Retropalatal Müller grade is associated with the severity of obstructive sleep apnea in non-obese Asian patients

Retropalatal Müller grade and OSA in non-obese

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Abstract

Purpose The aim of this study was to investigate whether physical evaluations could be used for predicting the presence and severity of obstructive sleep apnea (OSA) in non-obese snoring patients.

This work was performed at the National Taiwan University Hospital.

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Methods This is a retrospective study, and a total of 244 non-obese (body mass index, BMI, $<27 \text{ kg/m}^2$) snoring patients (178 men and 66 women; mean age = 43.1 ± 12.1 years) were included. Each patient underwent polysomnography and a thorough physical examination, including flexible nasopharyngoscopy and Müller maneuver. Patients were divided into four groups based on apnea–hypopnea index (AHI) scores: normal (simple snoring), $\text{AHI} < 5$; mild OSA, $5 \leq \text{AHI} < 15$; moderate OSA, $15 \leq \text{AHI} < 30$; severe OSA, $\text{AHI} \geq 30$. Logistic regression was used to identify risk factors for OSA severity. **Results** Fifty-nine patients (24%) were simple snorers. The prevalence of sleep apnea (mild, moderate, or severe OSA) for our non-obese snoring patients was 76%. Univariate logistic analyses showed that higher BMI, male gender and retropalatal Müller grades were significantly associated with OSA severity. Multivariate logistic regression analysis identified male gender and retropalatal Müller grade as risk factors for OSA in non-obese snoring patients.

Conclusions Physical examination may be useful for studying the upper airway in non-obese snoring patients. Flexible nasopharyngoscopy with Müller maneuver appears to be useful for evaluating the severity of OSA in non-obese patients. Retropalatal Müller grade is highly related to both the presence and severity of OSA, particularly in males.

Keywords Apnea–hypopnea scale · Body mass index · Obstructive sleep apnea · Upper airway · Müller maneuver · Airway collapsibility

Introduction

Snoring is a major symptom of obstructive sleep apnea (OSA) and may be the main reason why patients with

OSA seek medical evaluation. Patients may be simple snorers, but also have OSA. OSA patients have a high risk of developing cardiovascular and cerebrovascular disease [1].

Obesity is the most important risk factor for OSA [2]. However, OSA has become more apparent among the less obese [3]. Research performed at a single large sleep clinic in Edinburgh revealed that 50% of patients with OSA were in fact non-obese [4]. Significant exacerbations of OSA occurred in patients who were not actively treated [5], emphasizing the importance of early diagnosis and active treatment even for mild OSA.

The significance of a patient's history for predicting OSA is controversial. Pouliot et al. proposed that the Epworth Sleepiness Scale score could be used to predict OSA [6]. However; others have found no predictive value in subjectively reported daytime sleepiness in patients with OSA compared to simple snorers [7, 8]. Questionnaires regarding daytime sleepiness, fatigue and reported apnea were not able to distinguish between simple snorers and individuals with OSA [9].

Pharyngeal changes, such as redundant soft palate, elongated uvula, enlarged tonsils, and oropharyngeal crowding have been reported to be associated with OSA in obese individuals [10]. However, precise physical anatomical alterations associated with OSA in non-obese adults have not been clearly established. Although polysomnography (PSG) is the standard procedure used to diagnose OSA, it is expensive and labor intensive. Use of endoscopy with Müller maneuver (MM) in the supine position has been found to reveal significant differences between snorers and non-snorers and provides a simple, inexpensive means of predicting OSA in patients who snore, regardless of weight [11]. Given this finding, we hypothesized that flexible nasopharyngoscopy with MM (FNMM) could also be used to predict OSA even in non-obese snoring patients.

No single factor has been identified to successfully predict OSA in the clinical setting [12]. Given that there are increasing numbers of non-obese patients with sleep-disordered breathing problems, it would be of benefit if a specific physical examination could be performed to accurately predict OSA. Despite a strong association between obesity and OSA, body mass index (BMI) does not consistently correlate with the severity of OSA as measured by the apnea–hypopnea index (AHI) [13]. In the present study, we evaluated OSA among non-obese patients and examined several clinical variables, including tonsil size, retroglossal and retropalatal size, and redundancy of uvula and soft palate, in an attempt to identify clinical risk factors for OSA before PSG testing.

Methods and materials

Patient selection

We retrospectively reviewed the medical records of consecutive patients who visited the National Taiwan University Hospital otolaryngology clinic with a chief complaint of snoring (53% had daytime sleepiness and 32% had witnessed sleep apnea) from 2004 to 2006. Obese patients ($\text{BMI} \geq 27$) were excluded from the study based on guidelines of the Taiwan Department of Health (http://www.doh.gov.tw/CHT2006/DM/SEARCH_RESULT.aspx).

Other exclusion criteria included abnormal lung function, such as a prescription for continuous positive airway pressure, severe cardiac failure responsible for Cheynes–Stokes breathing, upper airway neoplasm, acute rhinitis resulting in nasal obstruction at the time of the study, and central sleep apnea. A total of 244 patients met the inclusion criteria and were enrolled. Each of these patients had undergone both a thorough otolaryngological evaluation and a polysomnographic analysis (described below). This study was approved by the institutional internal review board.

Polysomnography and AHI

PSG included modified electroencephalogram (EEG) monitoring, a bilateral electrooculogram and submental, intercostal, and anterior tibialis electromyograms. Airflow was monitored by oral and nasal thermistors. Respiratory effort was monitored with chest wall and abdominal piezoelectric bands and intercostal electromyography. Cardiac monitoring was performed by modified V1 telemetry while continuous oxygen saturation was monitored by pulse oximetry. Obstructive apnea was defined as the total cessation of airflow for ≥ 10 s with continued respiratory effort. Obstructive hypopnea was defined as an event lasting ≥ 10 s that was associated with two of the following: a decrease in airflow of 50%, an EEG arousal or oxygen desaturation $\geq 4\%$. AHI was defined as the number of apneic and hypopneic events per hour of sleep.

Clinical evaluations

A complete physical examination was followed by a nose and throat examination in the sitting position, including anterior rhinoscopy, oropharyngeal evaluation and flexible nasopharyngoscopy. Nasal speculum examinations were performed with the head tilted slightly backwards to assess septal deviation, turbinate hypertrophy, nasal polyps, other masses and internal nasal pathways. The oropharyngeal evaluation included oropharyngeal crowding, tonsil size and redundancy of the uvula and soft palate. This was performed with the patients' mouths widely opened and

tongues relaxed without phonation. Tonsil size and redundancy of the uvula and soft palate were graded. Oropharyngeal crowding was determined with respect to modified Mallampati classification (MMP). Details regarding the grading of MMP, tonsils size, and redundancy of the uvula and soft palate are summarized in Table 1. Weight (kilograms, with all heavy clothing removed) was measured using digital scales (Hanson, Watford, Hertfordshire, United Kingdom). Barefoot height (meters) was measured using a portable stadiometer (Holtain, Crymmych, Wales). BMI was calculated as weight (kg)/height² (m²).

Flexible nasopharyngoscopy with Müller maneuver (FNMM)

Patients were examined in the sitting position using a flexible nasopharyngoscope (OLYMPUS ENF Type V, Lake Success, NY) with the pharynx in both relaxed and active states [14]. “Relaxed” was defined as normal breathing status. “Active” was defined as, with the mouth closed, the patient vigorously inhaled while an examiner occluded the nostrils. Images were recorded by computer. The FNMM procedure is summarized in Table 2. All patients were examined by the same physician (Dr. Tan).

Table 1 also summarizes retroglossal and retropalatal area sizes and Müller grading. Retroglossal and retropalatal area sizes were graded in accordance with previous reports [15, 16]. The degrees of retroglossal and retropalatal obstructions by airway collapse when patients performed MM were calculated by computer-assisted area measurement, and used for grading retroglossal Müller and retropalatal Müller (Figs. 1 and 2). Firstly, we calculated the cross-sectional area of the retroglossal level when it was in relaxed status (Ar). Then, we calculated the same level cross-sectional area when in active status (Aa). The retroglossal Müller grade was calculated by the formula: $(Ar - Aa)/Ar \times 100\%$. The same method was repeated to obtain the retropalatal Müller grade. The grades in Table 1 refer to these calculated values for diminished cross-sectional areas.

Statistical analysis

Results for continuous variables are given as means $\pm$ standard deviation, and categorical variables are given as number (*n*) and percentage (%). In order to make comparisons between patients with varying degrees of disease severity, patients were divided into two groups based on different treatment modalities [11]. The early stage OSA group comprised patients who exhibited simple snoring and mild OSA and were kept under close observation. Patients in the advanced stage group included those with moderate and severe OSA who potentially required immediate, aggressive treatment. Continuous

Table 1 Grading systems used during physical examination

Grade	
MMP grading	
1	Soft palate, pillars, and tonsils were clearly visible
2	Uvula, pillars, and upper poles of tonsils were visible
3	Only part of the soft palate was visible; the tonsils, pillars, and base of the uvula could not be seen
4	Only the hard palate was visible
Tonsil size grading	
0	Patient had undergone tonsillectomy
1	Tonsils were in the tonsillar fossa, barely seen behind the anterior pillars
2	Tonsils were visible behind the anterior pillars
3	Tonsils extended three quarters of the way to the midline
4	Tonsils were completely obstructing the airway (“kissing” tonsils)
Redundancy of uvula and soft palate grading	
0	Not redundant
1	Slightly redundant
2	Markedly redundant
Retroglossal size grading	
1	Normal: allows visualization of the larynx
2	Small: allows visualization of a portion of the vocal folds
3	Very small: allows only a view of the posterior arytenoid
4	Obstructed: apposition of the tongue base or epiglottis to the posterior pharyngeal wall
Retropalatal size grading	
1	Normal: widely patent and may allow visualization of the oropharynx
2	Small: limits view of the pharynx, but opposing walls are not in proximity
3	Very small: constricted with opposing walls approaching contact
4	Obstructed: apposition of opposing walls
Retroglossal and retropalatal Müller grading	
0	Diminishing cross-sectional area less than 25%
1	Diminishing cross-sectional area between 25% to 50%
2	Diminishing cross-sectional area between 50% to 75%
3	Diminishing cross-sectional area more than 75%

variables were compared between groups (early and advanced stage OSA) by independent two-sample *t* tests. Corresponding categorical variables were compared by Chi-square or Fisher’s exact test. Logistic regression analysis (univariate and then multivariate) was used to identify risk factors for OSA severity. A receiver operating characteristic (ROC) curve was generated to assess sensitivity and specificity. All statistical assessments were two-sided and evaluated at the 0.05 level of significance using SPSS 15.0 statistical software (SPSS Inc, Chicago, IL).

Table 2 FNMM procedures

1. Introduced the scope via transnasal route to the level of the epiglottis
All portions of the larynx and pharynx were examined for pathology
2. Withdraw the scope to a position where the tip was in the lower oropharynx to examine the retroglossal area size
3. Asked the patient to perform MM. Firstly, inhaled and exhaled three times, then, with the mouth closed, vigorously inhaled while an examiner occluded the nostrils
Noted any tendency for the lower pharyngeal airway to collapse by motion of the tongue in a posterior direction and/or the lateral walls in a medial direction
4. Observed the supraglottic larynx for collapse over the laryngeal inlet in patients whose pharynx remained patent
5. Retracted the scope to locate the tip in the nasopharynx just cephalad and posterior to the nasopharyngeal surface of the soft palate
Observed the size of the area surrounded by the soft palate and the junction of the nasopharynx and oropharynx. We defined this as the retropalatal area
6. Repeated MM three times and evaluated the degree of airway obstruction

Results

A total of 244 patients who underwent PSG were enrolled. The demographic characteristics of these patients are summarized in Table 3 with respect to whether they had early or advanced stage OSA. For these comparisons, early stage OSA was defined as $AHI < 15$, while advanced stage OSA was defined as $AHI \geq 15$. These categories were based on the International Classification of Sleep Disorders [17], which reflect different risks for cardiovascular disease and needs for treatment interventions. There were significant differences between these groups for BMI, height, weight, gender, and retropalatal Müller. Advanced stage OSA patients were significantly heavier ($P < 0.001$) and had greater retropalatal Müller severity ($P < 0.001$).

Patients were further classified into four groups with respect to OSA severity based on AHI scores: normal (simple snoring), $AHI < 5$; mild OSA, $5 \leq AHI < 15$; moderate OSA, $15 \leq AHI < 30$; and severe OSA, $AHI \geq 30$ [16].

Fig. 1 Image from a representative patient showing the retropalatal area in relaxed status. Size grading, 1

Fifty-nine patients (24%) were simple snorers. Thus, the prevalence of sleep apnea (mild, moderate or severe OSA) in our non-obese snoring patients was 76% (185/244).

Univariate logistic regression analysis showed that BMI and retropalatal Müller grades were significantly associated with OSA severity in male patients; however, no factors were associated with OSA severity in females (Table 4). Subsequent multivariate logistic regression analysis identified BMI and retropalatal Müller grades as significant risk factors for developing advanced stage OSA in male patients. After controlling for retropalatal Müller, males with higher BMI were significantly more likely to have advanced OSA than those with lower BMI. Moreover, after controlling for BMI, male patients with retropalatal Müller grades of 2 and 3 were significantly

Fig. 2 Image from the same patient in Fig. 1 showing the retropalatal area in active status. Using digital image recording and computer-assisted area calculation indicated that 18.03% of the cross-sectional area remained patent. The cross-sectional area diminished by 81.97%. Retropalatal Müller grading, 3

Table 3 Summary of demographic variables for patients with early and advanced stage obstructive sleep apnea (OSA, n=244)

	Total (n=244)	Early OSA (n=123)	Advanced OSA (n=121)	P value
Age (years) ^a	43.1±12.10	41.6±11.57	44.6±12.48	0.055
BMI (kg/m ²) ^a	23.5±2.35	22.9±2.32	24.2±2.21	<0.001*
Height (cm) ^a	167.4±8.06	165.8±8.67	169.1±7.05	0.001*
Weight (kg) ^a	66.2±10.02	63.3±10.19	69.2±8.93	<0.001*
Gender (n (%)) ^b				
Male	178 (73.0%)	71 (57.7%)	107 (88.4%)	<0.001*
Female	66 (27.0%)	52 (42.3%)	14 (11.6%)	
MMP (n (%)) ^{b, d}				
1	19 (7.9%)	10 (8.3%)	9 (7.5%)	
2	115 (47.7%)	66 (54.5%)	49 (40.8%)	0.088
3	90 (37.3%)	40 (33.1%)	50 (41.7%)	
4	17 (7.1%)	5 (4.1%)	12 (10.0%)	
Tonsil size (n (%)) ^{c, d}				
0	10 (4.2%)	7 (5.7%)	3 (2.5%)	
1	167 (69.6%)	87 (71.3%)	80 (67.8%)	0.116
2	59 (24.6%)	28 (23.0%)	31 (26.3%)	
3	4 (1.7%)	0 (0.0%)	4 (3.4%)	
Redundancy of uvula and soft palate (n (%)) ^{b, d}				
0	35 (14.6%)	22 (18.2%)	13 (11.0%)	
1	47 (19.7%)	27 (22.3%)	20 (16.9%)	0.111
2	157 (65.7%)	72 (59.5%)	85 (72.0%)	
Retroglossal size (n (%)) ^{c, d}				
1	126 (52.3%)	69 (56.6%)	57 (47.9%)	
2	106 (44.0%)	50 (41.0%)	56 (47.1%)	0.311
3	9 (3.7%)	3 (2.5%)	6 (5.0%)	
Retropalatal size (n (%)) ^{b, d}				
1	145 (60.2%)	70 (57.4%)	75 (63.0%)	
2	79 (32.8%)	43 (35.2%)	36 (30.3%)	0.666
3	17 (7.1%)	9 (7.4%)	8 (6.7%)	
Retroglossal Müller (n (%)) ^{c, d}				
0	129 (53.5%)	71 (58.2%)	58 (48.7%)	
1	66 (27.4%)	25 (20.5%)	41 (34.5%)	0.096
2	42 (17.4%)	24 (19.7%)	18 (15.1%)	
3	4 (1.7%)	2 (1.6%)	2 (1.7%)	
Retropalatal Müller (n (%)) ^{b, d}				
0	23 (9.5%)	18 (14.8%)	5 (4.2%)	
1	50 (20.7%)	33 (27.0%)	17 (14.3%)	<0.001*
2	78 (32.4%)	40 (32.8%)	38 (31.9%)	
3	90 (37.3%)	31 (25.4%)	59 (49.6%)	

Results are means±standard deviations or numbers (percentages)

BMI body mass index, MMP modified Mallampati classification

* $P<0.05$, indicates a significant between group difference for a given variable

^aIndependent two-sample *t* test

^bChi-square

^cFisher's exact test

^dIndicates that there were missing values for this variable

more likely to have advanced OSA than those with grades of 0 and 1 (OR, 2.48; 95% CI, 1.24 and 4.98; $P=0.010$) (Table 5).

The ROC curve for non-obese male patients for developing advanced stage OSA is shown in Fig. 3. The area under the curve was 0.67 ($P<0.001$; 95% CI=0.60 to 0.76). When the probability was greater than 0.60, advanced stage OSA was predicted with a sensitivity of 72.6% and specificity of 57.7%.

Discussion

It has been estimated that the prevalence of OSA in middle-aged men and women is 4% and 2%, respectively [18]. This increases markedly to 20% to 40% in obese individuals [19]. Obesity is the most important factor for provoking disease in many adults with OSA [2, 20]. Indeed, significant differences in BMI have been found between snoring and non-snoring individuals [11]. Ko and

Table 4 Univariate logistic regression analysis of risk factors for developing advanced stage OSA by gender

	Male (n=178)		Female (n=66)	
	OR (95% CI)	P value	OR (95% CI)	P value
Age (years)	2.02 (0.10, 1.05)	0.109	1.04 (0.98, 1.09)	0.196
BMI (kg/m ²)	1.24 (1.05, 1.45)	0.009*	1.03 (0.82, 1.29)	0.805
MMP				
1	1.00		1.00	
2	0.90 (0.30, 2.68)	0.844	0.65 (0.06, 7.64)	0.734
3	2.19 (0.69, 6.92)	0.183	0.68 (0.06, 8.00)	0.761
4	4.38 (0.71, 27.16)	0.113	2.00 (0.11, 35.81)	0.638
Tonsil size				
0	1.00		1.00	
1	3.04 (0.54, 17.30)	0.209	0.73 (0.07, 7.80)	0.732
2	2.76 (0.46, 16.51)	0.265	0.86 (0.06, 13.48)	0.857
3	Indeterminate	0.999	–	
Redundancy of uvula and soft palate				
0	1.00		1.00	
1	1.18 (0.37, 3.73)	0.782	0.93 (0.16, 5.45)	0.935
2	1.43 (0.54, 3.78)	1.433	1.32 (0.29, 5.99)	0.720
Retroglossal size				
1	1.00		1.00	
2	1.56 (0.83, 2.93)	0.165	2.25 (0.61, 8.27)	0.222
3	2.49 (0.48, 12.96)	0.278	Indeterminate	1.000
Retropalatal size				
1	1.00		1.00	
2	1.05 (0.55, 2.03)	0.876	0.27 (0.05, 1.36)	0.112
3	1.02 (0.27, 3.83)	0.973	1.11 (0.18, 6.78)	0.909
Retroglossal Müller				
0	1.00		1.00	
1	1.64 (0.80, 3.36)	0.174	1.46 (0.32, 6.64)	0.626
2	0.74 (0.33, 1.63)	0.449	0.556 (0.06, 5.11)	0.556
3	1.47 (0.13, 16.84)	0.757	Indeterminate	
Retropalatal Müller				
0	1.00		1.00	
1	1.67 (0.47, 5.96)	0.432	Indeterminate	
2	2.87 (0.87, 9.51)	0.085	Indeterminate	
3	5.3 (1.61, 17.43)	0.006*	Indeterminate	

Results are ORs and CIs

OR odds ratio, CI confidence interval

* $P < 0.05$, indicates a significant risk factor

Su found that patients with a high BMI (>27) had a higher respiratory disturbance index (RDI) and more severe OSA than individuals with lower BMI (<27) [11]. The mean BMI in our advanced stage OSA group was significantly higher than that in the early stage group. Thus, it would appear that BMI also affects the presence and severity of OSA in non-obese snorers.

Importantly, our study of non-obese snoring patients revealed that only around 24% of the cohort was simple snorers, while the majority of patients had definite OSA. This finding is compatible with a previous report noting that healthy patients with very low BMI can still have OSA [10]. What we have found for the relatively high prevalence

of OSA among non-obese snorers in our study was that BMI was a relatively less important factor contributing to OSA, at least among males. One possible reason why the study revealed a high prevalence of sleep apnea in non-obese snoring patients might be that patients would come to a tertiary hospital only when they thought their health problem is significant.

Predisposing factors for OSA can be divided into anatomical and physical categories. Anatomically, it has been reported that the most common site of obstruction in OSA is at the level of the oropharynx [21]. Any upper airway structural abnormality may affect airway size, leading to OSA. It has been reported that OSA patients

Table 5 Multivariate logistic regression analysis of risk factors for developing advanced stage OSA in male patients

	OR (95% CI)	P value
BMI (kg/m ²)	1.21 (1.02, 1.42)	0.026*
Retropalatal Müller		
0 and 1	1.00	
2 and 3	2.48 (1.24, 4.98)	0.010*

Data are presented as ORs and CIs

OR odds ratio, CI confidence interval

* $P < 0.05$, indicates a significant risk factor

have structurally smaller airways than normal subjects and simple snorers [22]. Along the upper airway, the retropalatal and retroglossal areas are found to be the most frequent occlusive sites [23–25]. Friedman et al. created MMP to grade oropharyngeal crowding and found that MMP and tonsil size were highly predictive for the presence and severity of OSA [10]. Schellenberg et al. reported that oropharyngeal soft tissues, including the tonsils, soft palate, uvula and tongue, played an important role in mediating airway size [13]. Given these findings, uvulopalatopharyngoplasty (UPPP) should be of benefit for snoring patients with oropharyngeal structural abnormalities. However, Sher et al. reported that the overall success rate associated with UPPP was only 40.7% in unselected patients [26]. This suggests that the tonsils, soft palate, and uvula may not play important mediating roles in some snoring patients. Therefore, it was not unexpected that we found no significant differences between the early and advanced stage groups for any of these parameters.

Nasopharyngoscopic observation of the upper airway while performing MM in awake patients with OSA was first described by Borowiecki et al. [27]. OSA patients often have a positive MM manifested by collapse of the pharynx. Subsequent studies emphasized the utility of FNMM for differentiating OSA patients from simple snorers [9, 28, 29]. As for apnea, it is related to increasing upper airway collapsibility during sleep [30]. Even in asymptomatic snorers, greater degrees of airflow obstruction are observed with increasing levels of upper airway collapsibility [31]. No previous report, however, has focused on assessing upper airway collapsibility in non-obese snoring patients. Our findings indicate that only retropalatal Müller grade was significantly different between patients with early and advanced stage OSA. Thus, physical obstructive factors would appear to be more useful for predicting OSA in non-obese snorers.

Suratt and colleagues found that a narrow airway was more likely to collapse during sleep when there was a generalized decrease in muscle tone and concluded that the pharyngeal airway of awake sleep apnea patients was more

collapsible with a higher resistance than normal when sub-atmospheric pressure was applied [20]. The level of resistance was found to correlate with the severity of sleep-disordered breathing. In addition, Haponik et al. reported that upper airway alterations apparent during sleep in patients with OSA persisted during the daytime [32]. Furthermore, it has been found that the mechanism of obstruction observed in awake patients with OSA was similar to that observed during sleep [33]. In the present study, we examined patients awake during the daytime and found that endoscopic observation of the airway with MM was an effective, easily performed method to evaluate upper airway collapsibility and that FNMM predicted OSA in non-obese snorers.

In individuals with and without OSA, Walsh et al. found that the velopharynx (our retropalatal area) had the smallest cross-sectional area along the pharynx, and that the oropharynx (our retroglossal area) had the second smallest area [34]. Moreover, patients with OSA had a smaller than normal velopharyngeal cross-sectional area [35]. Retropalatal or retroglossal areas may be the most susceptible to collapse due to small areas. Ko and Su reported that the collapsing ratios of the retropalatal and retrolingual areas allowed for differentiation between snoring and non-snoring individuals, but that only the collapsing ratio of the retropalatal area was positively correlated with RDI (equivalent to AHI in our study) and OSA staging among snorers [11]. Our results indicate that retropalatal area collapsibility could be used to differentiate patients with early and advanced OSA. Thus, the retropalatal area may be critical for influencing the development of OSA, regardless of BMI, while the degree of collapsibility of this area would appear to be associated with OSA severity.

Fig. 3 Receiver operating curve (ROC) for non-obese male patients for developing advanced stage obstructive sleep apnea OSA

With regard to assessing OSA in our study, several methodological aspects warrant further discussion. Firstly, patient relaxation is important, especially for assessing the retropalatal area, as the size of this area is frequently underestimated when first introducing the flexible nasopharyngoscope due to patient nervousness. To obtain a more accurate retropalatal area size, we first evaluated the retroglossal area and then the retropalatal area. Secondly, FNMM should be performed by a skilled, experienced physician to obtain a fixed examination location between maneuvers. Third, it is important to utilize digital image recording and computer-assisted area calculation to increase the accuracy of assessment. In this study, we focused on non-obese patients; in these patients, the retropalatal airway is usually not compromised. So when performed FNMM, the percentage of retropalatal area change could be easily evaluated. Previous assessments of retropalatal collapsibility using these methods during Müller maneuver found high predictive power when patients were supine [35]. In this study, we were able to obtain good results when we evaluated patients in an erect position.

In summary, we found that OSA prevalence in non-obese snoring patients was surprisingly high (approximately 76%). Of concern, nearly half (49.4%) of these patients had advanced stage OSA and required aggressive treatments to prevent the development of more serious medical conditions. Not surprisingly, OSA prevalence and severity were much higher in males. Retropalatal Müller grade was found to be highly related to both the presence and severity of OSA. Our findings suggest that FNMM is an easy, fast and accurate means to assess retropalatal area collapsibility, and may be useful for determining OSA severity.

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