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Nasal and oral snoring endoscopy: novel and promising diagnostic tools in OSAS patients

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Abstract The aim of the present study was to investigate if any of the three awake procedures [fiberoptic nasopharyngoscopy with modified Müller Maneuver (FNMM), nasal snoring endoscopy (NSE), or oral snoring endoscopy (OSE)] could efficiently predict the grade or pattern of upper airway (UA) collapse found with drug-induced sleep endoscopy (DISE), which is considered by many authors as the current gold standard in optimizing obstructive sleep apnea syndrome (OSAS) patient selection for UA surgery. Twenty consecutive patients (simple snorers and OSAS patients) were studied with FNMM, NSE, OSE, and DISE. The inter-test agreement was evaluated with Cohen's kappa coefficient (κ). In the current series, we found that NSE and OSE were better than FNMM in predicting the pattern of collapse found with DISE. A significant pattern agreement between NSE and DISE was present in all sub-sites, and the agreement was measured with a scale proposed by Landis and Koch as: moderate in velo- and oropharynx ($\kappa = 0.52$, $p = 0.001$, and $\kappa = 0.47$, $p = 0.003$, respectively), and substantial in hypopharynx ($\kappa = 0.63$, $p < 0.00001$). Comparing OSE with DISE, the pattern agreement was almost perfect at oropharyngeal level ($\kappa = 0.82$, $p < 0.00001$), and moderate at hypopharyngeal level ($\kappa = 0.55$, $p = 0.0002$); while a trend towards significance was found at velopharyngeal level ($\kappa = 0.20$, $p = 0.07$). FNMM showed a fair pattern agreement with DISE only at oropharyngeal level ($\kappa = 0.31$, $p = 0.009$); while in the other sub-sites, no significant agreement was found. NSE and OSE are new promising diagnostic tools in OSAS patients. Further investigations are needed to see if they could predict the effectiveness of UA surgery.

Keywords OSAS · Simulated snoring · Snoring endoscopy · DISE · Müller Maneuver

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Introduction

The human body muscle tone, ordinarily, relaxes during sleep, and the airway could collapse causing sleep apnea events. Obstructive sleep apnea syndrome (OSAS) is characterized by recurrent episodes of apnea and hypopnea during sleep that are caused by repetitive upper airway (UA) collapse and often result in decreased oxygen blood levels and arousal from sleep [1]. It affects up to 5 % of adults in Western countries. Hospital-based polysomnography (PSG) and home-based sleep studies are both two acceptable and objective tests to establish a diagnosis of OSAS and determine the severity of the disease [2]. Continuous positive airway pressure (CPAP) therapy is considered as the gold standard treatment for moderate to severe OSAS, but in patients with mild to moderate OSAS, or in cases of CPAP failure, oral appliance therapy and/or UA surgery can be considered [3]. Identification of predictors of treatment outcome is important in selecting patients who might benefit from non-CPAP therapies.

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Examination of the UA is mandatory when OSAS has been suspected or diagnosed. The aim of UA evaluation is not only to determine the site of obstruction, but also to improve treatment success rates by selecting the most appropriate therapeutic option for the individual patient [4]. UA clinical examination is limited by the fact that these tests are performed during wakefulness and in static condition which may not represent the dynamic UA behavior during snoring. Also its prognostic value is discussed, as multiple authors did not found a correlation between anatomic alterations of UA (high Mallampati/Friedmann index, and tonsil size, for instance) and OSAS [5, 6]. Fiberoptic nasopharyngoscopy with modified Müller Maneuver (FNMM) was introduced in clinical practice by Sher et colleagues in 1985 [7]. They performed a nasopharyngoscopy while awake patients made a vigorous inspiration with nostrils and mouth closed. Several authors have propagated the use of the Müller Maneuver (MM), which creates a negative pressure in the UA, as an appropriate way of inducing a pharyngeal collapse similar to the anatomic situation during sleep [8]. Recent studies have provided evidence that the collapse during the MM differs from the sleep-time pharyngeal collapse [9]. FNMM may identify the tendency of the pharyngeal wall to collapse under forced negative inspiratory pressure instead of the tendency to simulate obstruction during sleep, and thus FNMM role in predicting the effectiveness of UA surgery is debated [10].

Sleep nasendoscopy, nowadays commonly referred as drug-induced sleep endoscopy (DISE), was introduced by Croft and Pringle in 1991 [11], and represents an appropriate way to investigate UA during pharmacologically induced sleep. The procedure allows the visualization of the site of obstruction and the assessment of UA collapse pattern in a dynamic mode during sedation [12]. DISE is considered as the gold standard to optimize OSAS patient selection for surgical UA interventions and can also be helpful in selecting patients for oral appliance therapy [13]. Due to the monetary and logistic efforts, it is questionable whether this procedure might be used as a routine diagnostic tool.

Few studies have been conducted on simulated snoring (SS) through the nose or mouth [14]. Dalmasso and Prota [15], analyzing the UA during SS with the Linear Prediction Code method and with simultaneous fluoroscopy, identified three snoring patterns: nasal, oral and oro-nasal. Herzog et colleagues in 2006 [16] introduced the snoring endoscopy (SE), an endoscopic examination of UA during SS through the mouth in awake patients. They found that the patients with a high degree of pharyngeal collapse at the level of the tongue base, in combination with dorsal movement of the tongue base during SS through the mouth, revealed a probability of 75 % to have an apnea–hypopnea index (AHI) more than 10, and of 92 % for an AHI more than 5 [16]. These findings shed new light on the endoscopic examination of UA during SE in awake patients, as it could represent a promising diagnostic tool in patients with suspected OSAS. The association between SE and DISE findings has not yet been investigated. To the best of our knowledge, there are no previous studies on SE with simulated snoring through the nose.

In the present investigation, we studied 20 consecutive patients (simple snorers and OSAS patients) with FNMM, nasal snoring endoscopy (NSE), oral snoring endoscopy (OSE), and DISE. The aim was to investigate if any of the three awake procedures (FNMM, NSE, or OSE) could efficiently predict the grade or pattern of UA collapse found with DISE, the current gold standard in optimizing OSAS patient selection for surgical UA interventions.

Materials and methods

Patients

The present investigation was approved by our Otolaryngology Section's ethical committee. Twenty consecutive patients (18 men, 2 women) who had to be studied with DISE for OSAS or for simple snoring at the Neurosciences Department, Otolaryngology Section of Padova University, were included. All included patients were able to produce the forced inspiratory suction required for the MM, and to simulate snoring sounds through the nose and the mouth in awake conditions.

All patients were evaluated with home-based sleep studies, before being included in the study. The documented parameters were airflow, respiratory effort, oxygen saturation, body position, and ECG. All home tests produced technically satisfactory results. Therefore, a hospital-based PSG was not needed [3], and the diagnosis of simple snoring or OSAS was established according to the AHI calculated from the home-based sleep studies as follows: simple snoring, AHI <5; mild OSAS, $5 \leq$ AHI < 15; moderate OSAS, $15 \leq$ AHI < 30; severe OSAS, AHI ≥ 30. Five patients were classified as simple snorers, three had mild OSAS, six moderate OSAS, and six severe OSAS. The mean AHI was 20.8/h (median 21.0/h, SD 16.0/h).

Clinical examination

A regular ENT examination in sitting position was performed. The size of the tonsils was classified into 4° according to the intertonsillar distance: grade 1, no tonsil; grade 2, tonsils covered 0–33 % of the intertonsillar distance; grade 3, tonsils covered 33–66 % of the intertonsillar distance; grade 4, tonsils covered 66–100 % of the intertonsillar distance. The Mallampati/Friedmann index

was used to classify the position of the tongue in the oral cavity, according to the visibility of the uvula and palate: grade 1, uvula was completely visible; grade 2, uvula was partly visible; grade 3, only soft palate was visible; grade 4, only hard palate was visible. For each patient, BMI and Epworth Sleepiness Scale (ESS) score were calculated.

Endoscopic UA examinations: FNMM, NSE, OSE, and DISE

The endoscopic examinations were performed in a semi-dark and silent operating room with the patient lying supine. The fiber laryngoscope (Olympus ENF-GP, diameter 3.7 mm, Olympus Europe GmbH, Hamburg, Germany), connected to a high-resolution video system (Karl Storz Endovision TRICAM, Tuttlingen, Germany), was introduced through the nose to assess the UA.

For the FNMM, patients were asked to produce a forced inspiratory suction with mouth and nose closed. Then patients were instructed to produce snoring sounds through the nose for NSE, and through an open mouth for OSE.

The DISE was carried out with the collaboration of an anesthetist who was responsible for the infusion of the drug. With patient lying in supine position, the light was dimmed, and artificial sleep was induced by propofol using a TCI target-controlled infusion pump (TE-371, Terumo, Japan). The depth of sedation was monitored by means of bispectral (BIS) index monitor (A-2000 BIS Monitor, Aspect Medical Systems, MA). The sedation of the patient was achieved in 3–4 min, and a constant depth of sleep as monitored by the BIS values was maintained. During the procedure, ECG and oxygen saturation were continuously monitored. Usually, snoring began within 5–10 min, and obstructive episodes could be observed.

Grade and pattern of UA collapse were evaluated, for each of the four tests, at the velopharyngeal, oropharyngeal and hypopharyngeal level. The grade of UA collapse was classified as suggested by Croft and Pringle [11]: grade 1, minimal collapse; grade 2, <50 % collapse; grade 3, >50 % collapse; grade 4, 100 % collapse. The different patterns of collapse were also defined as: transversal, if a movement of the lateral pharyngeal walls towards the center of the airway was identified; anterior–posterior, if a collapse towards the posterior pharyngeal wall was detected; concentric, if a combination of lateral plus anterior–posterior pharyngeal walls collapse pattern was visualized.

Statistical analysis

Cohen's kappa coefficient (κ) was used to evaluate the inter-test agreement between the awake endoscopic examinations (FNMM, NSE, and OSE) and DISE. It was calculated for grade and pattern of collapse in the three sub-sites considered (velopharynx, oropharynx, and hypopharynx). Cohen's kappa coefficient is thought to be a more robust measure than simple percent agreement calculation, since it takes into account the agreement occurring by chance. For each κ value, a p value was calculated: if a non-significant p value was obtained, the inter-test agreement had to be attributed to chance. The κ agreement was measured, with a scale proposed by Landis and Koch [17], as follows: $\kappa < 0.0$, poor agreement; $0.0 < \kappa \leq 0.20$, slight; $0.20 < \kappa \leq 0.40$, fair; $0.40 < \kappa \leq 0.60$, moderate; $0.60 < \kappa \leq 0.80$, substantial; $0.80 < \kappa < 1.00$, almost perfect agreement.

Fisher exact test was used to confront UA collapse grade with clinical parameters (Mallampati/Friedmann index, tonsil size), BMI, ESS score, and AHI.

A p value <0.05 was considered significant, while values in the range of $0.07 \geq p \geq 0.05$ were assumed to indicate a statistical trend. The STATA^{TM} 8.1 (Stata Corp, College Station, TX, USA) statistical package was used for all analyses.

When required, the continuous quantitative variables were dichotomized using the median values: BMI ($\leq$27.1 vs. >27.1); ESS score ($\leq$9 vs. >9); AHI ($\leq$21 vs. >21). The other dichotomized variables were: Mallampati/Friedmann index (grade 1–3 vs. grade 4); tonsil size (grade 1–3 vs. grade 4); grade of collapse at velopharyngeal level (grade 1–3 vs. grade 4); grade of collapse at oro- and hypopharyngeal level (grade 1–2 vs. grade 3–4).

Results

Patients and clinical examination

The mean age of the 20 included patients was 50.8 years (median 51 years, SD 18.2 years). The mean BMI was 26.8 kg/m^2 (median 27.1 kg/m^2, SD 3.0 kg/m^2). ESS score was calculated for each patient and the mean value was 8.5 (median 9, SD 5.1).

At clinical examination Mallampati/Friedmann index was grade 2 in 6 patients, grade 3 in 3, and grade 4 in 11. Tonsil size was grade 1 in 7 patients, grade 2 in 7, and grade 4 in 6.

All patients were able to produce a valid forced inspiratory suction for the MM and to simulate snoring sounds through the nose and the mouth in awake conditions.

FNMM, NSE, OSE, and DISE: inter-test agreement

The grade and pattern of UA collapse at the different pharyngeal levels, obtained with each endoscopic examination, were reported in Table 1.

Table 1 Grade and pattern of collapse obtained with the 4 endoscopic examinations at the different pharyngeal levels

	Velopharynx				Oropharynx				Hypopharynx			
	FNMM	NSE	OSE	DISE	FNMM	NSE	OSE	DISE	FNMM	NSE	OSE	DISE
Grade												
1	1	1	1	0	1	2	2	2	5	3	3	0
2	2	1	1	2	8	7	10	4	7	7	11	5
3	12	9	7	4	7	9	7	7	8	10	5	5
4	5	9	11	14	4	2	1	7	0	0	1	10
Pattern												
AP	4	6	13	6	0	2	5	3	3	5	6	9
T	7	3	2	0	18	11	11	12	13	10	9	6
C	9	11	5	14	2	7	4	5	4	5	5	5

AP anterior-posterior, *C* concentric, *DISE* drug-induced sleep endoscopy, *FNMM* fiberoptic nasopharyngoscopy with modified Müller Maneuver, *NSE* nasal snoring endoscopy, *OSE* oral snoring endoscopy, *T* transversal

Table 2 Inter-test agreement [evaluated with Cohen's kappa coefficient (κ) and p value] at the different pharyngeal levels

	κ value	p value
FNMM vs. DISE		
Velop		
Grade	0.42	0.09
Pattern	0.01	0.13
Orop		
Grade	0.50	**0.008**
Pattern	0.31	**0.009**
Hypop		
Grade	0.13	0.27
Pattern	0.2	0.06
NSE vs. DISE		
Velop		
Grade	0.32	**0.04**
Pattern	0.52	**0.001**
Orop		
Grade	0.47	**0.01**
Pattern	0.47	**0.003**
Hypop		
Grade	0.3	0.06
Pattern	0.63	**<0.00001**
OSE vs. DISE		
Velop		
Grade	0.27	0.1
Pattern	0.20	0.07
Orop		
Grade	0.26	0.08
Pattern	0.82	**<0.00001**
Hypop		
Grade	0.08	0.28
Pattern	0.55	**0.0002**

Significant p values are in bold

DISE drug-induced sleep endoscopy, *FNMM* fiberoptic nasopharyngoscopy with modified Müller Maneuver, *Hypop* hypopharynx, *NSE* nasal snoring endoscopy, *Orop* oropharynx, *OSE* oral snoring endoscopy, *Velop* velopharynx

As previously described, we evaluated the inter-test agreement confronting the awake tests (FNMM, NSE, and OSE) with DISE. The Cohen's kappa values and p values were reported in Table 2. As explained, a non-significant p value meant that the agreement had to be attributed to chance.

Comparing the grade of collapse, we found a significant moderate agreement at oropharyngeal level for FNMM ($\kappa = 0.50, p = 0.008$), and for NSE ($\kappa = 0.47, p = 0.01$) as opposed to DISE. No significant grade agreement was found confronting OSE and DISE in the present patients series.

Considering the pattern of collapse, NSE and OSE had better agreement with DISE than FNMM in our case series. A significant pattern agreement between NSE and DISE was present in all sub-sites in the current series, and it can be measured with the scale proposed by Landis and Koch as follows: moderate in velo- and oropharynx ($\kappa = 0.52$, $p = 0.001$, and $\kappa = 0.47$, $p = 0.003$, respectively), and substantial in hypopharynx ($\kappa = 0.63$, $p < 0.00001$). Comparing OSE with DISE, the pattern agreement was almost perfect at oropharyngeal level ($\kappa = 0.82$, $p < 0.00001$), and moderate at hypopharyngeal level ($\kappa = 0.55$, $p = 0.0002$), while a trend towards significance was found at velopharyngeal level ($\kappa = 0.20$, $p = 0.07$). FNMM had a fair pattern agreement with DISE only in oropharynx ($\kappa = 0.31$, $p = 0.009$), while in the other sub-sites no significant agreement was found.

Clinical parameters, BMI, ESS score, AHI, and grade of collapse

Fisher's exact test ruled out any significant association in the present patients series between clinical parameters (Mallampati/Friedmann index and tonsil size) and grade of UA collapse in all the sub-sites considered in the four tests (FNMM, NSE, OSE, and DISE).

A high grade of UA collapse, disclosed with NSE in the oropharynx, was significantly associated with a BMI >27.1

in the current series (Fisher's exact test, $p = 0.005$). BMI >27.1 was found also associated with high grade of collapse at hypopharyngeal level with DISE (Fisher's exact test, $p = 0.033$). No other significant differences in BMI were found in our series.

In the present patient series, we found that ESS score >9 was significantly associated with high grade of collapse in the velopharynx with FNMM (Fisher's exact test, $p = 0.005$). A trend towards a significant association was also found between ESS score and grade at hypopharyngeal level with NSE (Fisher's exact test, $p = 0.07$). No other significant associations were discovered between ESS score and grade of collapse in the other sub-sites or with the other examinations.

A trend towards significant association was disclosed between AHI >21 and higher grade of collapse with NSE at velopharyngeal and oropharyngeal levels (Fisher's exact test, $p = 0.07$ and $p = 0.07$, respectively). No other significant associations were discovered between AHI and grade of collapse in the other sub-sites or with the other examinations in our case series.

Discussion

In OSAS patients, the most frequent sites of pharyngeal collapses are soft palate, lateral pharyngeal walls, and base of the tongue. Frequently, UA collapse occurs at the same time at different section levels. The identification of the site and of the dynamic pattern of obstruction is mandatory in therapeutical decision-making [18]. Several authors have used FNMM to evaluate UA in OSAS patients, but Pringle and Croft [19], comparing FNMM with DISE in patients suffering from OSAS, were the first that found a poor correlation between the two tests, and they suggested MM to be less accurate than previously believed. Also Campanini et colleagues [20], comparing the results of the two in 250 cases, disclosed discrepancies involving the oropharyngeal and hypopharyngeal sites, respectively, in about 33 and 50 % of the patients. In fact, pharyngeal collapse at FNMM is believed to depend mostly on patient inspiratory effort, and the role of FNMM in predicting the effectiveness of UA surgery is still controversial [10].

On the contrary, several studies have demonstrated the validity [21] and reliability [22] of DISE, and this is considered by many authors as the gold standard test for characterizing the pattern of UA obstruction in OSAS patient. Unfortunately, this way of investigation requires important logistical and financial efforts to obtain information about the site of obstruction. Besides that, DISE has a potential risk of anesthetic side effects, especially in patients with cardiorespiratory diseases. The ideal test for OSAS patients should be easy to perform in an out-patient setting, should identify the sites and pattern of UA collapse and correlate with effectiveness of OSAS therapy.

Recently, Herzog et colleagues [16] proposed to endoscopic evaluate patients with suspected OSAS while they simulated to snore with open mouth. They found a significant correlation between an increased dorsal movement of the tongue base, as well as with pharyngeal collapse at the level of the tongue base during SS, and the AHI. The correlation was not present, in their case series, between AHI and FNMM, Mallampati/Friedmann index, or tonsil size [16]. Contrary to DISE, the endoscopic evaluation of the UA in awake patients during SE is an inexpensive test that can be conducted by most ENT specialists in private practice. The principal advantage of snoring endoscopy seems to be that it is a dynamic evaluation of UA behavior during SS. Furthermore, the frequency analysis of snoring sound revealed similarity between awake oral SS and rhythmic nocturnal snoring [23], suggesting there might be a common UA behavior during simulated and nocturnal snoring.

In the present study, we examined 20 consecutive patients (simple snorers and OSAS patients) with FNMM, NSE, OSE, and DISE. The purpose was to compare the awake tests (FNMM, NSE, and OSE) with the DISE, in terms of grade and pattern of UA collapse. We tested nasal and oral SS as OSAS patients could snore either with the nose or with open mouth during night time. All patients were able to produce snoring sounds through the nose and the mouth. The nasal SS was not easy to perform without proper instructions, as reported also by Perez-Padilla et colleagues [24], and several attempts (3–5) were needed before patients could produce proper nasal snoring. All examinations were performed with patients lying supine to mimic the natural sleeping position. The main limitations of our study are the restricted number and the non-homogeneity (simple snorers and OSAS) of cases considered.

In the current series, we found higher grades of UA collapse with DISE than with other endoscopic examinations, and thus the inter-test agreement for grade was not relevant. We found a moderate grade agreement between NSE and DISE at oropharyngeal level, comparable with that between FNMM and DISE at the same pharyngeal level. Furthermore, the grade of collapse with all the four tests was not associated with Mallampati/Friedmann index, and tonsil size, confirming the poor prognostic role of these clinical parameters.

Similar to what reported by Herzog et colleagues [16], we found a trend towards significant association between AHI and grade of collapse with NSE at velopharyngeal and oropharyngeal levels. We did not found such an association between grade of collapse with OSE and AHI, and we think this could be reasonably due to the limited number of patients considered in this investigation.

Another possible explanation might be that the scoring system used in the present study was different from the one adopted by Herzog et al. [16]. We used the scoring system adopted for DISE also for NSE and OSE. Several scoring systems have been introduced over the years, but a standard approach toward assessment and classification of DISE findings has not been universally accepted. Also, in a very recent European position paper, authors had not reached a consensus on the scoring and classification system [18]. Many authors use the Fujita classification in which UA obstruction is evaluated at velopharyngeal and at hypopharyngeal/retrolingual level. We instead preferred to score the oropharyngeal lateral walls separately from the hypopharyngeal region, as proposed also by Kezirian et al. [25].

Considering the pattern of collapse, NSE and OSE were better than FNMM in predicting the results of DISE in our case series. A significant inter-test agreement for pattern of collapse between NSE and DISE was present in all sub-sites, and it can be measured according to Landis and Koch scale [17] as moderate in velo- and oropharynx, and substantial in hypopharynx. Comparing OSE with DISE, the pattern agreement was almost perfect at oropharyngeal level, and moderate at hypopharyngeal level, while a trend towards significance was found at velopharyngeal level. FNMM showed a fair pattern agreement with DISE only at oropharyngeal level, while in the other sub-sites, no significant agreement was found.

A major goal for surgical evaluation in the treatment of snoring and OSAS is the determination of the site and pattern of airway obstruction in an individual patient to design targeted, effective treatment [26]. In the current series of simple snorers and OSAS patients, we found that NSE and OSE were better than FNMM in predicting the pattern of UA collapse found with DISE. Further investigations are needed to see if these new diagnostic tools could predict the effectiveness of UA surgery in OSAS patients.

Conflict of interest This was not an industry-supported study. The authors have no funding, financial relationships, or conflicts of interest to disclose.

Statement of human rights All procedures performed in the study were in accordance with the ethical standards of our Institutional research committee and with the 1964 Helsinki declaration and its later amendments.

Informed consent Informed consent was obtained from all individual participants included in the study.

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