

Evaluation of Drug-Induced Sleep Endoscopy as a Patient Selection Tool for Implanted Upper Airway Stimulation for Obstructive Sleep Apnea

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Study Objectives: To study the possible predictive value of drug-induced sleep endoscopy (DISE) in assessing therapeutic response to implanted upper airway stimulation (UAS) for obstructive sleep apnea (OSA).

Methods: During DISE, artificial sleep is induced by midazolam and/or propofol, and the pharyngeal collapse patterns are visualized using a flexible fiberoptic nasopharyngoscope. The level (palate, oropharynx, tongue base, hypopharynx/epiglottis), the direction (anteroposterior, concentric, lateral), and the degree of collapse (none, partial, or complete) were scored in a standard fashion.

Results: We report on the correlation between DISE results and therapy response in 21 OSA patients (apnea-hypopnea index [AHI] $38.5 \pm 11.8/h$; body mass index [BMI] $28 \pm 2 \text{ kg/m}^2$, age $55 \pm 11 \text{ y}$, 20 male/1 female) who underwent DISE before implantation of a UAS system. Statistical analysis revealed a significantly better outcome with UAS in patients ($n = 16$) without palatal complete concentric collapse (CCC), reducing

AHI from $37.6 \pm 11.4/h$ at baseline to $11.1 \pm 12.0/h$ with UAS ($p < 0.001$). No statistical difference was noted in AHI or BMI at baseline between the patients with and without palatal CCC. In addition, no predictive value was found for the other DISE collapse patterns documented.

Conclusions: The absence of palatal CCC during DISE may predict therapeutic success with implanted UAS therapy. DISE can be recommended as a patient selection tool for implanted UAS to treat OSA.

Keywords: Electrical stimulation, hypoglossal nerve, neuromodulation, obstructive sleep apnea hypopnea syndrome, prediction, sleep disordered breathing, snoring

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Obstructive sleep apnea (OSA) is characterized by repetitive upper airway collapse during sleep, causing hypoxemia and sleep fragmentation that lead to daytime sleepiness and increased risk of cardiovascular incidents, motor vehicle, and occupational accidents.¹⁻³ The gold standard for the treatment of OSA is continuous positive airway pressure (CPAP).^{4,5} It has been demonstrated that successful CPAP treatment improves systemic hypertension and prolongs survival.⁶ However, the clinical effectiveness of CPAP is often limited by low patient acceptance, poor tolerance, and suboptimal compliance.⁷ Therefore, non-CPAP alternatives for the treatment of sleep disordered breathing, such as oral appliance therapy with custom-made titratable mandibular advancement devices, surgery, or upper airway stimulation (UAS) have gained growing interest.⁸⁻¹³ UAS therapy, which uses electrical stimulation of the hypoglossal nerve, has been previously reported to be safe and efficacious in a select group of OSA patients who cannot or will not use CPAP as primary treatment.¹³⁻¹⁷ In non-selected OSA

BRIEF SUMMARY

Current Knowledge/Study Rationale: Upper airway stimulation (UAS) using respiratory-paced electrical stimulation of the hypoglossal nerve is a safe and efficacious non-CPAP therapy in a well-selected group of patients with moderate to severe obstructive sleep apnea (OSA). Patient baseline characteristics and the pattern and sites of upper airway obstruction are suggested to be predictors of UAS treatment success.

Study Impact: In this study, the predictive value of drug-induced sleep endoscopy (DISE) was assessed towards UAS treatment success in 21 OSA patients. The results demonstrate a strong correlation between the absence of a complete circular collapse at the level of the palate as documented during DISE and a successful treatment outcome with UAS; based on these results, DISE can be recommended as a patient selection tool for implanted UAS to treat OSA.

patients undergoing UAS therapy, a large interindividual difference in response to stimulation is observed.^{13,14} A recent study by Van de Heyning et al. examined a set of factors predictive for therapy response to UAS.¹³

Drug-induced sleep endoscopy (DISE) is increasingly being performed, offering the possibility of dynamic upper airway evaluation during artificial sleep as a promising technique for selecting the proper non-CPAP treatment for OSA patients.^{18,19}

The aim of this study was to perform a detailed assessment of the possible predictive value of DISE in the evaluation of therapeutic response to implanted UAS therapy for OSA. Some of the results of this study have been previously reported in the form of an abstract.²⁰

METHODS

We report on OSA patients who underwent a DISE before UAS system implantation.¹³ Patients with moderate to severe OSA (apnea-hypopnea index [AHI] ≥ 15 /h sleep) and BMI < 35 kg/m² were selected for UAS system implantation if they failed or were intolerant of CPAP treatment. Exclusion criteria included chronic obstructive pulmonary disease, New York Heart Association class III or IV congestive heart failure, neuromuscular diseases, or prior upper airway surgeries not related to OSA. The trial was approved by the institutional review boards or ethics committees at all participating centers, and informed consent was obtained from all study subjects.

Polysomnography

An 18-channel in-laboratory polysomnography examination was conducted according to the American Academy of Sleep Medicine (AASM) guidelines.²¹ Hypopneas were scored according to the AASM 2007 Rule 4a: a nasal pressure drop $\geq 30\%$ of baseline, duration > 10 sec, $\geq 4\%$ desaturation from baseline, and $\geq 90\%$ of the event duration must meet the amplitude reduction criteria for hypopnea.

Drug-Induced Sleep Endoscopy (DISE)

The DISE procedure was performed by an ENT surgeon in a semi-dark and silent operating room with the patient in supine position.^{22,23} Continuous monitoring of cardiac rhythms and oxygen saturation was provided.²² Unconscious sedation was induced by intravenous administration of midazolam with a bolus injection of 1.5 mg and/or with propofol using a target-controlled infusion system at a target of 2.0 to 3.0 mcg/mL. During DISE, the level (palate, oropharynx, tongue base, hypopharynx/epiglottis), the direction (anteroposterior [AP], concentric, lateral), and degree of upper airway collapse (none, partial, or complete) were scored in a standard fashion.²²⁻²⁶ The palate is defined as the particular portion of the upper airway at the level of the soft palate and uvula, while the oropharynx is defined by the pharyngeal region at the levels of the tonsils (above the tongue base). The tongue base is defined as the retroglossal area, and the hypopharynx is defined as the upper airway region below the tongue base, including of the tip of the epiglottis. The collapse patterns were assessed during inspiration. All ENT surgeons who performed DISE in the present study were experienced with this procedure, and the DISE videos were assessed by the ENT surgeon who performed the procedure. The mean duration of the procedure was 25 ± 18 minutes.

Upper Airway Stimulation (UAS) System

The UAS system consists of a respiration sensor, a programmable implanted pulse generator, and stimulating electrodes (Inspire Upper Airway Stimulation therapy, Inspire Medical Systems, Minneapolis, MN, USA). The Inspire II Upper Airway Stimulation (UAS) system (Inspire Medical Systems, Maple Grove, MN) consisted of a respiration sensor, programmable implanted pulse generator (IPG), and stimulating electrodes. The sensor detected respiratory efforts from the chest that were analyzed by the IPG. From the sensor signal, the IPG predicted the onset of inspiration, delivering stimulation pulses between the end of expiration and the beginning of the next expiratory phase of each respiratory cycle. The electrical pulses were applied to the hypoglossal nerve through platinum/iridium electrodes. The patient was given a programming device capable of initiating and terminating the UAS therapy. The operative technique of the implantation of the UAS system used in this study has been described in detail previously.^{13,27}

Definition of Treatment Success

The present study used the criteria established by Sher et al. to define treatment success as AHI < 20 /h after treatment and an AHI reduction $\geq 50\%$ as compared to baseline.²⁸ Additionally, success rates were assessed for a success definition of AHI < 15 /h sleep. To assess daytime sleepiness, patients filled out the Epworth Sleepiness Scale (ESS).²⁹

Statistical Analysis

The pre-implantation AHI was compared to AHI 6 months after implantation. Statistical analysis was performed using MATLAB (The Mathworks, Natick, MA, USA) and Excel (Microsoft Corp, Redmond, WA, USA). A Wilcoxon signed-rank test was used to compare the pre-implantation AHI to the post-implantation AHI. Differences were considered statistically significant if the p-value was less than 0.05. Results were presented as means and standard deviations.

RESULTS

Subjects

DISE videos were recorded for 21 patients with an established diagnosis of moderate to severe OSA before the implantation of the UAS system. Patients were predominantly male, with an average age of 55 ± 11 years, a baseline AHI of 38.5 ± 11.8 /h, and a BMI of 28 ± 2 kg/m² (Table 1).

DISE Analysis

An overview of the distribution of the levels of upper airway collapse for all patients included in this study based on DISE scoring is provided in Figure 1 and Table 2. The majority of patients (91%) had multilevel collapse, predominantly at the palatal and tongue base levels and rarely at the oropharyngeal and hypopharynx/epiglottis levels (Figure 1). The most common upper airway collapse patterns noted in this study were AP collapse at the levels of the palate (76.2%) and the tongue base (71.4%) (Table 2).

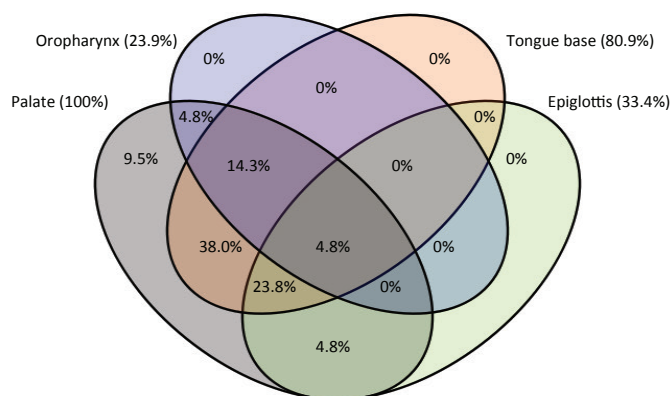
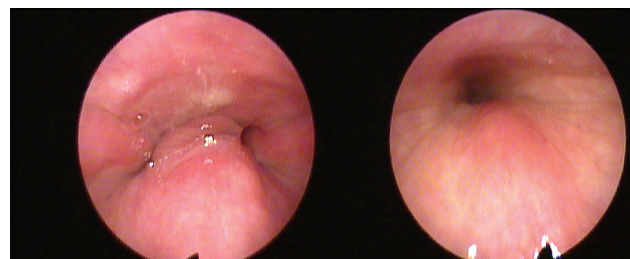
Sixteen patients were categorized as having predominant AP palatal collapse, and 5 were categorized as having complete

Table 1—Patient demographics, including baseline differences between patients with and without complete concentric collapse (CCC) at the level of the palate

	Baseline AHI (events/hour)	BMI (kg/m ²)	Age (years)	Gender (M / F)
All patients (n = 21)	38.5 ± 11.8	28 ± 2	55 ± 11	20 / 1
Palatal non-CCC (n = 16)	37.6 ± 11.4	28 ± 2	55 ± 11	15 / 1
Palatal CCC (n = 5)	41.5 ± 13.8	29 ± 2	55 ± 9	5 / 0

Table 2—Overview of the distribution of the levels of upper airway collapse including the corresponding direction of upper airway collapse based on DISE scoring (n = 21)

	Palate	Oropharynx	Tongue Base	Hypopharynx/Epiglottis
Anterior-posterior	76.2%	4.8%	71.4%	28.6%
Concentric	23.8%	4.8%	4.8%	4.8%
Latero-lateral	0.0%	14.3%	4.8%	0.0%
None	0.0%	76.2%	19.0%	66.7%

Figure 1—Venn diagram showing the percentages per upper airway level including the percentages of overlap between the different levels in case of multi-level collapse**Figure 2**—Example of anteroposterior (left) versus concentric (right) collapse at the level of the palate during DISE

provement in the AHI, decreasing from 38.0 ± 10.3 at baseline to 13.6 ± 12.1 with UAS ($p < 0.001$).

Treatment Success Analysis

The overall UAS treatment success rate for all 21 patients included in this study using Sher's criteria was 62% (13/21). Treatment success in the subset of patients without CCC collapse at the level of the palate was 81% (13/16), while treatment success could not be achieved in any patient with CCC collapse at the level of the palate in this study (0/5). When assessing the success rates specifically for AHI < 15, overall success would be achieved in 11/21 (52.4%) patients. In patients without palatal CCC success would be achieved in 11/16 patients (68.8%); in patients with palatal CCC this would be 0/5 (0%). There was no significant difference in BMI between baseline and 6 months in either group. Overall, ESS improved significantly from baseline 8.2 ± 5.0 to 6.4 ± 4.3 ($p = 0.02$; $n = 18$).

DISCUSSION

This study evaluates DISE as a patient selection tool for implanted UAS therapy to treat OSA. The results of this study indicate that the absence of CCC at the level of the palate as documented during DISE may predict therapeutic success for OSA patients with implanted UAS therapy. These findings are highly relevant to the field, as previous studies have indicated that the application of hypoglossal nerve stimula-

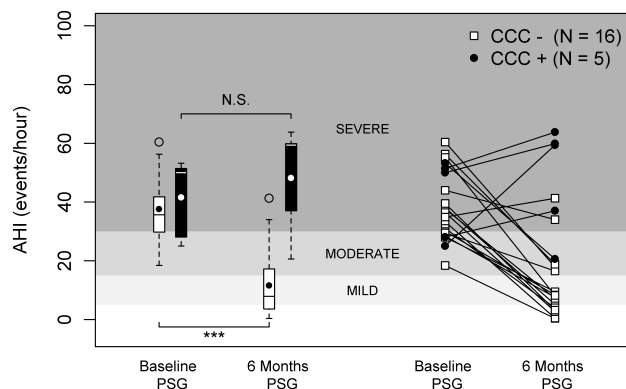
concentric collapse (CCC) at the palatal level (**Figure 2**). There was no significant difference in baseline AHI, BMI, or age between patients with and without palatal CCC (**Table 1**).

In this patient group, 19 of 21 patients had multilevel collapse. All patients had at least a collapse at the level of the palate (**Figure 1**), whereas tongue base, hypopharynx/epiglottis, and oropharynx collapse were noted in 80.9%, 33.4%, and 23.9% of patients, respectively (**Figure 1**). Conversely, no patients had tongue base collapse without palatal collapse (**Figure 1**). The most common combination of multilevel collapse was the combination of AP palatal and AP tongue base collapse without epiglottis collapse, which occurred in 33% of the patients.

UAS Effect on Various Collapse Types

Patients with palatal CCC did not have a significant change in AHI with UAS 6 months after implantation, as baseline AHI was $41.5 \pm 13.8/h$ and AHI with UAS was $48.1 \pm 18.7/h$, ($p = 0.44$; **Figure 2**). The patients without palatal CCC had a significant improvement in AHI with UAS despite multilevel collapse at the palate and tongue base. For this subset of patients, AHI went from $37.6 \pm 11.4/h$ at baseline to $11.6 \pm 11.7/h$ with UAS ($p < 0.001$; **Figure 2**). Thirteen patients with both palatal AP and tongue base AP collapse had a significant im-

Figure 3—Apnea-hypopnea index (AHI) in patients with (black color) and without (white color) complete concentric collapse (CCC) at the level of the palate 6 months after UAS implantation during stimulation as compared to baseline without UAS; the different grayscales represent the distinction between normal nocturnal breathing (AHI < 5/h sleep), mild OSA (AHI 5-15/h), moderate OSA (AHI 15-30/h), and severe OSA (AHI > 30/h)



Left panel: boxplots showing the 75th and 25th percentiles by the upper and lower margins, the mean values by the closed circle, and the median values by the horizontal line. Whiskers represent the maximum value (top) and the minimum value (bottom) of the dataset; this range includes all data except the outliers. Outliers are represented by an open circle. Right panel: the individual patient response data are plotted in line graphs, with the white squares being the AHI values in patients without CCC and the black circles being the AHI values in patients with CCC. N.S., not significant; *** $p < 0.001$.

tion in non-selected OSA patients leads to high interindividual variation in therapeutic effectiveness.^{13,15-17,30} The role of DISE in patient selection for implanted UAS therapy was recently addressed; however, the present study population consists of 5 additional subjects and provides specific demographics of the various combinations of multilevel upper airway collapse in this population. Patients with palatal CCC did not have a significant change in AHI with UAS 6 months after implantation (AHI $41.5 \pm 13.8/h$ at baseline versus $48.1 \pm 18.7/h$ with UAS), suggesting that the tongue protrusion resulting from the UAS therapy is not sufficient to overcome the airway obstruction in patients with CCC at the level of the palate. The results of this study also suggest that the stimulation at the base of tongue can potentially overcome AP obstruction not only at the base of tongue level but also at the palatal level. A statistically significant reduction in AHI was seen in patients with both AP palatal and tongue base collapse, suggesting that UAS can resolve multilevel collapse. One possible explanation might be that an AP palatal collapse is due to a tongue base obstruction pushing back the soft palate. In this concept, UAS is able to maintain airway patency as the tongue base is directly hindered from obstruction which keeps the palate in an anterior position. These results showing that palatal CCC prohibits therapeutic success with UAS might indicate that an AP movement induced by hypoglossal nerve stimulation cannot resolve a concentric collapse of the upper airway. Thus,

the actual effects of upper airway muscle activation on upper airway shape are dependent on both the upper airway region and cross-sectional area.³¹ Further research on DISE as a patient selection tool for implanted UAS may focus on upper airway behavior during UAS as assessed during DISE. In a recent study by Goding et al., cross-table fluoroscopic images were obtained during hypoglossal nerve stimulation in 26 subjects while two-dimensional changes in the AP dimensions of both the retropalatal and the retrolingual airway spaces were recorded.³² The results of this fluoroscopy study indicate that during hypoglossal nerve stimulation, an opening of the upper airway at the level of the palate occurs in a majority of cases, confirming the beneficial effect of hypoglossal nerve stimulation on the AP upper airway dimensions.³²

There is great interest in the prospective prediction of treatment outcome of non-CPAP options such as surgery and oral appliance therapy.^{22,33} DISE provides an alternative method of studying the upper airway in OSA patients while performing a fiberoptic endoscopy during sedation. The lack of uniformity in the methods used for sedation during DISE as well as the fact that a consensus on DISE scoring systems has not yet been established, are clear limitations to this study.^{22,23,34,35} Recent studies that address the test-retest and the intra- and interobserver variability in DISE scoring indicate that the reliability of both are moderate to fair, and that inter-observer agreement is higher in ENT surgeons who are experienced with DISE.³⁶⁻³⁹ The limitations of this study also include the fact that DISE was performed only in the supine position, whereas upper airway collapse patterns should ideally be assessed in both the supine and non-supine position⁴⁰.

It is well known that the probability of a multilevel collapse is significantly associated with the severity of OSA, as higher AHI values are correlated with a higher percentage of multilevel collapse.^{25,35,41} This finding might explain the high prevalence of multilevel collapse in our study (91%) given the relatively high overall baseline AHI of $38.5 \pm 11.8/h$. Upper airway collapse at the level of the palate was the most common level of collapse in this study, with collapse at the level of the tongue base being the second most common (Figure 1). Again, these findings are in line with previous studies.^{35,41}

Two recent studies have shown a correlation between a patient's BMI and the therapeutic response to UAS.^{13,32} In addition, a baseline AHI $\leq 50/h$ turned out to be a predictor of UAS therapy response.¹³

Although the number of patients included in this study was relatively low, a clinically and statistically significant difference in AHI was detected between the two groups of OSA patients (those with versus those without palatal CCC; Figure 3). According to Sher's criteria, treatment success in the patients without palatal CCC was 81%, while no patients with CCC at the level of the palate could be treated successfully with UAS. The correlation between the absence of CCC at the level of the palate and treatment success with UAS turned out to be independent from baseline AHI and the patient's BMI (Table 1). Given that both parameters were previously described as predictors of therapeutic outcome with hypoglossal nerve stimulation for OSA, the fact that the absence of palatal CCC remains highly predictive independent from AHI and BMI certainly adds to the power of these findings.

In conclusion, based on the results of the reported study, DISE can be recommended as a patient selection tool for implanted UAS to treat OSA. Further analysis of the predictive value of DISE in assessing therapeutic response to UAS therapy needs to be performed in larger multicenter trials that are currently ongoing.

ABBREVIATIONS

AP, anteroposterior
 AHI, apnea-hypopnea index
 BMI, body mass index
 CCC, complete concentric collapse
 CPAP, continuous positive airway pressure
 DISE, drug-induced sleep endoscopy
 OSA, obstructive sleep apnea
 UAS, upper airway stimulation

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investigator for Inspire Medical Systems Inc. Mr. Hamans is a consultant for Philips Healthcare. Mr. Lin has participated as a co-investigator in clinical trials sponsored by Inspire Medical Systems Inc. and has served as a consultant for Inspire Medical Systems Inc. Dr. Anders is co-investigator for a study supported by Inspire Medical Systems Inc. He had paid speaking engagements with Inspire Medical Systems Inc. (USA), GlaxoSmithKline (Germany), Weinmann (Germany), Olympus (Germany), ResMed (Germany), Neuwirth (Germany), Medtronic (USA) and Heinen & Löwenstein (Germany). He has also received paid speaking engagement and surgical cadaver training for beginners. Dr. de Vries is medical advisor for MSD, ReVENT, NightBalance; investigator for Inspire Medical Systems Inc.; consultant for Philips; and has stock options in ReVENT. Dr. Van de Heyning is an investigator for Inspire Medical Systems Inc. The other authors have indicated no financial conflicts of interest.