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Application value of joint NoSAS score and Epworth Sleepiness Scale for assessment of obstructive sleep apnea hypopnea syndrome

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ABSTRACT

Objective: By comparing the predictive value of the NoSAS (Neck circumference, Obesity, Snoring, Age and Sex) score combined with the Epworth Sleepiness Scale (ESS), STOP-Bang Questionnaire (STOP-Bang), STOP Questionnaire (STOP) and Berlin Questionnaire (Berlin), the application value of the NoSAS score combined with ESS in screening Obstructive sleep apnea hypopnea syndrome (OSAHS) in the population is evaluated.

Method: 2560 suspected OSAHS patients visited the Sleep Medical Center of the First Hospital of Guangzhou Medical University between September 1, 2016 and October 31, 2020, and were monitored with a polysomnogram (PSG) after completing the NoSAS score, ESS, STOP-Bang, STOP and Berlin. The sensitivity, specificity, positive predictive value, negative predictive value and receiver operating characteristic (ROC) curve of each scale were calculated, and the accuracy in predicting OSAHS of the NoSAS score combined with ESS and each scale was analyzed.

Results: The areas under the ROC curve scored by Berlin were higher than those of the other four questionnaires with Apnea Hypopnea Index (AHI) cutoffs of $\geq$5 and $\geq$ 10 events/h, while the area under the ROC curve scored by the NoSAS score was the highest with AHI cutoffs of $\geq$15, $\geq$20, $\geq$25 and $\geq$ 30 events/h. Among the five scales, the diagnostic odds ratio (DOR) of the NoSAS score was the highest. When a NoSAS score of $\geq$7 was used as the cutoff point for diagnostic NoSAS, it had higher sensitivity and specificity with a NoSAS score of $\geq$8 as the cutoff point for diagnostic NoSAS. A NoSAS score of $\geq$7 combined with ESS significantly improved its specificity for predicted OSAHS patients.

Conclusion: The NoSAS score is a simple and effective new tool for screening patients for OSAHS, while a NoSAS score of $\geq$7 combined with ESS can further improve its specificity. Thus, we suggest further screening with ESS after a NoSAS score of $\geq$7 in suspected populations.

1. Introduction

Obstructive sleep apnea hypopnea syndrome (OSAHS) is the most common respiratory disorder in sleep. It is mainly manifested by snoring during sleep, accompanied by apnea and superficial breathing. Hypoxemia, hypercapnia and sleep disorder occur repeatedly at night, resulting in daytime drowsiness, cardiovascular, cerebrovascular and pulmonary complications, and even multiple organ damage in patients with OSAHS. As a systemic disease, OSAHS has a high prevalence rate [1,2] while being harmful and even leading to death. Previous studies have shown that OSAHS is associated with increased mortality in patients [3,4]. As we all know, the polysomnogram (PSG) is the gold standard for the diagnosis of OSAHS, but it requires sleeping rooms and professional technicians, making it expensive, complex and time-consuming,

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and precluding it from widespread use in primary hospitals at present. Currently, the commonly used clinical screening tools to assist in the diagnosis of OSAHS are the Epworth Sleepiness Scale (ESS), STOP-Bang Questionnaire (STOP-Bang), STOP Questionnaire (STOP) and Berlin Questionnaire (Berlin). The NoSAS (Neck circumference, Obesity, Snoring, Age and Sex) score is a new screening tool for the risk assessment of suspected sleep dyspnea, and preliminary studies have confirmed its simplicity and effectiveness [5,6]. In this study, patients with suspected OSAHS were evaluated with the NoSAS score, ESS, STOP-Bang, STOP and Berlin at the same time, and then the PSG data was statistically analyzed to compare the predictive value of the above five screening tools. It was recently found that STOP-Bang combined serum bicarbonate can significantly improve the diagnostic value of STOP-Bang for OSAHS patients [7], but blood drawing tests are troublesome and time-consuming, while ESS deals with subjective symptoms, and the diagnostic value of the NoSAS score is better than that of STOP-Bang. Therefore, this study further evaluates the application value of the NoSAS score combined with ESS for screening OSAHS in the population.

2. Materials and methods

2.1. Study subjects

All participants were recruited from the Sleep Medical Center of the First Affiliated Hospital of Guangzhou Medical University, Guangzhou, China, from September 1, 2016 to October 31, 2020. From a total of 2560 patients, 2158 were eventually included: 1693 males and 867 females; mean age of 47.62 years; average neck circumference of 38.43 cm; and mean BMI of 26.48 kg/m^2. This study was approved by the Ethics Committee of the First Affiliated Hospital of Guangzhou Medical University with Ethical Approval No. 05, 2017, and all patients gave and signed their informed consent. The inclusion criteria were (1) older than 18 years; (2) total sleep time of >4 h; (3) autonomous behavior and cognitive ability; and (4) able to answer the questionnaire. Subjects who met the following criteria were excluded from this study: (1) history of various mental and psychological diseases; (2) brain tumors or epilepsy; (3) long-term or current use of benzodiazepines, barbiturates or other sedative and sleeping drugs; (4) severe organ failure leading to an inability to complete the examination; (5) previously diagnosed or treated; (6) did not complete or finish completing the questionnaire; (7) total sleep time of <4 h; and (8) OSAHS dominated by central or mixed events.

2.2. Methods

In our study, we collected the basic data of the 2158 suspected patients: (1) basic anthropological data; (2) basic demographics (e.g., sex, age, occupation); (3) anthropometric parameters (height, weight, neck circumference, waist circumference, etc.); (4) previous history (history of hypertension, diabetes, cardiovascular and cerebrovascular diseases, and other related diseases); (5) personal history (smoking and drinking); and (6) sleep-related breathing events (e.g., snoring, apnea, sleep suppression). Patients were asked to complete the NoSAS score, ESS, STOP-Bang, STOP and Berlin 1 h before the PSG examination. According to the PSG monitoring results, the patients were divided into AHI <5 events/h (n = 657), AHI ≥5 and < 15 events/h (n = 453), AHI ≥15 and < 30 events/h (n = 345) and AHI ≥30 events/h (n = 703).

2.3. Questionnaire

The NoSAS score (as shown in Table 1), which ranges from 0 to 17, includes 5 questions, allocating 4 points for having a neck circumference of more than 40 cm, 3 points for having a body mass index (BMI) of 25–30 kg/m^2 or 5 points for having a BMI of 30 kg/m^2 or more, 2 points for snoring, 4 points for being older than 55 years of age and 2 points for being male. The NoSAS score identifies individuals at risk of clinically significant OSAHS using a threshold of 8 points [6]. ESS, which includes 8 questions, asks respondents to rate their sleepiness from 0 to 3 in eight daily situations. For each question, a score of 0 indicates no lethargy, and 1, 2 and 3 indicate light, moderate and heavy lethargy respectively. The highest score of ESS is 24 (the most excessive daytime sleepiness), with a threshold for daytime sleepiness of 9 points or more [8]. STOP has four questions on snoring, fatigue, observed apnea and hypertension that are answered with “yes” or “no”. It adds 1 point for “yes” and 0 points for “no”. When the total points are greater than >2,[9] this indicates that the patient is at high risk for OSAHS. STOP-Bang, based on STOP, has four additional indexes called “Bang”: B (BMI >35 kg/m^2), A (>50 years old), N (neck circumference >40 cm) and G (male). For each question, if the answer is “yes”, 1 point will be added, otherwise no points will be added. When the total points are greater than 3 [10], this indicates that the patient is at high risk for OSAHS. Berlin is widely used as an qualitative diagnosis tool for OSAHS worldwide, and its credibility has been confirmed by many studies [11]. It includes 11 questions on three topics: (I) severity of snoring; (II) daytime sleepiness; and (III) high blood pressure or obesity. The assessment of each topic is negative or positive. If the assessment of 2 or more topics is positive, then the patient is considered to be at high risk for OSAHS.

Table 1
The NoSAS score.

Index	score
Neck circumference>40 cm	4
25 kg/m^2 < BMI < 30 kg/m^2	3
BMI≥30 kg/m^2	5
Snoring	2
Age>55岁	4
Male	2
NoSAS score	

The NoSAS score allocates 4 points for having a neck circumference ≥40 cm, 3 points for having a BMI of 25–30 kg/m 2, 5 points for having a BMI of 30 kg/m 2 or more, 2 points for snoring, 4 points for being older than 55 years, and 2 points for being male, and it uses a threshold of 8 points or more to indicate the presence of OSAHS.
BMI = body mass index.

2.4. Polysomnogram

All patients were synchronously monitored with an Alice 5 PSG (Philips Wellcome, USA) for at least 7 h, and the use of alcohol, coffee, sedatives and hypnotics was prohibited on the same day. The monitoring indicators included electro-encephalogram, electromyography, blood oxygen saturation, electro-oculogram, electrocardiogram, snoring, mouth airflow, nasal airflow, chest breathing and body position.[12]The raw data was automatically read by the instrument, then manually analyzed by trained sleep professionals for parameters such as sleep duration and sleep breathing events based on the *Manual for the Scoring of Sleep and Associated Events* published by the American Academy of Sleep Medicine (AASM) in 2012, and finally corrected by the same physicians [12]. According to the guidelines for the diagnosis and treatment of OSAHS, patients were defined as having OSAHS when their obstructive apnea was dominated by respiratory events and their Apnea Hypopnea Index (AHI) was not below 5 events/h.

Patients with suspected OSAHS were classified into four groups based on AHI: AHI <5 events/h, AHI ≥5 and < 15 events/h, AHI ≥15 and < 30 events/h and AHI ≥30 events/h.

2.5. Statistical analysis

Statistical analysis was performed using the SPSS v16.0. One-Way ANOVA was adopted for the normal distribution of data. Post hoc analysis was conducted for comparison between the two groups. The chi-square test was used for comparison between count data groups. The diagnostic results of each scale and PSG were calculated as the sensitivity, specificity, positive predictive value and negative predictive value of each scale in a four-grid scale form. The diagnostic results of PSG and each scale were analyzed in a fourfold table, and the sensitivity, specificity, positive predictive value and negative prediction value of each amount was calculated. The ROC curve was used to analyze the OSAHS diagnostic performance of the NoSAS score combined with ESS and each scale.

3. Results

3.1. General data

A total of 2158 suspected patients (including 1693 males) were recruited into this study (as shown in Fig. 1). The mean age of the subjects was 47.62 ± 13.92 years old, the mean BMI was 26.48 ± 4.11 kg/m^2 and the mean neck and waistline circumferences were 38.43 ± 3.87 and 95.41 ± 13.42 cm respectively. The mean AHI of the subjects was 24.65 ± 25.72 events/h, and the mean lowest oxygen saturation (LSpO2) was 78.01 ± 13.79%. The mean NoSAS, ESS, STOP, STOP-Bang, Berlin scores were 8.64 ± 3.84, 7.90 ± 5.69, 1.89 ± 1.07, 3.54 ± 1.49 and 1.52 ± 0.90 points respectively. There was no statistically significant difference in age between AHI <5 events/h and AHI ≥5 and < 15 events/h, AHI ≥15 and < 30 events/h and AHI ≥30 events/h, and there was no statistically significant difference in snore between AHI ≥15 and < 30 events/h and AHI ≥30 events/h, except for the remaining item differences in the 4 groups. The proportion of men, higher in the AHI ≥5 and < 15 events/h than in the AHI <5 events/h, and higher in the AHI ≥15 and < 30 events/h and AHI ≥30 events/h than in the AHI ≥5 and < 15 events/h, was statistically significant (P < 0.05). Similarly, these differences were reflected in the indicators of BMI, neck circumference, waist circumference and AHI, and NoSAS, ESS, STOP, STOP-Bang and Berlin (as shown in Table 2).

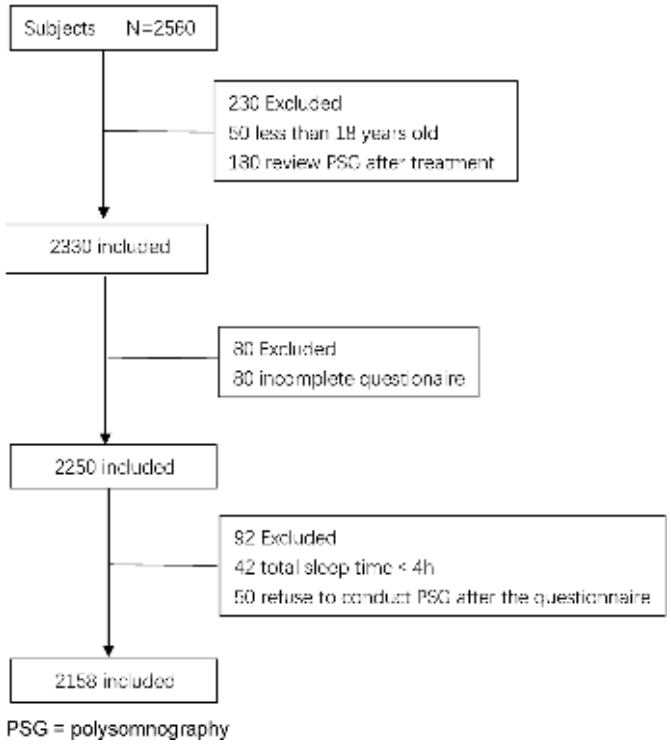

Fig. 1. Flow Diagram
PSG = polysomnography.

3.2. Predictive value of various scales

3.2.1. Area under ROC curve of various scales

The area under the curve (AUC) of the various scales was compared using AHI cutoffs of 5, 10, 15, 20, 25 and 30 events/h respectively (as shown in Fig. 2). We found that when the cutoff point of AHI was 5 and 10 events/h, the AUC of Berlin was the highest at 0.732 (95%CI 0.709–0.755) and 0.709 (95%CI 0.687–0.731) respectively. When the cutoff point of AHI was 15, 20, 25 and 30 events/h, the AUC of the NoSAS score was the highest at 0.707 (95%CI 0.686–0.729), 0.708 (95%CI 0.686–0.730), 0.714 (95% CI 0.692–0.736) and 0.706 (95%CI 0.684–0.729) respectively. In particular, when the cutoff point was ≥20 events/h, the AUC was significantly higher than that of the other four scales.(as shown in Table 3). The correlations between AHI and the NoSAS, ESS, Berlin, STOP, and STOP-Bang questionnaires were found as follows (r = 0.384,0.324,0.427,0.288,0.375,P < 0.001).

When the AHI cutoffs of ≥5 events/h, the ROC Curve of Five Screening Tools was shown in Fig. 3, and When the AHI cutoffs of ≥15, 30 events/h, the ROC Curve of Five Screening Tools was shown in Fig. 4 and Fig. 5 respectively.

3.2.2. The sensitivity and specificity of NoSAS were compared when 7 and 8 were used as diagnostic cutoff points

"Sensitivity" refers to the probability of testing positive in the gold standard judged ill (positive) population, reflecting the ability of the questionnaire to screen out OSAHS patients, while "specificity" refers to the probability of testing negative in the gold standard judged disease-free (negative) population, reflecting the ability of the questionnaire to detect the normal population.

Using the NoSAS score of 7 as the cutoff for diagnostic NoSAS, its sensitivities for AHI ≥5 events/h, AHI ≥15 events/h and AHI ≥30 events/h were 0.821, 0.867 and 0.896 respectively, and its specificities were 0.528, 0.472 and 0.373. When the cutoff point of 8 was used, its sensitivities for AHI ≥5 events/h, AHI ≥15 events/h and AHI ≥30 events/h were 0.676, 0.737 and 0.773 respectively, and its specificities were 0.635, 0.561 and 0.511 (as shown in Table 4).

The specificities of NoSAS (≥7 points) were 0.528 (0.490–0.566), 0.472 (0.441–0.503) and 0.373 (0.349–0.398) for AHI ≥5 events/h, AHI ≥15 events/h and AHI ≥30 events/h respectively. When combined with ESS, the specificities increased to 0.895 (0.872–0.918), 0.851 (0.830–0.872) and 0.825 (0.805–0.844) (as shown in Table 5).

3.2.3. The two-step screening procedure screens for the risk of OSAHS disease

According to the above analysis, a two-step screening procedure was formed. In the first step, the NoSAS score was used to screen all 2158 patients, for those with a score below 7, the risk of OSAHS, moderate-severe OSAHS and severe OSAHS was 0.44 (0.40–0.48), 0.23 (0.19–0.26) and 0.12 (0.09–0.14) respectively. These patients were less likely to have OSAHS.

For 1255 patients (NoSAS score ≥7), the risk of OSAHS was further evaluated by ESS. For patients with ESS of greater than or

Table 2
Baseline characteristics of study subjects.

	All	AHI<5	5 ≤ AHI<15	15 ≤ AHI<30	AHI≥30	F/χ2	P
n	2158	657	453	345	703		
Male (n, %)	1693 (78.5)	436 (66.4)	341 (75.3)	276 (80.0)	640 (91.0)	1145	< 0.001
Snore (n, %)	1980 (91.8)	523 (79.6)	428 (94.5)	338 (98.0)	691 (98.3)	189.90	< 0.001
Age (years)	47.62 ± 13.92	47.12 ± 14.77	49.60 ± 13.19	49.68 ± 14.07	45.81 ± 13.20	9.941	< 0.001
BMI (kg/m^2)	26.48 ± 4.11	24.79 ± 3.94	26.06 ± 3.44	26.58 ± 3.68	28.29 ± 4.12	94.958	< 0.001
NC (cm)	38.43 ± 3.87	36.50 ± 3.77	37.97 ± 3.54	38.68 ± 3.28	40.41 ± 3.44	141.54	< 0.001
WC (cm)	95.41 ± 13.42	89.92 ± 10.90	93.79 ± 10.65	96.01 ± 10.14	101.30 ± 15.94	95.22	< 0.001
AHI (events/h)	24.65 ± 25.72	1.89 ± 1.45	9.42 ± 2.76	21.17 ± 4.05	57.45 ± 17.30	3928.61	< 0.001
LSpO2 (%)	78.01 ± 13.79	88.05 ± 6.21	82.36 ± 9.13	78.01 ± 13.79	65.81 ± 14.24	557.56	< 0.001
NoSAS	8.64 ± 3.84	6.54 ± 3.80	8.35 ± 3.45	9.23 ± 3.33	10.48 ± 3.32	147.99	< 0.001
ESS	7.90 ± 5.69	6.23 ± 5.11	7.16 ± 5.17	7.32 ± 5.27	10.24 ± 5.96	68.15	< 0.001
STOP	1.89 ± 1.07	1.45 ± 0.89	1.83 ± 0.94	2.06 ± 1.21	2.27 ± 1.07	77.27	< 0.001
STOP-Bang	3.54 ± 1.49	2.73 ± 1.33	3.41 ± 1.27	3.80 ± 1.49	4.24 ± 1.36	147.80	< 0.001
Berlin	1.52 ± 0.90	0.97 ± 0.85	1.48 ± 0.82	1.69 ± 0.75	1.98 ± 0.78	183.04	< 0.001

Data is presented as mean ± standard deviation unless otherwise noted. AHI = apnea hypopnea index, BMI = body mass index, NC = neck circumference, WC = waist circumference, LSpO2 = lowest oxygen saturation.

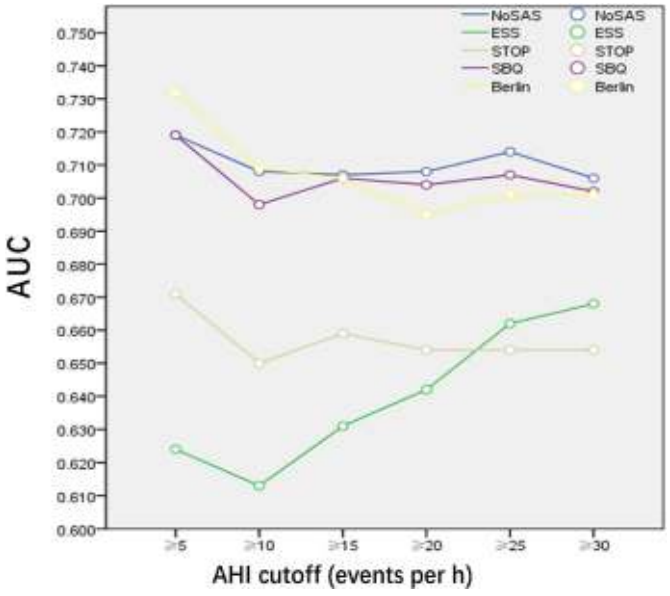

Fig. 2. Performance of NoSAS Score Compared with ESS, STOP, SBQ and Berlin scores The AUC of the NoSAS score was lower than that of Berlin when using an AHI cutoff of ≥5 or 10 events/h, whereas it was higher than that of Berlin when using an AHI cutoff of ≥15, 20, 25 or 30 events/h. The diagnostic value of the NoSAS score was better than those of the other questionnaires. AHI = Apnea Hypopnea Index, AUC = area under the curve, ESS = Epworth Sleepiness Scale.

equal to 10, the risk of OSAHS, moderate-severe OSAHS and severe OSAHS was 0.88 (0.85–0.90), 0.70 (0.66–0.73) and 0.54 (0.50–0.57) respectively The risk was significantly higher than that of patients with ESS of less than 10 (as shown in Fig. 6). In particular, the risk of severe OSAHS was as much as 1.8 times higher.

4. Discussion

In this study, 1501 of the 2158 patients suspected of OSAHS were confirmed, and the proportion of men was far higher than that of women, in line with the epidemiological characteristics of OSAHS. In this study, the area under the ROC curve showed that the NoSAS score had the highest predictive value for OSAHS patients, especially moderate-severe OSHAS, with STOP-Bang slightly lower than NoSAS and ESS, and STOP significantly lower than the other three scales. Although Berlin had the highest predictive value for the mild OSAHS group, the predictive value was lower for the moderate and severe groups than NoSAS and STOP-Bang considering the BMI impact correlation, even if the severe group failed to reach the questionnaire threshold of 30 kg/m^2. The same BMI will affect the two scales of NoSAS and STOP-Bang, but the BMI bound was divided into 25–30 and 30 kg/m^2 in NoSAS, so it was relatively less affected. The results of this study are similar to those of other studies [13–15] which show that the NoSAS score is a simple, effective and easy tool for risk assessment in patients with suspected OSAHS. The cohort study of Tan et al. [13] on verifying the utility of NoSAS score screening for sleep respiratory disorders in Asian populations showed that the sensitivity for moderate-severe OSAHS was 60.3%, slightly lower than that of this study (73.3%), and the specificity was 79.9%, slightly higher than that of this study (56.1%).

DOR was applied in the meta-analysis to compare the accuracy of various prediction models and questionnaires for SDB [16]. In this study, the highest NoSAS score DOR among the five scales was consistent with previous findings by Qing S. M. et al. [17] The DOR of OSAHS diagnosed with cutoff scores of 7 and 8 points was 5.131 and 3.630 respectively; that of moderate-severe OSAHS was 5.827 and 3.508; and that of severe OSAHS was 5.125 and 3.558. Therefore, the NoSAS score has a better predictive value compared to the other four questionnaires. At the same time, this study found that

Table 3
AUC (95%) of various scales.

AHI	NoSAS	ESS	STOP	STOP-Bang	Berlin
≥5	0.719(0.695–0.743)	0.624(0.599–0.649)	0.671(0.647–0.694)	0.719(0.696–0.742)	0.732(0.709–0.755)
≥10	0.708(0.686–0.730)	0.613(0.589–0.637)	0.650(0.627–0.673)	0.698(0.676–0.720)	0.709(0.687–0.731)
≥15	0.707(0.686–0.729)	0.631(0.608–0.655)	0.659(0.636–0.682)	0.706(0.684–0.727)	0.706(0.685–0.727)
≥20	0.708(0.686–0.730)	0.642(0.619–0.666)	0.654(0.630–0.678)	0.704(0.682–0.727)	0.695(0.673–0.717)
≥25	0.714(0.692–0.736)	0.662(0.638–0.686)	0.654(0.630–0.678)	0.707(0.684–0.729)	0.701(0.679–0.724)
≥30	0.706(0.684–0.729)	0.668(0.644–0.693)	0.654(0.629–0.679)	0.702(0.678–0.725)	0.701(0.679–0.724)

AUC = area under the curve, CI = confidence interval, AHI = apnea hypopnea index, ESS = Epworth Sleepiness Scale.

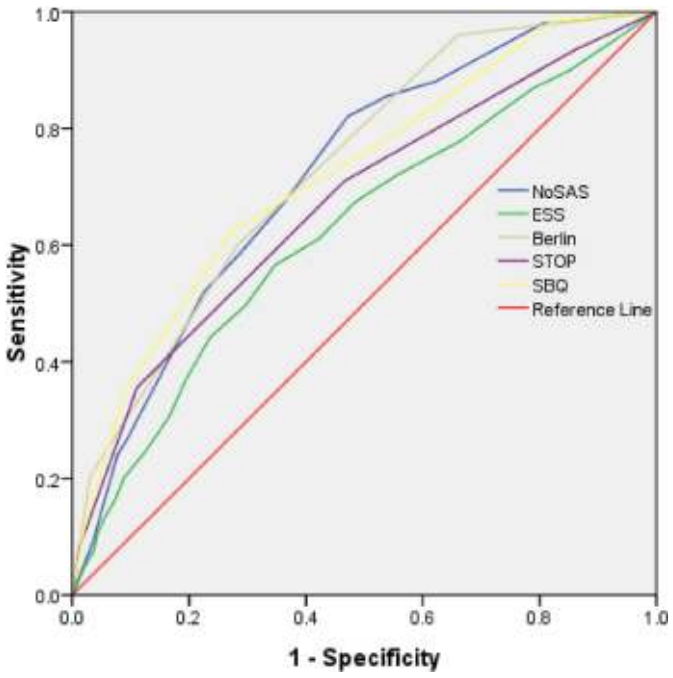

Fig. 3. ROC Curve of Five Screening Tools at AHI Cutoff of ≥5 Events/h
At an AHI cutoff of ≥5 events/h, the diagnostic performance of the Berlin score was better than those of the other four questionnaires. AHI = Apnea Hypopnea Index, ESS = Epworth Sleepiness Scale, SBQ = STOP-Bang Questionnaire, ROC = receiver operating characteristic.

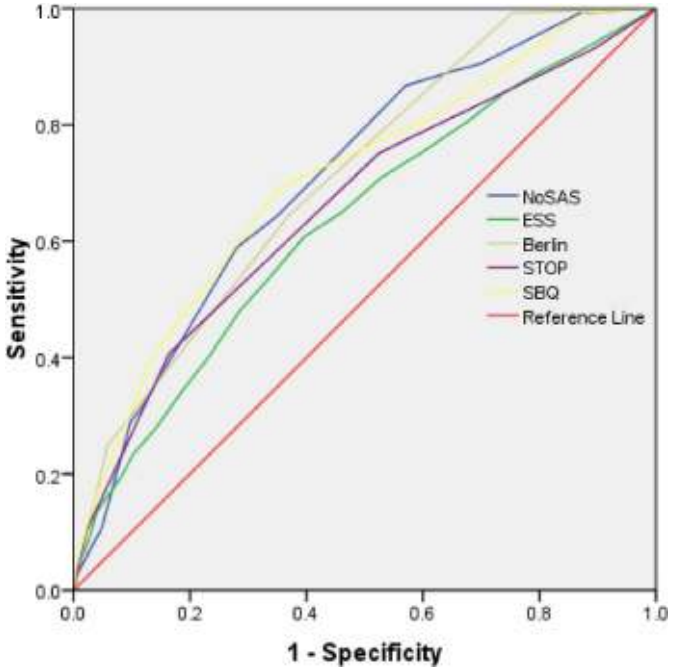

Fig. 4. ROC Curve of Five Screening Tools at AHI Cutoff of ≥15 Events/h
At an AHI cutoff of ≥15 events/h, the diagnostic performance of the NoSAS score was better than those of the other four questionnaires. AHI = Apnea Hypopnea Index, ESS = Epworth Sleepiness Scale, SBQ = STOP-Bang Questionnaire, ROC = receiver operating characteristic.

the NoSAS score, as a new screening tool, has a higher DOR value with 7 as the cutoff than with 8. The reason for this is not only the low age of onset in China, but also the low BMI and small neck

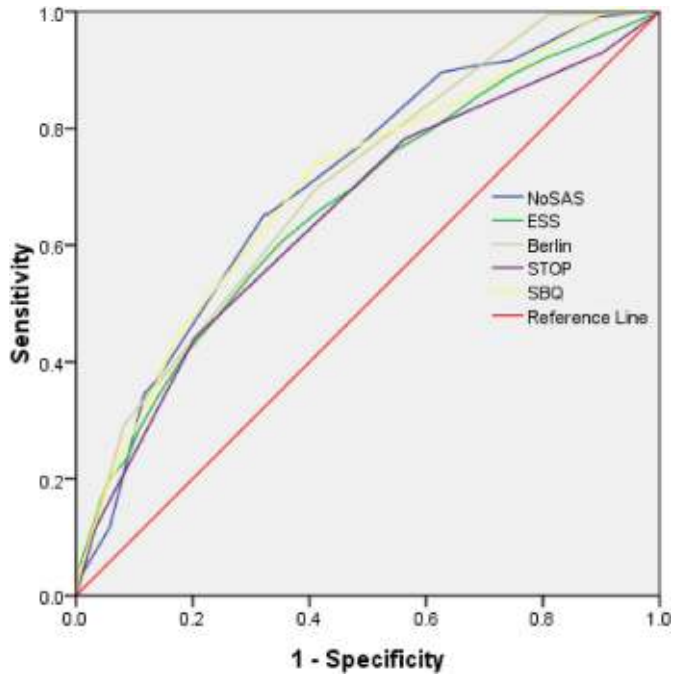

Fig. 5. ROC Curve of Five Screening Tools at AHI Cutoff of ≥30 Events/h
At an AHI cutoff of ≥30 events/h, the diagnostic performance of the NoSAS score was better than those of the other four questionnaires. AHI = Apnea Hypopnea Index, ESS = Epworth Sleepiness Scale, SBQ = STOP-Bang Questionnaire, ROC = receiver operating characteristic.

circumference in China. The NoSAS score can often struggle to identify high-risk OSAHS patients with low BMI and neck circumference [6].

The lack of awareness of OSAHS among the public and health professionals has resulted in an estimated 80–90% of OSAHS patients failing to receive a timely diagnosis [18]. Untreated OSAHS is an all-cause death risk factor, and the risk of death significantly increases with the severity of the condition [19]. In addition, due to adverse reactions to anesthesia and sedation in OSAHS patients, surgical patients face high risk with perioperative OSAHS, and previous studies have shown that OSAHS patients have more events of hypoxia, respiratory failure, cardiac events and transfer to ICU than patients without OSAHS after non-cardiac surgery [20,21]. Recent studies have found that undiagnosed severe OSAHS is significantly associated with increased cardiovascular risk within 30 days of major non-cardiac surgery [22]. The preoperative identification of these high-risk patients appears particularly important, but unfortunately the majority of OSAHS patients remain unidentified preoperatively, increasing the risk of perioperative complications. The gold standard for the diagnosis of OSAHS is a polysomnotive sleep monitoring map, but such an examination is time-consuming and expensive, and the long waiting time makes a timely preoperative diagnosis difficult to achieve. To achieve the early identification of surgical patients with OSAHS and schedule further treatment, tools for screening patients at high risk for OSAHS appear increasingly important.

The results of this study provide a simple and effective protocol for the screening of patients with suspected OSAHS. We suggest a two-step screening process. In the first step, the NoSAS score is used for primary screening. Due to its high sensitivity, patients with a score of lower than 7 have a low risk of OSAHS, but the specificity is not high, making it easy to cause a high false positive rate. Therefore, the second step of screening for those with a score of 7 or more is required.

Table 4
Scale predictors of patient groups (percentage (95%CI)).

Scale	Sensitivity	Specificity	PPV	NPV	DOR
AHI ≥5 events/h					
NoSAS (≥8)	0.676(0.653–0.700)	0.635(0.598–0.672)	0.809(0.787–0.831)	0.462(0.429–0.494)	3.630
NoSAS (≥7)	0.821(0.801–0.840)	0.528(0.490–0.566)	0.799(0.779–0.819)	0.563(0.524–0.602)	5.131
ESS	0.496(0.471–0.522)	0.703(0.668–0.738)	0.793(0.767–0.818)	0.379(0.352–0.407)	2.329
STOP	0.710(0.687–0.732)	0.534(0.496–0.572)	0.777(0.755–0.799)	0.446(0.411–0.481)	2.999
STOP-Bang	0.790(0.770–0.811)	0.447(0.409–0.486)	0.766(0.745–0.787)	0.483(0.443–0.522)	3.041
Berlin	0.600(0.575–0.625)	0.717(0.682–0.751)	0.829(0.807–0.851)	0.440(0.410–0.470)	3.800
AHI ≥15 events/h					
NoSAS (≥8)	0.733(0.706–0.760)	0.561(0.532–0.590)	0.612(0.585–0.639)	0.690(0.660–0.720)	3.508
NoSAS (≥7)	0.867(0.847–0.888)	0.472(0.441–0.503)	0.630(0.605–0.655)	0.774(0.741–0.807)	5.827
ESS	0.539(0.509–0.569)	0.662(0.634–0.690)	0.601(0.570–0.632)	0.603(0.576–0.631)	2.290
STOP	0.752(0.726–0.778)	0.475(0.445–0.504)	0.575(0.549–0.601)	0.670(0.637–0.702)	2.743
STOP-Bang	0.818(0.794–0.841)	0.377(0.348–0.405)	0.553(0.529–0.578)	0.686(0.650–0.723)	2.720
Berlin	0.645(0.616–0.674)	0.630(0.601–0.658)	0.622(0.593–0.651)	0.653(0.624–0.681)	3.094
AHI ≥30 events/h					
NoSAS (≥8)	0.773(0.742–0.804)	0.511(0.485–0.537)	0.433(0.406–0.461)	0.823(0.798–0.848)	3.558
NoSAS (≥7)	0.896(0.874–0.919)	0.373(0.349–0.398)	0.409(0.385–0.434)	0.881(0.856–0.907)	5.125
ESS	0.607(0.570–0.643)	0.647(0.623–0.672)	0.454(0.422–0.486)	0.773(0.749–0.796)	2.831
STOP	0.783(0.752–0.813)	0.436(0.411–0.462)	0.402(0.376–0.428)	0.806(0.778–0.833)	2.789
STOP-Bang	0.847(0.820–0.873)	0.345(0.320–0.369)	0.385(0.361–0.409)	0.822(0.792–0.753)	2.916
Berlin	0.696(0.662–0.730)	0.589(0.564–0.615)	0.451(0.421–0.480)	0.800(0.776–0.824)	3.281

ESS = Epworth Sleepiness Scale, PPV = positive predictive value, NPV = negative predictive value, DOR = diagnostic odds ratio.

Table 5
Comparison of NoSAS (≥7) and with NoSAS (≥7) combined with ESS scale predictors of each patient group (percentage (95%CI)).

Scale	Sensitivity	Specificity	PPV	NPV
AHI ≥5 events/h				
NoSAS (≥7)	0.821(0.801–0.840)	0.528(0.490–0.566)	0.799(0.779–0.819)	0.563(0.524–0.602)
NoSAS (≥7) with ESS	0.344(0.320–0.368)	0.895(0.872–0.918)	0.882(0.856–0.908)	0.374(0.350–0.398)
AHI ≥15 events/h				
NoSAS (≥7)	0.867(0.847–0.888)	0.472(0.441–0.503)	0.630(0.605–0.655)	0.774(0.741–0.807)
NoSAS (≥7) with ESS	0.402(0.372–0.431)	0.851(0.830–0.872)	0.718(0.682–0.755)	0.601(0.577–0.625)
AHI ≥30 events/h				
NoSAS (≥7)	0.896(0.874–0.919)	0.373(0.349–0.398)	0.409(0.385–0.434)	0.881(0.856–0.907)
NoSAS (≥7) with ESS	0.470(0.433–0.507)	0.825(0.805–0.844)	0.565(0.525–0.605)	0.763(0.742–0.784)

ESS = Epworth Sleepiness Scale, PPV = positive predictive value, NPV = negative predictive value.

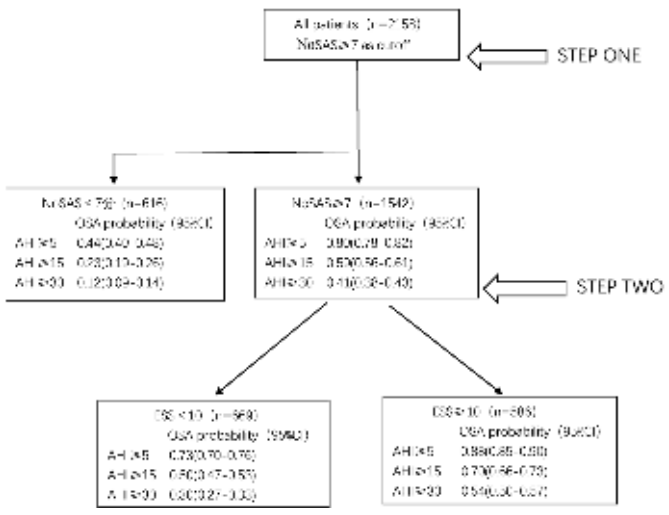

Fig. 6. Diagnostic strategy.

It is not difficult to see that when a score of 7 is used as the cutoff point for the diagnosis of NoSAS, it has higher sensitivity, while when a score of 8 is used, it has higher specificity. In addition, in this study, when combined with ESS, the specificity of the NoSAS score in predicting OSAHS, moderate-severe OSAHS and severe OSAHS patients was 0.895, 0.851 and 0.825 respectively. It can be seen that the specificity of the NoSAS score combined with ESS in predicting OSAHS patients can be significantly improved. Therefore, we suggest that the second step of screening should be carried out in combination with ESS for people with a NoSAS score of 7 or more. For patients at high risk for OSAHS, we suggest a PSG examination followed by stratified management according to the examination results, including behavior adjustment (avoiding drinking, using sedative drugs, etc.), weight loss, drugs, continuous positive airway pressure ventilation, oral appliances, surgery and other treatments. Other studies [23,24] have initially confirmed the effectiveness of sublingual nerve stimulation for OSAHS, which is expected to become a new treatment choice for OSAHS patients in the future. Although OSAHS management still faces many unsolved problems, with the deep public understanding of OSAHS and the formation and efforts of multidisciplinary teams, its future is promising.

Like many studies, this study has several shortcomings. The first is that diagnosis of mild OSA was based on AHI without considering sleep-related symptoms and complications. Secondly, the sample in our study is the suspect population in the hospital, not a community population, it would be suitable to have not a convenience sample, and the single-center cohort study mainly includes subjects from Guangzhou, but as the National Respiratory Medicine Center, our unit accepts a large number of research subjects from all over the country and should represent the Chinese population to some extent; and the members of the normal and severe OSAHS

groups were younger than those of the mild and moderate groups, which may have had a certain impact on the results.Lastly, the current diagnostic OSA is recommended based on RDI rather than AHI, however, our center only has AHI data because the Chinese OSA guidelines recommend using AHI as the diagnostic criterion for OSA. And AHI are used in our earlier studies [5] and many previous studies on the screening of OSA with ESS and NoSAS questionnaires [6,8,25], in order to better compare with the previous results, AHI is convenient for comparison with the results of previous studies.

In conclusion, combining ESS with the NoSAS score improves its specificity at the cost of reducing its sensitivity in predicting OSAHS, so we recommend a two-step screening process for suspected OSAHS patients: the initial screening using the highly sensitive NoSAS score (7 points), and then combining it with ESS to improve the specificity. This screening approach can help doctors to carry out stratified management according to the OSAHS risk levels of patients, and effectively identify high risk patients early to further examine the clear diagnosis of early intervention treatment, thereby minimizing the harm caused by OSAHS.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Riken Chen: Methodology, Software, Writing – original draft. **Yitao Zhang:** Conceptualization, Methodology. **Yateng Luo:** Writing – original draft, Formal analysis. **Donghao Wang:** Formal analysis, Methodology. **Zhenzhen Zheng:** Investigation. **Xiaofen Su:** Methodology. **Kang Wu:** Data curation. **Wei Fu:** Resources. **Dongxing Zhao:** Visualization, Supervision. **Nuofu Zhang:** Project administration, Writing – review & editing.

Declaration of competing interest

All authors have seen and approved the manuscript.The authors have no conflicts of interest.

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