ORIGINAL RESEARCH—SLEEP MEDICINE

Rapid risk stratification for obstructive sleep apnea, based on snoring severity and body mass index

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OBJECTIVE: It is unclear whether all snoring patients require polysomnography, and there are no highly sensitive clinical predictors of sleep apnea. Our objective was to develop a simple clinical screening test for OSA in snoring patients.

STUDY DESIGN: Prospective, IRB-approved study at a university sleep disorders center.

SUBJECTS AND METHODS: In 211 patients undergoing polysomnography, snoring severity, Epworth sleepiness scale, body mass index, demographic, and sleep study data were collected. Receiver operating characteristic (ROC) analysis and Pearson correlation were used to develop a sensitive screening test for OSA.

RESULTS: Snoring severity score (SSS) and BMI were the two most accurate predictors of OSA on the ROC curve. A bipartite threshold of SSS = 4 or BMI = 26 carried sensitivity of 97.4%, specificity of 40%, positive predictive value of 82.3%, and negative predictive value of 84.2% for moderate/severe OSA. Patients at high risk were those with BMI $\geq$32 (89% PPV) or SSS $\geq$7 (92% PPV).

CONCLUSIONS: The statistic most predictive of OSA was snoring severity. Combining this with BMI yielded a highly sensitive screening test for moderate/severe OSA. This clinical assessment may be useful in risk-stratifying patients for polysomnography and therapy, facilitating deferred work-up in low-risk patients and expedited therapy in high-risk patients.

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Sleep disorders are commonly encountered by the otolaryngologist, with snoring affecting 44% of men and 28% of women, but obstructive sleep apnea (OSA) is only present in 4% of men and 2% of women.[1] Although the cardinal symptom of OSA is snoring, the great majority of snoring patients do not have sleep apnea.

It is not clear if all snorers require sleep studies. The standard work-up for these patients is nocturnal polysomnography (NPSG), which is the gold standard diagnostic test for OSA. This is a costly and labor-intensive procedure, but there are no reliable clinical predictors for OSA in snoring patients. For example, parameters such as age, gender, body mass index (BMI), Epworth Sleepiness Scale score, bed partner snoring evaluation, and Mallampati score are all correlated with OSA severity. However, none of these parameters are sufficiently sensitive to serve as a screening test.[2-5]

OSA is a treatable disease that carries significant cardiovascular morbidity. The objective of this study was to determine whether clinical parameters easily assessed during an office visit might permit risk stratification for snoring patients. The goal would be a highly sensitive and easily performed screening test that would identify patients at low risk and high risk for OSA. In low-risk patients, this might lead the clinician to defer expensive and time-consuming referral for NPSG. High-risk patients could be more effectively counseled about the likelihood of an OSA diagnosis and accordingly, sleep centers might consider performing split-night sleep studies on these patients, allowing titration to nasal continuous positive airway pressure (CPAP) immediately and avoiding a second sleep study. We report on the utility of combining one subjective (snoring severity) and one objective (BMI) measure into a screening test.

METHODS

Following approval by the Institutional Board of Research Associates at New York University School of Medicine, a prospective study was conducted of 225 consecutive patients referred to a university-affiliated sleep disorders center for evaluation of sleep-disordered breathing with NPSG. The only exclusion criteria were NPSGs performed for central sleep disorders (insomnia, narcolepsy), peripheral limb movement disorders, or CPAP titration; these criteria excluded 14 patients during the period of the study, leaving 211.

Prior to performance of the sleep study, data on the following clinical parameters were collected: age, gender, BMI, Epworth Sleepiness Scale (ESS), and Snoring Severity Scale (SSS). The ESS is a widely used questionnaire assessing daytime sleepiness. The SSS is a questionnaire

Figure 1 The Snoring Severity Scale (SSS) is a subjective three-question instrument.

completed by patients and their bed partners, which was initially developed by Lim and Curry[3] and has recently been modified and validated by our group[6] as a useful and reliable measure of snoring severity. The SSS is a three-question instrument that assesses snoring loudness, frequency, and duration (Fig 1). Even for patients without a bed partner, we were able to validate the questionnaire for patients who were able to answer the questions based on prior information from friends and family. We found the SSS to be internally consistent among patients, externally independent of age and gender, and externally valid, as it is highly correlated with respiratory disturbance index (RDI), apnea-hypopnea index, and ESS score. Nevertheless, this is a subjective, not objective, measure of snoring severity. Objective measures of snoring character (for example, via audio recording or sound level meter) would not meet our requirement that the screening test be easily performed during an office visit.

Polysomnography was performed in the standard fashion for all patients, with monitoring including electroencephalogram, electro-oculogram, submental electromyogram, electrocardiogram, thoracic and abdominal impedance plethysmography, and respiratory assessment via oral/nasal thermistors and pulse oximetry. Scoring was accomplished via the standard Rechtschaffen method. RDI was calculated as the sum of hourly apneas, hypopneas, and respiratory event–related arousals.

Patients were dichotomized into two groups: those with moderate-to-severe apnea (RDI ≥ 15) and those without apnea or only mild OSA (RDI <15). Pearson correlation and receiver operating characteristic (ROC) curves were used to evaluate independent variables for utility in predicting OSA. The ROC curve is a graphical plot of true-positive rate against false-positive rate using a binary classifier (presence or absence of OSA) of varying threshold. Statistical analysis was performed using SPSS v. 14.0 (SPSS, Chicago, IL).

These data were used to identify the factors most useful for risk-stratifying patients for OSA. Parameters and numerical thresholds were then determined for a highly sensitive screening test for the presence of moderate-to-severe OSA (RDI >15).

RESULTS

A total of 211 patients were included, with mean age of 47.5 years ($\pm$ 16.3), comprising 147 men and 64 women. Mean BMI was 30.2 ($\pm$ 5.9). Mean ESS score was 10.6 ($\pm$ 5.6) out of 24, and mean SSS score was 4.9 ($\pm$ 2.5) out of 9.

Ultimately, 175 patients (69.2%) were diagnosed with obstructive sleep apnea. Mean RDI among all 211 patients was 33.4 ($\pm$ 29.0). Mean apnea-hypopnea index was 21.4 ($\pm$ 26.9) and mean number of respiratory event–related arousals was 11.6 ($\pm$ 9.3).

Age did not correlate with RDI ($r = 0.12$, $P = 0.08$). However, BMI ($r = 0.40$), Epworth Sleepiness Scale score ($r = 0.45$), and Snoring Severity Scale score ($r = 0.50$) were all highly significantly correlated with RDI (all $P < 0.0001$). SSS also correlated significantly with both ESS ($r = 0.40$, $P < 0.0001$), and oxygen saturation nadir ($r = -0.35$, $P < 0.0001$). All demographic and correlative data are outlined in Table 1.

The three clinical parameters that significantly correlated with RDI were included in ROC analysis (Fig 2). The area under the ROC curve was highest for SSS score (0.82), followed by BMI (0.71) and ESS (0.69). Accordingly, SSS and BMI were chosen as the two optimal predictors of RDI.

Using a bipartite threshold of SSS = 4 or BMI = 26, a highly sensitive test was obtained. Sensitivity was 97.4%, specificity was 40%, and accuracy was 87.1%. Positive predictive value was 82.3%, and negative predictive value was 84.2%. The addition of ESS did not improve the sensitivity, specificity, or accuracy of this test. Because only a small number (n = 3) of OSA patients had negative screen-

Table 1
Mean demographic data, and correlation with RDI (n = 211)

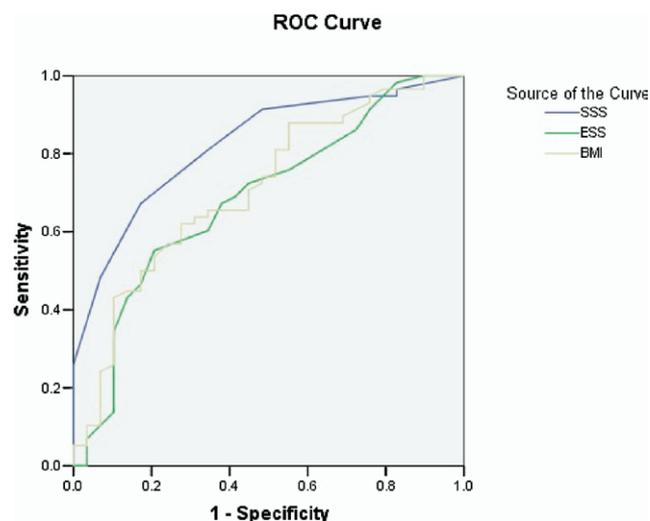| Factor	Mean ($\pm$ SD)	Correlation with RDI (Pearson r)
Age	47.5 (16.3)	0.12
BMI	30.2 (5.9)	0.40*
ESS	10.6 (5.6)	0.45*
SSS	4.9 (2.5)	0.50*
RDI	33.2 (28.1)	—
% with OSA	69.2	—

*$P < 0.05$.

Figure 2   Receiver operating characteristic (ROC) curves, reflecting sensitivity and specificity of the Snoring Severity Scale (SSS), Epworth Sleepiness Scale (ESS), and body mass index (BMI).

ing tests, we were unable to determine any common characteristics of this subgroup of false-negative results.

If this screening test were employed for snoring patients, our data suggest that negative results place patients in a low-risk group: only 2.6% of patients with SSS <4 and BMI <26 actually had OSA. If utilized, such a screening test would have avoided NPSG in 13% of the patients in our cohort.

Conversely, two numerical thresholds placed patients into a high-risk group. These were BMI ≥32 (positive predictive value = 89%), and SSS ≥7 (positive predictive value = 92%).

DISCUSSION

There are no clearly defined parameters defining which snoring patients should be referred for polysomnography. Some clinicians make this decision on an individual basis, considering multiple risk factors, and many clinicians routinely refer all snoring patients for NPSG.

Two simple parameters, easily and quickly assessed in an office visit, provide rapid risk stratification for OSA (Fig 3). These are body mass index (an objective measure) and score on the Snoring Severity Scale (a subjective measure). Patients with both SSS score <4 and BMI <26 are at very low risk (2.6% in our cohort) for OSA. We suggest that polysomnography can be deferred in these patients, although appropriate close follow-up should be tailored to each individual patient. Depending on the patient, this might involve re-evaluation once or several times per year, with NPSG ordered in the event of worsening snoring symptoms, comorbid cardiac or other medical conditions, or the development of nonsnoring symptoms suggestive of apnea, such as daytime sleepiness, fragmented sleep, or morning head-

aches. If surgical or medical therapy is being considered for snoring, NPSG would also be prudent.

At the same time, any patient with BMI ≥32, or with SSS score ≥7, should be considered at high risk for OSA. SSS had slightly higher positive predictive value than BMI. These patients should be counseled on the likelihood of OSA and promptly referred for NPSG, rather than observed. Sleep disorder centers may consider planning split-night studies on these patients, in which the second half of the night is devoted to titrating the patient to an appropriate level of nasal CPAP. This would avoid the need for a second sleep study in these patients.

The sleep literature has not established criteria for the risk of OSA based on clinical parameters, although both BMI[4] and ESS[7] are known to be correlates of OSA. Snoring severity has not been extensively investigated as a factor.

In fact, it has traditionally been believed that sleep-disordered breathing cannot be assessed based on noisy sleep breathing, and most authors have failed to demonstrate a clear correlation between snoring and RDI, although some investigators have demonstrated that snoring sound intensity may be a measure of respiratory effort. These results are likely related to the lack of a reliable measure of snoring severity.

It is therefore critical to utilize a reliable assessment of snoring in order to effectively study this question. The SSS was originally described by Lim and Curry in 1999,[3] and subsequently modified and validated by our group.[6] This three-question instrument is completed by the patient and (when available) his or her bed partner. Of the independent clinical variables assessed in this study, SSS corresponded to the highest area under the ROC curve, suggesting that subjectively assessed snoring severity may be the most useful parameter to assess in patients being evaluated for possible OSA.

Similar to the present study, Lim and Curry in 2000[8] attempted to elucidate the role of clinical assessment in identifying snorers with OSA, utilizing three criteria: the
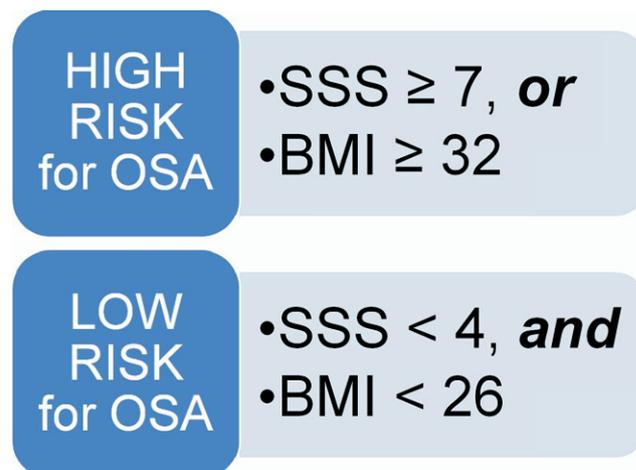

Figure 3   Rapid risk stratification based on snoring severity and body mass index.

presence of various clinical symptoms, ESS >15, and BMI >28. This method was optimized to provide 93.4% sensitivity and 60% specificity for the presence of OSA.

Our results suggested that two measures—BMI and SSS—alone provide a highly sensitive screening test for OSA, with sensitivity of 97.4%, and that ESS did not provide additional information. Based upon these two pieces of data, many patients can be identified as low-risk and high-risk for OSA.

CONCLUSIONS

When evaluating a patient for possible OSA, we recommend collecting data on body mass index and snoring severity, measured on the Snoring Severity Scale. These two numbers may provide a basis for considering patients as low-risk or high-risk for OSA. Further data collection is underway to further define criteria for snoring patients in whom sleep study referral might be deferred.

AUTHOR INFORMATION

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AUTHOR CONTRIBUTIONS

FINANCIAL DISCLOSURE

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