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Screening for Obstructive Sleep Apnea in a Diverse Bariatric Surgery Population

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Abstract

Objective: Obstructive sleep apnea (OSA) is common among bariatric surgery patients and is associated with perioperative risk. Preoperative screening is recommended, but some screening tools lack validation, and their relative performance is unclear in this population. The study objective was to compare the ability of four existing tools (STOP-BANG, NO-OSAS, No-Apnea, and the Epworth Sleepiness Scale [ESS]) to screen for moderate to severe OSA in a diverse bariatric cohort.

Methods: Data from patients presenting for first-time bariatric surgery who underwent a sleep study within 1 year of the initial encounter were retrospectively reviewed. Performance of the four tools for detecting moderate to severe OSA was compared based on the area under the receiver operating characteristic curves (AUC).

Results: Of the included 214 patients (83.2% female, median age 39 years), 45.3% had moderate to severe OSA. Based on AUC, STOP-BANG (0.75 [95% CI: 0.68–0.81], $N = 185$), NO-OSAS (0.76 [95% CI: 0.69–0.82], $N = 185$), and No-Apnea (0.69 [95% CI: 0.62–0.76], $N = 190$) had similar performance ($P > 0.16$). Compared with STOP-BANG and NO-OSAS, ESS (0.61 [95% CI: 0.54–0.68], $N = 198$) had a significantly lower AUC ($P < 0.01$). Hispanic/Latino self-identification, sex, or obesity class did not significantly modify test performance.

Conclusions: STOP-BANG and NO-OSAS may be preferable to No-Apnea and ESS when screening bariatric surgery patients for moderate to severe OSA. Efforts to screen bariatric patients for OSA are recommended.

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Supporting information: Additional Supporting Information may be found in the online version of this article.

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Introduction

Obesity is a major risk factor for obstructive sleep apnea (OSA), and weight loss is notoriously challenging to accomplish effectively (1). Bariatric surgery has been increasing in popularity in recent years as the risks have become quite modest and the effectiveness in achieving sustained weight loss has been well demonstrated (2). However, OSA is common in the bariatric surgery cohort, with prevalence estimates ranging from 35% to 96% depending on the demographic characteristics of the participants (3,4–9). Studies have shown OSA to be an independent risk factor for perioperative surgical complications (10). Moreover, undiagnosed severe OSA was recently associated with an increased risk of a composite end point of myocardial injury, cardiac death, heart failure, thromboembolism, atrial fibrillation, and stroke within 30 days of surgery (11). Thus, many organizations, including the American Academy of Sleep Medicine, have recommended routine screening for OSA in the bariatric population (12).

The optimal screening strategy for OSA in bariatric surgery patients is unclear. Routine preoperative polysomnography (PSG) would be the gold standard but it is an expensive approach that may lead to delays in surgery. Compared with PSG, home sleep testing (HST) may be less costly, more readily available, and perhaps equally reliable, particularly in patients with obesity who are prone to desaturation, but it has not been well studied in this context. Several questionnaires also have been developed for OSA screening, but their value in the bariatric population is not clear, and further validation is required.

Our standard of care, as enforced by our medical and surgical teams, is that all patients undergoing surgical evaluation are screened for the need for formal sleep evaluation, and the vast majority of bariatric patients at our institution are seen in our sleep center. Because of the rich diversity in our community, our cohort is relatively unique, with roughly half of patients self-identifying as Hispanic/Latino, a group that has received inadequate attention in some of the prior literature. Furthermore, because bariatric cohorts are typically predominantly women, the validation of various tests in other OSA cohorts could be questioned since many such studies have included primarily men.

Our goal was to test the hypothesis that commonly used screening questionnaires differ in their relative performance to detect moderate to severe OSA in a diverse bariatric population. Thus, we performed a detailed analysis of patients who underwent both sleep testing and bariatric surgery at our institution.

Methods

Study population

We retrospectively obtained data from adult patients consecutively scheduled for first-time bariatric surgery at the University of California (UC) San Diego from January 2015 to March 2019. Patients were included in the study if they had a sleep study, either PSG or HST, that was performed (a) within 1 year of the initial bariatric surgery encounter and (b) prior to the bariatric surgery. The UC San Diego Institutional Review Board approved this study.

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Data collection

Epic Slicer Dicer software (Epic Systems Corp., Verona, Wisconsin, USA) was used to identify patients who had bariatric surgery within the targeted time frame through a search of procedural codes. The following demographic data were collected from the medical record: age, sex, ethnicity, BMI, and neck circumference. Time-varying data (i.e., age, BMI, and neck circumference) were obtained from the initial bariatric encounter or, if unavailable, from the sleep medicine evaluation.

Sleep study

The following data were collected from the PSG (alternatively from the HST if no PSG was available): apnea-hypopnea index (AHI) and lowest oxygen saturation. Hypopnea was defined by flow reduction of at least 30% with a 4% oxygen desaturation, lasting 10 or more seconds; hypopneas were scored only if valid oximetry data were available. Presence and severity of OSA were based on the AHI. An AHI < 5/h indicated no OSA, 5 to 14.9/h indicated mild OSA, 15 to 29.9/h indicated moderate OSA, and ≥ 30/h indicated severe OSA (13).

Epworth Sleepiness Scale

The Epworth Sleepiness Scale (ESS) is a tool that measures subjective daytime sleepiness by asking patients to rate the likelihood of falling asleep in eight different scenarios on a 4-point scale (0 would never doze; 3 high chance of dozing) (14). The total score thus ranges from 0 to 24, with scores ≥ 11 indicating excessive daytime sleepiness. In bariatric surgery patients, the performance of the ESS for moderate to severe sleep apnea has been consistently lower than screening tools that include more objective data (3,4,7,15). At our institution, it is routinely self-administered before the sleep encounter and documented in the electronic medical record.

STOP-BANG

STOP-BANG is a tool that was originally developed to screen for sleep apnea in the preoperative setting and it has subsequently been validated in a variety of populations (16). One point is assigned for each of the following parameters: loud Snoring, daytime Tiredness, Observed apnea, hypertension (blood Pressure), BMI > 35 kg/m^2, Age > 50 years, Neck circumference > 40 cm, and male sex (Gender). Scores ≥ 3 indicate a high risk for moderate to severe sleep apnea. Scores ≥ 4 were shown to have a high sensitivity of 88% when applied to a cohort of 310 surgical patients with severe obesity (17). Previous studies of STOP-BANG in bariatric surgery patients have shown an area under the receiver operating characteristic curve (AUC) of 0.66 to 0.77 when the tool was applied to screening for moderate to severe OSA, although most of these studies were done in predominantly white populations (4,7,15). Presence of snoring, tiredness, and observed apnea is routinely assessed and recorded in the medical record by the bariatric surgery and sleep teams at our institution.

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NO-OSAS

NO-OSAS was developed by Duarte et al. to identify bariatric surgery patients at high risk for moderate to severe OSA using data from 1,089 patients in a single center in Rio de Janeiro, Brazil (3). It is composed of six components that are also seen in STOP-BANG; however, it uses different thresholds for neck circumference, BMI, and age. One point is assigned for each of the following parameters: Neck circumference ≥ 42 cm, BMI ≥ 42 kg/m^2 (Obesity), Observed apnea, Snoring, Age ≥ 37 years, and male Sex. Scores ≥ 3 demonstrated a sensitivity of 82.8% and a specificity of 57.9% in the original study (3). However, its performance has so far not been validated in an independent cohort.

No-Apnea

No-Apnea is a simplified OSA screening tool that uses two variables: neck circumference and age. It was created using data from 4,072 patients referred to a sleep center through their primary care physicians and was originally developed for screening any degree of OSA (AHI ≥ 5/h) (18). Scores of 0 to 9 are calculated on the summation of points taken from measurements of neck circumference (< 37.0 cm, 0 points; 37.0–39.9 cm, 1 point; 40.0–42.9 cm, 3 points; ≥ 43 cm, 6 points) and age (< 35 years, 0 points; 35–44 years, 1 point; 45–54 years, 2 points; ≥ 55 years, 3 points). A cutoff value of ≥ 3 is considered “positive.” When used to screen a bariatric surgery population of 411 Brazilian patients for moderate to severe OSA, it had a sensitivity of 87.9% and an accuracy comparable to STOP-BANG; however, specificity was notably lower compared with STOP-BANG (40.9% vs. 58.4%) (15).

Statistical analysis

Data were analyzed using MedCalc software version 19.1.3 (Ostend, Belgium). Continuous data are reported as means ± SDs, and categorical data are reported as percentages and absolute numbers. The differences of the variables’ means and proportions between patients with and without moderate to severe OSA were compared using an independent samples *t* test and χ^2 test. Empiric receiver operating characteristic curves and AUCs were calculated using MedCalc software, and AUCs were compared using the DeLong method (19). This method was also used to compare differences in the performance of each screening tool for subgroups that were based on sex, Hispanic/Latino self-identification, and obesity class (class 2, BMI 35–39.9; class 3, BMI 40–49.9; super obesity, BMI ≥ 50 kg/m^2). Sensitivity, specificity, and accuracy were calculated for various cutoff values for each model.

De novo model

We also developed a de novo prediction model for moderate to severe OSA using multivariate logistic regression with a forward selection procedure and $P < 0.05$ as cutoff to enter, and we compared its performance as judged by the AUC against the published models. Significance level was set at 0.05 for all analyses. Observed apnea, snoring, male sex, hypertension, tiredness, and Hispanic/Latino self-identification were treated as dichotomous variables. Neck circumference, age, ESS, and BMI were treated as continuous variables in the analysis.

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Results

Patient demographics

Out of 375 patients, we included 214 in the final analysis (Figure 1): we excluded 115 patients because they had a sleep study more than 1 year prior to their initial bariatric surgery encounter and 16 patients for whom the results of an outside sleep study were unavailable. We further excluded 30 patients who did not undergo a sleep study prior to surgery; these patients had a significantly lower BMI and less snoring, tiredness, observed apnea, and hypertension (Supporting Information Table S1), suggesting a relatively low prevalence of moderate to severe OSA in this subgroup. As shown in Table 1, included patients were predominantly young women (83.2% female, median age 39 years), approximately half of which self-identified as Hispanic/Latino (49.1%).

Sleep study data

The majority of patients underwent PSG (65.9%). The prevalence of OSA was 70.1% (AHI ≥ 5/h) and of moderate to severe OSA was 45.3% (AHI ≥ 15/h). A total of 44 patients (20.6%) had severe OSA.

Clinical variables

Patients with moderate to severe OSA compared with those with no or mild OSA were significantly more likely to score positively on each component of STOP-BANG, NO-OSAS, and No-Apnea with the exception of BMI (component of STOP-BANG and NO-OSAS, $P = 0.08$) and tiredness (component of STOP-BANG, $P = 0.17$). The ESS was significantly higher in the moderate to severe OSA group as well (7.8 vs. 6.0, $P < 0.01$). There was no difference in the prevalence of sleep apnea in patients who self-identified as Hispanic/Latino compared with those who did not.

Performance of published screening tools

Based on the AUC, STOP-BANG (0.75 [95% CI: 0.68–0.81], $N = 185$), NO-OSAS (0.76 [95% CI: 0.69–0.82], $N = 185$), and No-Apnea (0.69 [95% CI: 0.62–0.76], $N = 190$) had similar performance ($P > 0.16$; Figure 2). Compared with those of STOP-BANG and NO-OSAS, the AUC of the ESS (0.61 [95% CI: 0.54–0.68], $N = 198$) was significantly lower ($P < 0.01$). Visual inspection of the AUC suggested that ESS cutoffs with a sensitivity greater than 80% may achieve a similar specificity as the other three tools (Figure 2). However, when comparing actual cutoff values with a sensitivity between 80% and 90%, STOP-BANG and NO-OSAS tended to achieve a higher specificity (i.e., lower false-positive rate) and, to a lesser degree, higher accuracy than No-Apnea and the ESS (50%−60% vs. 30%−40% for sensitivity; 50%−60% vs. 60%−70% for accuracy) (Table 2). For STOP-BANG, a cutoff value of ≥ 4 best optimized sensitivity and specificity compared with the standard cutoff of ≥ 3 (Figure 2, Table 2). Hispanic/Latino self-identification, sex, or obesity class did not significantly modify performance of the four screening tools (Supporting Information Table S2).

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Performance of de novo prediction model

Based on univariate logistic regression, observed apnea, neck circumference, age, snoring, male sex, hypertension, and ESS were significant predictors of moderate to severe versus no or mild OSA. However, in multivariate logistical regression, only observed apnea (odds ratio $[OR]_{yes\ vs.\ no} = 4.5$), neck circumference ($OR_{per\ cm} = 1.2$), and age ($OR_{per\ year} = 1.05$) emerged as independent predictors of moderate to severe OSA (Table 3). This multivariate model had an AUC of 0.76 (95% CI: 0.70–0.82), which was comparable to the AUCs of STOP-BANG, NO-OSAS, and No-Apnea.

Discussion

Our study adds to the existing literature as it provides new data regarding the potential utility of various screening techniques for the diagnosis of OSA in a very diverse bariatric population. In our study, the STOP-BANG, NO-OSAS, and No-Apnea questionnaires all had similar overall performance for the diagnosis of moderate to severe OSA, which was superior to the ESS. Importantly, when used for pre-operative screening (i.e., identification of the highest-risk individuals who warrant further testing with a sleep study), both STOP-BANG and NO-OSAS appeared to have a higher specificity (i.e., lower false-positive rate) compared with No-Apnea and the ESS, although confidence intervals (CI) slightly overlapped. This is consistent with a study by Duarte et al., which also found a lower specificity with No-Apnea compared with STOP-BANG when using cutoffs with comparable sensitivity (15). Moreover, our results validate the use of previously established cutoffs for the screening of moderate to severe OSA in a diverse bariatric surgery population: as in prior studies, STOP-BANG ≥ 4, NO-OSAS ≥ 3, and No-Apnea ≥ 3 achieved a sensitivity > 80% while maintaining a similar specificity as in previous studies (50%−60% for STOP-BANG and NO-OSAS vs. 30%−40% for No-Apnea) (3,15,17). Of note, high-sensitivity cutoff points for the ESS (≥ 1–3 for sensitivity > 80%) are well within the “normal” range (≥ 11 is commonly used as a cutoff) and therefore they have poor face validity as a marker for pathology. In our study, test performance was not significantly modified by Hispanic/Latino ethnicity or female sex, further suggesting that results from prior studies are generalizable to such populations.

The optimal approach to the preoperative evaluation of the bariatric surgery patient is unclear. Several points deserve emphasis. First, obesity is clearly a risk factor for OSA, although OSA is not invariably present in bariatric cohorts. The wide reported prevalence ranges likely occur as a result of sex and racial/ethnic mix as well as degree of obesity. For example, premenopausal females have relatively low risk of OSA and therefore may be somewhat protected even in those who have obesity. Second, untreated OSA, particularly if severe, is likely a risk factor for perioperative complications. In the Longitudinal Assessment of Bariatric Surgery study, OSA was identified in multivariate analyses to be an independent risk factor for perioperative complications (20). Similarly, Chan et al. recently reported a high event rate of a composite end point including various perioperative complications in patients with severe undiagnosed OSA (11). Third, despite the well-documented risks associated with OSA, few studies have shown any beneficial effects of continuous positive

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airway pressure (CPAP) interventions with regard to reducing perioperative risk (21). Thus, further work is clearly needed regarding the optimal management strategy.

The reason for the failure of studies to show an impact of CPAP interventions in the perioperative setting is unclear. Some have argued that the event rates are relatively low and that massive sample sizes would be required to show any important improvement in event rates. In addition, anesthesiologists have become quite facile with managing the “difficult airway” such that known interventions (which might help the risk of OSA-related complications) may already be in common use. Thus, for at least some centers, the diagnosis of OSA may not greatly change management. Nonetheless, we and others are of the opinion that the OSA diagnosis is important prognostically and we recommend OSA screening in bariatric cohorts. The OSA diagnosis can also help in getting surgery insurance coverage, which typically requires the documentation of comorbidities depending on the BMI range. In addition, more careful attention to detail may occur if the OSA diagnosis is known in the perioperative setting. A diagnosis may also help motivate some patients with OSA to pursue weight loss. Indeed, many bariatric programs, including our own, provide lifestyle and nutrition counseling preoperatively. These measures may well be helpful at least for a subset of patients undergoing surgery. Moreover, a diagnosis of moderate to severe OSA has health implications beyond perioperative management. For example, OSA is a cause of secondary hypertension and risk factor of cardiovascular disease; thus diagnosis and treatment would be beneficial for general health management regardless of whether a patient ends up having surgery (22,23).

The optimal approach to screening for OSA preoperatively is complex. Regarding decision analysis, one could argue that maximizing sensitivity is important since inadvertently sending an untreated patient with OSA to the operating room may yield catastrophic results. Moreover, optimizing specificity may be valuable if it could help reduce the need for unnecessary PSG. Cost and feasibility considerations also come into play since routine preoperative PSG may not be logistically feasible in many health systems. We are aware of litigation that has resulted from perioperative deaths, making medico-legal factors also important to consider before determining an optimal cost-effective and ethical approach. Of note, one review of legal literature showed an increase in malpractice suits related to perioperative complications because of OSA (24). Another consideration is the ease of implementing these screening tools in a clinical setting. No-Apnea has few components but it might be cumbersome to score. STOP-BANG has the advantages of familiarity among many providers and a straightforward scoring system.

The Hispanic/Latino community has received inadequate attention in the OSA literature. This community may be unique for several reasons. The Hispanic/Latino community has unique genetic factors as well as diet and exercise habits that may impact the occurrence of OSA, the distribution of body fat, and other important pathophysiological variables (25–27). In addition, the reporting of sleep symptoms may vary; for example, self-reported features, such as fatigue, may differ based on culture (28). Depending on socioeconomic status, some comorbidities may be underdiagnosed in disadvantaged populations, which could result in differences in screening questionnaires based on the quality of health care received. For instance, one study found decreased awareness, treatment, and management of hypertension

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(a component of STOP-BANG) in US Hispanic/Latinos compared with non-Hispanic/Latino white patients (29). Finally, the acceptance of CPAP may vary across different groups based on race and ethnicity (30). Thus, for a variety of reasons, we view the inclusion of Hispanic/Latino patients as a major strength of the present study. Our findings that the performance of the analyzed screening tools was similar in Hispanic/Latinos as compared with non-Hispanic/Latinos are reassuring, but we advocate for further study in this area.

Despite our study's strengths, we acknowledge some limitations. First, based on our study design, we cannot draw conclusions regarding the impact of interventions on patient outcomes. We did analyze the patients who underwent sleep testing compared with those who did not in our bariatric program and doubt that our results were importantly biased by this small group of patients who did not undergo sleep testing. Second, we included patients who underwent either HST or PSG, although we recognize these two tests may not be interchangeable. In general, HST relies on total recording time rather than total sleep time, so, in patients with poor sleep quality, HST may give a less reliable estimate of OSA severity compared with PSG. Moreover, HST is done in the patient's natural sleeping environment and may be more representative of the patient's usual sleep as compared with the in-laboratory setting for PSG. In general, the decision regarding HST versus PSG depends on the insurance provider, and we doubt there are any important biological differences between these groups. Our goal was to conduct a real-world study, and therefore we included both HST and PSG as per our usual care. Third, some participants may have used alcohol or hypnotics prior to their sleep study, which may have theoretically contributed to an AHI in the moderate to severe range. Given that patients may continue to use the same medications and consume the same degree of alcohol postoperatively, we did not think these variables would significantly change management. Moreover, the bulk of the data, including recent studies, suggests that common hypnotics do not systematically worsen sleep apnea (31–33). Fourth, based on the retrospective nature of our study, we relied on self-reported data and the information that was available in the electronic charts. For snoring, we relied on a yes/no question but could not verify whether a bed partner or other observer was present or not. Thus, some misreporting is possible if not likely. However, this problem exists in the real-world evaluation of these patients. Similarly, we had patients who did not complete the ESS or in whom neck circumference was not measured, but in general our data set is fairly complete. Despite these limitations, we view our findings as important and hope that they encourage further investigation in this area.

Conclusion

OSA is a highly prevalent disease with important risk, particularly in the perioperative period. The ideal approach to OSA perioperatively remains unclear, but our data suggest that STOP-BANG and NO-OSA may be useful screening tests for OSA in the bariatric patient population across diverse racial/ethnic backgrounds if the goal is to optimize both sensitivity and specificity. Moreover, in a preoperative setting in which a low rate of false-positive screening (i.e., high specificity) is not critically important (e.g., sleep studies are unavailable and screening is primarily for risk stratification), then No-Apnea and the ESS may be reasonable alternatives.Further data are required to determine the optimal management approach.

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Supplementary Material

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Study Importance

What is already known?

- Severe obstructive sleep apnea (OSA) has been associated with an increased risk of a composite end point of myocardial injury, cardiac death, heart failure, thromboembolism, atrial fibrillation, and stroke within 30 days of surgery.
- OSA is an independent risk factor for bariatric surgery complications.
- Established OSA screening tools include STOP-BANG and the Epworth Sleepiness Scale. Newer screening tools include NO-OSAS, which was specifically developed for the bariatric surgery population, and No-Apnea, a simplified tool developed from patients referred for polysomnography. The latter screening models have limited validation.

What does this study add?

- Here we validate the use of STOP-BANG, NO-OSAS, and No-Apnea for screening bariatric surgery patients for moderate to severe OSA.
- The optimal cutoff for STOP-BANG in our population was ≥ 4 (vs. ≥ 3 in nonbariatric populations).
- There were no significant differences in performance of screening questionnaires based on sex or ethnicity in our study.

How might these results change the focus of clinical practice?

- Our results support the need to screen for moderate to severe OSA in bariatric surgery patients given its high prevalence in this group.
- Our results support the use of newer screening tools (NO-OSAS and No-Apnea) and the alternative cutoff (≥ 4 vs. ≥ 3) for STOP-BANG in the clinical setting of a bariatric surgery evaluation.

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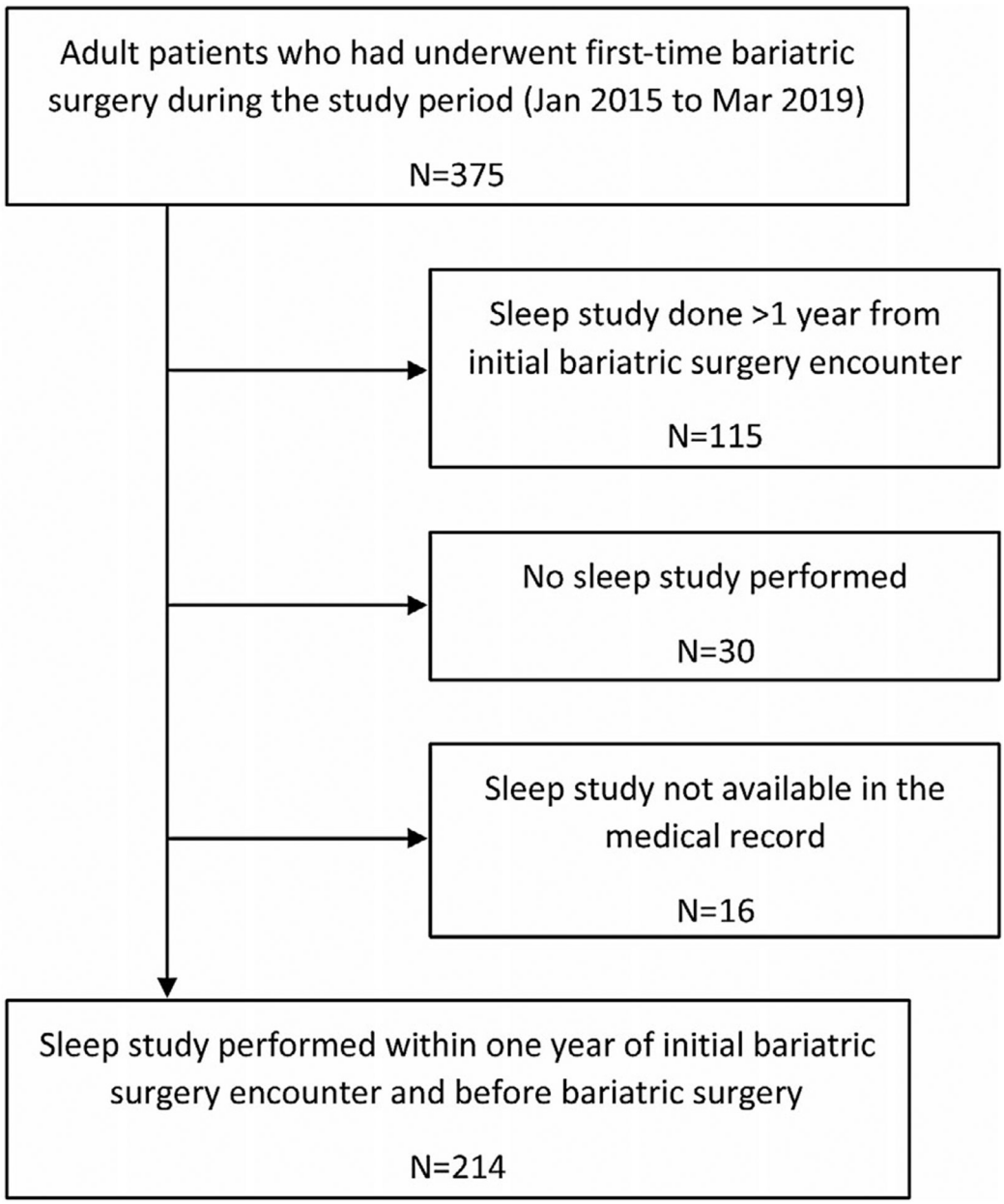

Figure 1.
Screening of study population.

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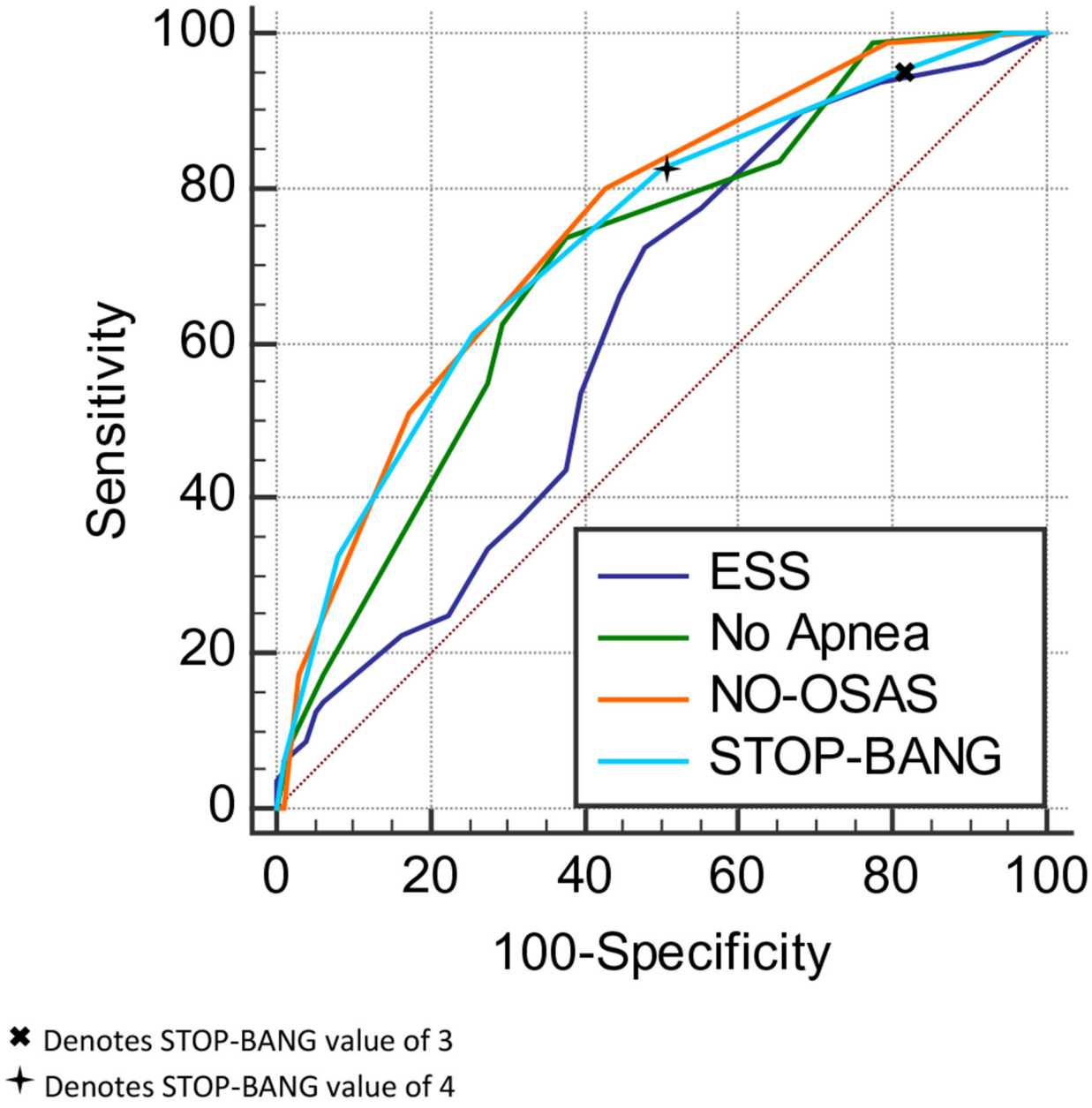

Figure 2.
Receiver operating characteristic curves of OSA screening tools.

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TABLE 1

Participant characteristics

	All included		No/mild OSA (AHI < 15/h)		Moderate/severe OSA (AHI ≥ 15/h)		
	Mean ± SD or % (n)	***N***	**Mean ± SD or % (n)**	***N***	**Mean ± SD or % (n)**	***N***	***P***
Patient demographics							
Male sex, % ***(n)***	16.8 (36)	214	10.3 (12)	117	24.7 (24)	97	< 0.01
Age, y	40.6 ± 11.2	214	38.1 ± 10.9	117	43.5 ± 10.9	97	< 0.01
Ethnicity		214		117		97	0.91
Hispanic/Latino	49.1 (105)		48.7 (57)		49.5 (48)		
Non-Hispanic/Latino	50.9 (109)		51.3 (60)		50.5 (49)		
Clinical variables							
BMI, kg/m^2	47.4 ± 8.6	214	46.4 ± 7.4	117	48 ± 9.7	97	0.08
Neck circumference, cm	41.6 ± 4.6	190	40.4 ± 4.3	103	42.9 ± 4.5	87	< 0.01
Snoring	81.8 (175)	214	74.4 (87)	117	90.7 (88)	97	< 0.01
Tiredness	59.9 (127)	212	55.7 (64)	115	64.9 (63)	97	0.17
Observed apnea	24.8 (51)	206	13.3 (15)	113	38.7 (36)	93	< 0.01
Hypertension	48.1 (103)	214	38.5 (45)	117	59.8 (58)	97	< 0.01
Epworth Sleepiness Scale	6.8 ± 4.9	198	6.0 ± 4.7	110	7.8 ± 4.9	88	0.01
Sleep study data							
Study type		214		117		97	0.37
Polysomnography	65.9 (141)		63.2 (74)		69.1 (67)		
Home sleep test	34.1 (73)		36.8 (43)		30.9 (30)		
AHI, events/h	21.2 ± 26.2	214	5.5 ± 4.0	117	40.2 ± 29.2	97	< 0.01
Lowest SpO_2, %	80.4 ± 10.2	213	84.7 ± 5.2	116	75.4 ± 12.3	97	< 0.01

SpO_2, lowest oxygen saturation.

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TABLE 2

Sensitivity, specificity, and accuracy of various cutoff points for OSA screening tools

Criterion	Sensitivity	(95% CI)	Specificity	(95% CI)	Accuracy[a]	(95% CI)
STOP-BANG						
≥ 2	100.0	(95.7–100.0)	5.0	(1.6–11.2)	48.1	(40.7–55.6)
≥ 3[b]	95.2	(88.3–98.7)	19.8	(12.5–28.9)	54.1	(46.6–61.4)
≥ 4[b]	83.3	(73.6–90.6)	50.5	(40.4–60.6)	65.4	(58.1–72.2)
≥ 5	63.1	(51.9–73.4)	75.3	(65.7–83.3)	69.7	(62.6–76.3)
≥ 6	35.7	(25.6–46.9)	92.1	(85.0–96.5)	66.5	(59.2–73.2)
NO-OSAS						
≥ 2	98.8	(93.5–100.0)	19.8	(12.5–28.9)	55.7	(48.2–63.0)
≥ 3[b]	81.0	(70.9–88.7)	57.4	(47.2–67.2)	68.1	(60.9–74.8)
≥ 4	52.4	(41.2–63.4)	82.2	(73.3–89.1)	68.7	(61.4–72.3)
≥ 5	20.2	(12.3–30.4)	97.0	(91.6–99.4)	62.2	(54.8–69.2)
≥ 6	2.4	(0.3–8.3)	99.0	(94.6–100.0)	55.1	(47.7–62.4)
No-Apnea						
≥ 2	97.7	(91.9–99.7)	22.3	(14.7–31.6)	56.8	(49.5–64.0)
≥ 3[b]	82.8	(73.2–90.0)	34.0	(24.9–44.0)	56.3	(48.9–63.5)
≥ 4	72.4	(61.8–81.5)	61.2	(51.1–70.6)	66.3	(59.1–73.0)
≥ 5	62.1	(51.0–72.3)	68.9	(59.1–77.7)	65.8	(58.6–72.5)
≥ 6	55.2	(44.1–65.9)	70.9	(61.1–79.4)	63.4	(56.4–70.5)
ESS						
≥ 1	96.6	(90.4–99.3)	8.2	(3.8–15.0)	47.5	(40.4–54.7)
≥ 2	93.2	(85.7–97.5)	20.0	(13.0–28.7)	52.5	(45.3–59.6)
≥ 3	88.6	(80.1–94.4)	30.9	(22.4–40.4)	56.6	(49.4–63.6)
≥ 4	77.3	(67.1–85.5)	42.7	(33.3–52.5)	58.1	(50.9–65.0)
≥ 5	71.6	(61.0–80.7)	50.0	(40.3–59.7)	59.6	(52.4–66.5)
≥ 6	65.9	(55.0–75.7)	53.6	(43.9–63.2)	59.1	(51.9–66.0)
≥ 7	53.4	(42.5–64.1)	59.1	(49.3–68.4)	56.6	(49.4–63.6)
≥ 8	43.2	(32.7–54.2)	61.8	(52.1–70.9)	53.5	(46.3–60.6)

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Criterion	Sensitivity	(95% CI)	Specificity	(95% CI)	Accuracy[a]	(95% CI)
≥ **9**	37.5	(27.4–48.5)	69.1	(59.6–77.6)	55.1	(47.8–62.1)
≥ **10**	34.1	(24.3–45.0)	73.6	(64.4–81.6)	56.1	(48.8–63.1)
≥ **11**[b]	**25.0**	(16.4–35.4)	79.1	(70.3–86.3)	55.1	(47.8–62.1)

[a] Accuracy = (TP + TN)/(TP + FP + FN + TN), where TP is true positive, FP is false positive, FN is false negative, and TN is true negative.

[b] Cutoffs commonly used for screening (see Methods).

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TABLE 3

Predictors of AHI ≥ 15 based on univariate and multivariate logistic regression models

	Univariate models			Multivariate model (forward selection)		
Variable	**Odds ratio**	**(95% CI)**	***P***	**Odds ratio**	**(95% CI)**	***P***
Observed apnea	4.13	(2.08–8.19)	<0.01 *	4.49	(2.05–9.80)	< 0.01 *
Neck circumference[a]	1.14	(1.06–1.22)	<0.01 *	1.15	(1.06–1.24)	< 0.01 *
Age[a]	1.05	(1.02–1.07)	< 0.01 *	1.05	(1.02 to 1.09)	< 0.01 *
Snoring	3.37	(1.51–7.52)	< 0.01 *			
Male sex	2.88	(1.35–6.12)	0.01 *			
Hypertension	2.38	(1.37–4.13)	< 0.01 *			
Tiredness	1.48	(0.85–2.58)	0.17			
ESS[a]	1.08	(1.02–1.15)	< 0.01 *			
BMI[a]	1.03	(1.00–1.06)	0.08			
Hispanic/Latino	1.03	(0.60–1.77)	0.91			

*$P < 0.05$.

[a]Variable analyzed as continuous variable.