

SCIENTIFIC INVESTIGATIONS

Interventional Drug-Induced Sleep Endoscopy: A Novel Technique to Guide Surgical Planning for Obstructive Sleep Apnea

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Study Objective: One of the challenges of surgery for obstructive sleep apnea (OSA) is identifying the correct surgical site for each patient. The objective of this study was to use drug-induced sleep endoscopy (DISE) and nasopharyngeal tube (NPT) placement to determine the effect of eliminating palatal collapse on the obstruction seen on other segments of the upper airway.

Methods: Forty-one OSA patients were enrolled in this prospective study. All patients had a polysomnogram followed by DISE. DISE findings were recorded and compared with and without placement of a NPT. Obstruction was graded with a scale that incorporates location, severity, and interval of obstruction.

Results: Most patients (83%) demonstrated multilevel obstruction on initial DISE. With the nasopharyngeal airway in place, many patients with multilevel obstruction had at least a partial improvement (74%) and some a complete resolution (35%) of collapse ($p < 0.05$). Reduction in collapse was observed at the lateral walls (86%), epiglottis (55%), and tongue base (50%). NPT placement did not significantly alter upper airway morphology of patients with incomplete palatal obstruction or mild OSA.

Conclusions: To our knowledge, this is the first study to evaluate the effect of soft palatal stenting on downstream pharyngeal obstruction during DISE. Our study provides evidence that reducing soft palatal collapse can reduce negative pharyngeal pressure and thereby alleviate other sites of upper airway obstruction. Taken together, these findings provide a means to identify appropriate candidates for isolated palatal surgery and better direct a minimally invasive approach to the surgical management of OSA.

Keywords: obstructive sleep apnea, OSA, nasopharyngeal tube, drug-induced sleep endoscopy, DISE

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INTRODUCTION

Obstructive sleep apnea (OSA) is a disorder characterized by episodes of upper airway collapse during sleep resulting in apnea and hypopnea. Apnea and hypopnea are defined by a cessation or reduction of airflow and oxygen desaturation.¹ OSA can be accompanied by complaints such as snoring and daytime sleeping and has been associated with serious health problems such as cardiovascular disease.^{2–7}

Nonsurgical options for treating OSA should be considered before attempting sleep surgery. In particular, a trial with continuous positive airway pressure (CPAP) remains the gold standard and primary treatment for OSA. CPAP acts to pneumatically splint open the upper airway, thereby eliminating obstructive events during sleep.⁸ However, many patients find CPAP difficult to use on a consistent basis or at all. The compliance rate of CPAP is less than 50% in some studies.^{9,10} Non-compliance limits the efficacy of CPAP and has driven the need for alternative treatment modalities. A variety of surgical techniques have been devised to potentially reduce specific sites of obstruction in the upper airway. Unfortunately, there is no clear consensus as to the best means to select the appropriate surgery for the appropriate patient.^{11,12} As a result, the rate of surgical cure of OSA has been less than optimal.

A more refined understanding of OSA patient specific upper airway dynamics could improve the success of sleep surgery

BRIEF SUMMARY

Current Knowledge/Study Rationale: Determination of the site of upper airway obstruction and selection of the appropriate surgical intervention for obstructive sleep apnea (OSA) can be difficult, especially as the primary area of collapse may induce an artificial secondary area of obstruction. We evaluate the utility of using a nasopharyngeal tube during drug-induced sleep endoscopy (DISE) to simulate the effects of isolated palatal surgery.

Study Impact: Nasopharyngeal tube placement appears to be a useful tool to delineate which patients could benefit from an isolated palatal surgery for OSA as opposed to a more extensive approach. A significant portion of patients who appeared to have multilevel collapse on DISE had complete resolution (35%) of collapse with nasopharyngeal tube placement alone.

procedures. One technique, referred to as drug-induced sleep endoscopy (DISE), was devised in 1991 by Pringle and Croft and allows for a targeted approach to surgery by visualization of obstruction during sedative-induced sleep.¹³ Critics of the technique have questioned the fidelity of sedative-induced sleep compared to natural sleep. However, the technique has been shown to be valid and reliable.^{14,15}

Nasopharyngeal tubes (NPT) are soft, flexible tubes which are used as an adjunct in airway management. A NPT is placed through the nasal cavity and nasopharynx into the oropharynx until the tip is just beyond the soft palate. A correctly placed

Table 1—Upper airway obstruction classification system.

Level	Degree		Sustainability	
	Partial	Complete	Intermittent	Sustained
Palate (velum)	p	P	–	–
Lateral wall/tonsillar pillars	l	L	–	–
Tongue base	t	T	1	2
Epiglottis	e	E	1	2

Partial = < 75% obstruction, complete = > 75% obstruction; intermittent = obstruction only during inspiration in an apneic episode, sustained = obstruction throughout an apneic episode, dash (–) = not visualized.

nasopharyngeal airway will stent open the palate by separating the soft palate from the posterior wall of the oropharynx.^{16,17} Some clinicians have proposed inclusion of NPT placement among the treatment options for OSA, especially as the palate is the primary level of collapse in most OSA patients. NPT placement as a treatment for OSA has shown some efficacy; however, its utility as a treatment modality has been limited by poor patient tolerance.¹⁸ More recently, researchers have studied the use of NPT placement in a diagnostic capacity to discern which patients will respond to isolated oropharyngeal surgery from those patients who require a multilevel approach.¹⁹ The difficulty lies in identifying those patients who will improve with a less extensive surgical approach. Some clinicians believe that stenting the palate open, such as with NPT placement or a palatal surgery, will not only improve palatal level collapse, but also decrease downstream pharyngeal collapse by reducing negative pharyngeal pressure.

To our knowledge, no study has evaluated the effect of a nasopharyngeal airway on upper airway obstruction during DISE. This study will determine whether preventing palatal obstruction with a nasopharyngeal airway alters other sites of airway collapse during DISE. Our study could help to provide evidence as to whether improving palatal collapse can improve upper airway collapse at other sites. It can also help to determine which patient would benefit the most from isolated palate surgery. These findings could enhance DISE as a tool to select the appropriate surgical intervention.

METHODS

Patient Selection

This study was conducted in accordance with the Declaration of Helsinki at an academic tertiary care center. The study subjects were 41 patients (age > 18 years) who had obstructive sleep apnea between July 2014 and November 2014. Patients with prior surgery for obstructive sleep apnea or allergy to propofol were excluded from the study. Formal laboratory polysomnography (PSG) was conducted prior to DISE. Obstructive apneas were defined by $\geq 90\%$ oronasal airflow reduction for > 10 seconds. Obstructive hypopneas were defined by $\geq 30\%$ decrease in airflow for > 10 seconds accompanied by $\geq 4\%$ decrease in oxygenation. Obstructive sleep apnea was classified based upon the AHI as mild (≥ 5 to 14 events/h), moderate (≥ 15 to 29 events/h), or severe (≥ 30 events/h). Oxygen desaturation

was defined as $\geq 4\%$ decrease in oxygenation. An author (MT) obtained physical and historical assessments. Eligibility for the study was made by a different author (AV). The Institutional Review Board at Baylor College of Medicine approved this study.

Interventional Drug-Induced Sleep Endoscopy and Classification of Morphological Features

Drug-induced sleep endoscopy was performed in an operating room and digitally recorded by the same endoscopist (MT). Patients were positioned on the operating room table with standard anesthetic monitoring, including pulse oximetry and electrocardiography. Unconscious sedation was induced with an intravenous bolus administration of the sedative propofol. Adequate sedation for DISE was defined as the absence of a response to verbal stimulation in a normal voice.^{14,15,20} Propofol infusion was slowly titrated and rate adjusted to avoid oversedation. Only propofol was used for the sedation protocol. Once the patient was sedated, a flexible video endoscope was introduced and the upper airway was observed for obstruction. All DISEs were recorded in a consistent manner keeping the orientation of the base of tongue at the bottom of the screen and posterior pharyngeal wall at the top of the screen. A recording device was used to store the video from the DISE. The flexible endoscope was removed and a Robertazzi nasopharyngeal tube (34 Fr, Rusch, Teleflex Medical GmbH, Kemen, Germany) was placed through the nasal cavity to the nasopharynx. The propofol sedation was adjusted to achieve adequate sedation. DISE was again performed, the endoscope was again introduced, and the upper airway was observed with the nasopharyngeal tube in position in the nasopharynx. The nasopharyngeal tube was then advanced just past the soft palate, using a flexible endoscope to position the tube at the same spot in all patients. The same size of Robertazzi nasopharyngeal tube (34 Fr) was able to be used for all patients. The sedation was adjusted and the upper airway again observed with the endoscope. Video recordings of the DISE were also collected. The senior author (MT) was then blinded as to the patient name, and the digital recordings were then evaluated for sites of collapse as described in **Table 1**.^{21–23}

Briefly, the potential sites of upper airway collapse included the palate, the lateral oropharyngeal walls, the base of tongue, and the epiglottis. Each area was further characterized by the degree of collapse, either as partial (< 75%) or as complete (> 75%). The location and degree of collapse was recorded by

listing the first letter of the site of collapse in either lower case, for partial obstruction, or upper case, for complete obstruction. No obstruction at a particular level would receive no letter designation and be left blank. A single letter could thereby convey both the site and degree of obstruction. Obstruction at the base of tongue and epiglottic levels were further classified by the sustainability of collapse, with intermittent obstruction only occurring during inspiratory effort and with sustained obstruction occurring throughout the respiratory cycle. Lateral wall and palatal obstruction did not clearly and consistently demonstrate this relationship to respiratory effort. The sustainability of collapse for the tongue base and the epiglottis was recorded by listing 1, for intermittent obstruction, or 2, for sustained obstruction. This number would follow the letter designation as described above.

Statistical Analysis

The primary comparison was between DISE with and without a nasopharyngeal airway in place. The McNemar test was used to analyze changes to the pattern of upper airway obstruction visualized by DISE with and without the nasopharyngeal airway. Correlation between tonsil size and BMI with other variables was carried out by the Spearman correlation test. The paired *t*-test was used to compare DISE findings with AHI and BMI. A *p* value of < 0.05 was considered statistically significant. Continuous variables were summarized using means and standard deviations. Categorical variables were summarized using percentages. Statistical analysis was performed with the STATA System (version 13.0, College Station, TX).

RESULTS

Forty-one patients, 33 male and 8 female, were enrolled in the study. Five patients were not enrolled during the study period due to the presence of prior surgery for obstructive sleep apnea. Demographic data for participants is summarized in **Table 2**. All patients had OSA with the severity, as defined by AHI, distributed as follows: mild (22%), moderate (44%), and severe (34%). The mean ESS was 14.8 ± 3.5 . The mean total sleep time (TST) during polysomnography was 346.5 minutes. There was no significant correlation between tonsil size or BMI and change in the pattern of upper airway obstruction with nasopharyngeal airway placement ($p > 0.05$).

Propofol-induced sleep endoscopy was administered to all patients in the supine position. Two patients had minimal anterior epistaxis related to insertion of the nasopharyngeal tube, both of which resolved spontaneously without intervention. Otherwise, no complications were incurred during or following sleep endoscopy. Most patients (82.9%) demonstrated multilevel obstruction on initial DISE with a minority demonstrating single level collapse (17.1%). The most common site of collapse was the palate (95.1%) in patients with single level and multilevel collapse. About half of the patients were found to have obstruction at the level of the tongue base (56.1%) and the epiglottis (53.7%). Just over one-third of patients demonstrated lateral wall collapse (34.1%).

Table 2—Study demographics.

Patient Characteristics	Mean \pm SD	Range
Age (y)	43.8 ± 12.1	19–69
Gender (M/F)	33/8	–
BMI (kg/m ²)	30.5 ± 7.6	18–44
AHI (events/h)	27.6 ± 20.2	6–88
Tonsil size (grade 0–4)	2.9 ± 1.7	0–4

SD = standard deviation, BMI = body mass index, AHI = apnea-hypopnea index.

The nasopharyngeal tube was successfully placed in all patients. The NPT was first placed through the nasal cavity to the nasopharynx. With the NPT in this position, there was no significant change in upper airway collapse compared to findings without the NPT. As the nasopharyngeal tube was advanced past the soft palate, apneic episodes during DISE were resolved in patients with isolated palatal collapse. Downstream pharyngeal morphology was not altered by placement of a NPT in patients with isolated palatal collapse.

DISE findings in patients with multilevel collapse are shown in **Table 3**. All of these patients had at least partial collapse at the palate, and nearly all had complete obstruction. A significant portion of patients with multilevel collapse demonstrated at least a partial improvement (74%) and some patients a complete resolution (35%) of downstream upper airway collapse with a nasopharyngeal airway in place ($p < 0.05$). No patient demonstrated worsening of downstream obstruction with NPT in place. At least partial reduction in collapse was observed at the lateral walls (86%), epiglottis (55%), and tongue base (50%). Completely resolution of collapse with NPT placement was rare at the tongue base level (13.0%), whereas it was common at the lateral wall (57.1%) and the epiglottis (42.9%) levels ($p < 0.05$). Of note, all patients who demonstrated change in downstream morphology with NPT placement had moderate or severe OSA. The pattern of downstream pharyngeal collapse in patients with mild OSA was the same with and without a NPT.

DISCUSSION

To our knowledge, this is the first study to evaluate the effect of soft palatal stenting on downstream pharyngeal obstruction during DISE. Our results demonstrate that reducing palatal collapse can reduce obstruction in downstream sites of the upper airway. The novel technique of placing a NPT during DISE may help sleep surgeons to better direct a minimally invasive approach to surgery for OSA.

Most patients with OSA have multiple levels of upper airway obstruction on DISE, with the palate being the most common site of collapse.²⁴ Similarly, our study found that multilevel obstruction was present in the majority of patients and palatal collapse present in nearly all patients. Although DISE has been shown to be reliable, some critics of the technique suggest that sedative-induced sleep only provides a small window into the

Table 3—Interventional drug-induced sleep endoscopy in patients with multilevel obstruction.

Level of Obstruction	Pre-NPT (percent of patients)	Post-NPT (percent of patients)	p value*
Palate (velum)	100%	—	—
Partial/flutter	26%	—	—
Complete	74%	—	—
Lateral wall or tonsillar pillars	41%	18%	< 0.05
Partial/flutter	9%	15%	NS
Complete	32%	3%	NS
Tongue base	68%	56%	NS
Partial intermittent	15%	27%	NS
Partial sustained	29%	18%	NS
Complete intermittent	12%	6%	NS
Complete sustained	12%	6%	NS
Epiglottis	62%	35%	< 0.05
Partial intermittent	41%	21%	NS
Partial sustained	21%	12%	NS
Complete intermittent	0%	3%	§
Complete sustained	0%	0%	§

Pre-NPT = prior to placement of nasopharyngeal airway, Post-NPT = after placement of nasopharyngeal tube, * = McNemar test for paired data, NS = not significant, § = insufficient subject number for statistical analysis.

complex and variable patterns of natural sleep.^{25–27} The present study demonstrates a more dynamic approach to DISE. The surgeon actively manipulated the upper airway with a NPT to better understand the interplay of the different sites of obstruction. Hopefully, future studies will continue to identify novel techniques to manipulate and better appreciate patient-specific patterns of upper airway collapse during DISE.

Although OSA affects 2% to 26% of the general population, the mechanism of upper airway collapse in OSA remains controversial.^{28,29} Many believe that a multifaceted interface of mechanical and neuromuscular factors culminate in upper airway obstruction during sleep.^{30,31} Others have suggested that the upper airway acts like a Starling resistor, similar to that observed in the vasculature.³² In the Starling resistor model, a single level of obstruction creates a downstream negative pharyngeal pressure leading to downstream airway collapse.³³ The findings of the current study demonstrate that improving complete palatal obstruction can reduce downstream pharyngeal collapse at the lateral wall and epiglottis. Lateral wall and epiglottis obstruction appeared to be dependent on palatal obstruction in these patients. In contrast, improving incomplete palatal obstruction did not significantly alter downstream upper airway morphology. These results suggest that complete palatal obstruction can create negative pressure and promote collapse downstream of the palate. Lateral wall collapse was the site most dependent on palatal obstruction followed by the epiglottis and then the tongue base. Tongue base obstruction appeared to act largely independently of palatal level obstruction. One explanation for this may be the susceptibility of the tongue base to gravitational-induced collapse, which could outweigh the forces of negative pharyngeal pressure. The role of gravitational-induced collapse on the tongue base was demonstrated in our previous study on positional OSA.³⁴ We found that lateral positioning, as

compared to supine positioning, significantly improved hypopharyngeal collapse in positional OSA patients. As the present study was conducted on patients in the supine position, gravitational-induced collapse could be in effect. Our findings also suggest that the mechanism of improved multilevel collapse with NPT placement was secondary to palatal stenting as opposed to alteration of nasal airflow. Placement of a NPT into the nasopharynx, but not to the level of the palate, did not change upper airway morphology on DISE. This is in agreement with prior studies demonstrating that DISE and polysomnography findings were largely unchanged after nasal surgery.^{23,35–37}

Interventional DISE techniques, such as with NPT, provide a means to potentially advance the role of DISE as a tool to guide surgical intervention. Placement of NPT during DISE may allow the surgeon to simulate the effects of a palatal sleep surgery and potentially identify patients who would respond to palatal surgery alone. Separating these patients from those who would require multilevel surgery is crucial to improving the cure rate of sleep surgery. In particular, it could help define the role of soft palate surgeries such as the uvulopalatopharyngoplasty (UPPP), which have been the most common sleep apnea surgical procedure performed during the past 25 years. Other recent studies have also supported the use of NPT placement to help identify these patients. Li et al. demonstrated that NPT placement and polysomnography identified patients who would benefit from UPPP alone as opposed to a multilevel surgery. These researchers suggested that an AHI < 15 after NPT insertion was a good indicator for isolated UPPP surgery. They proposed that an AHI > 15 after NPT placement should prompt consideration for a multilevel surgical approach.³⁸ Unfortunately, reliance on this technique of placement of a NPT during polysomnography does not allow for specific localization of the site of downstream collapse. Without the specific

site of persistent obstruction, a surgeon is still limited as to selecting the correct minimally invasive multilevel intervention. Interventional DISE may help address this limitation. Future studies should evaluate the efficacy of a minimally invasive approach guided by DISE and NPT placement.

Downstream pharyngeal morphology was not significantly altered in those patients with single level obstruction. However, patients with isolated palatal collapse demonstrated resolution of apneic episodes during DISE. Identifying patients with palatal obstruction has been shown to improve the success rate of uvulopalatopharyngoplasty.³⁹ Despite this, some of these patients will still experience treatment failure, likely due to multifactorial reasons such as increased BMI in the postoperative period. In addition, our findings provide some support for the inclusion of NPT placement in the treatment armamentarium for isolated palatal obstruction. Nasopharyngeal airway use has been suggested as an alternative therapeutic modality for OSA in the past. It has been shown to be effective clinically and on polysomnography in the adult population.¹⁸ Patients who did not seem to benefit from nasopharyngeal airway placement included those with higher AHI, lower oxygen saturation nadir, and higher partial pressure of carbon dioxide. Therefore, some have suggested targeting NPT placement to those patients who cannot tolerate CPAP, especially during the interim prior to undergoing sleep surgery. Unfortunately, only about half of adult OSA patients tolerate use of a nasopharyngeal airway.¹⁸ Patient intolerance is in part due to nasopharyngeal mucosal irritation and nasopharyngeal incompetence with regurgitation through the tube.⁴⁰ One way to minimize the potential for nasopharyngeal incompetence would be to only use the nasopharyngeal airway during sleeping hours. Clearly, limitations remain for widespread adoption of NPT placement as a treatment for OSA.

Some weaknesses of the present study should be acknowledged. A larger study could provide a more detailed evaluation of the effects of NPT placement on upper airway morphology during DISE. DISE also relies on a qualitative characterization of upper airway obstruction. Some methods such as the VOTE classification system have attempted to standardize this qualitative process.¹⁵ However, we did not use the VOTE classification in the present study, as it does not account for the sustainability of upper airway obstruction. Future studies could develop means of quantitative measurement of airway dimensions. The use of a single surgeon for performing DISE and reviewing the video recordings could have biased our study.

This study demonstrates a novel technique to dynamically understand upper airway collapse in OSA. This understanding is critical given the complex, multifactorial nature of upper airway collapse in many OSA patients. Our study provides a potential explanation for the treatment failures of UPPP in some patients. Our study also provides a potential means to identify a subset of patients who could benefit from a less invasive approach to multilevel collapse.

ABBREVIATIONS

CPAP, continuous positive airway pressure
DISE, drug-induced sleep endoscopy

NPT, nasopharyngeal tube
OSA, obstructive sleep apnea
PSG, polysomnography
TST, total sleep time
UPPP, uvulopalatopharyngoplasty

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