(0.26, 1.22)
Tongue base	1.25	(0.68, 2.29)	1.12	(0.60, 2.09)
Epiglottis	0.75	(0.39, 1.47)	0.80	(0.40, 1.57)
Age (years)	---	---	1.01	(0.99, 1.01)
Male Gender	---	---	0.59	(0.31, 1.13)
BMI (kg/m^2)	---	---	0.97	(0.90, 1.04)

BMI = body mass index; CI = confidence interval.