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SCIENTIFIC INVESTIGATIONS

Diagnostic performance of the STOP-Bang questionnaire as a screening tool for obstructive sleep apnea in different ethnic groups

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Study Objectives: The STOP-Bang questionnaire is a concise and easy screening tool for obstructive sleep apnea (OSA). Using modified body mass index (BMI), we assessed the diagnostic performance of the STOP-Bang questionnaire in predicting OSA in ethnically different groups of patients undergoing surgery.

Methods: This was a multicenter prospective cohort study involving patients with cardiovascular risk factors who were undergoing major noncardiac surgery. Patients underwent home sleep apnea testing. All patients completed the STOP-Bang questionnaire. The predictive parameters of STOP-Bang scores were calculated against the apnea-hypopnea index.

Results: From 4 ethnic groups 1,205 patients (666 Chinese, 161 Indian, 195 Malay, and 183 Caucasian) were included in the study. The mean BMI ranged from 25 ± 4 to 30 ± 6 kg/m^2 and mean age ranged from 64 ± 8 to 71 ± 10 years. For the Chinese and Indian patients, diagnostic parameters are presented using BMI threshold of 27.5 kg/m^2 with the area under curve to predict moderate-to-severe OSA being 0.709 (0.665–0.753) and 0.722 (0.635–0.808), respectively. For the Malay and Caucasian, diagnostic parameters are presented using BMI threshold of 35 kg/m^2 with the area under curve for predicting moderate-to-severe OSA being 0.645 (0.572–0.720) and 0.657 (0.578–0.736), respectively. Balancing the sensitivity and specificity, the optimal STOP-Bang thresholds for the Chinese, Indian, Malay, and Caucasian groups were determined to be 4 or greater.

Conclusions: For predicting moderate-to-severe OSA, we recommend BMI threshold of 27.5 kg/m^2 for Chinese and Indian patients and 35 kg/m^2 for Malay and Caucasian patients. The optimal STOP-Bang threshold for the Chinese, Indian, Malay and Caucasian groups is 4 or greater.

Clinical Trial Registration: Registry: ClinicalTrials.gov; Name: Postoperative Vascular Events in Unrecognized Obstructive Sleep Apnea; URL: https://clinicaltrials.gov/ct2/show/study/NCT01494181; Identifier: NCT01494181.

Keywords: obstructive sleep apnea, STOP-Bang questionnaire, screening tool, body mass index, surgery

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BRIEF SUMMARY

Current Knowledge/Study Rationale: This study examines the diagnostic performance of the STOP-Bang Questionnaire as a screening tool for obstructive sleep apnea in different ethnic groups.

Study Impact: For predicting moderate-to-severe OSA, we recommend BMI thresholds of 27.5 kg/m^2 for Chinese and Indian patients and 35 kg/m^2 for Malay and Caucasian patients. The optimal STOP-Bang threshold for the Chinese, Indian, Malay, and Caucasian groups is 4 or greater.

INTRODUCTION

Obstructive sleep apnea (OSA) is a common sleep-disordered breathing characterized by repeated episodes of apnea and hypopnea. OSA is associated with hypertension, cardiovascular diseases, neurocognitive conditions, and increased all-cause mortality.[1] In the general population, the prevalence of moderate-to-severe OSA was reported to be 6 to 17%.[2] The gold standard for the diagnosis of OSA is polysomnography, but it is costly and time-consuming. Using a simple questionnaire for screening of adults with OSA provides a convenient tool to identify sleep-disordered breathing for further diagnostic testing and treatment.

Many tools have been developed to screen patients for OSA. The STOP-Bang questionnaire (snoring, tiredness, observed apnea, pressure, body mass index [BMI], age, neck circumference, and gender), originally developed on a mostly Caucasian population, is an easy-to-administer validated tool consisting of 8 items.[3–6] Compared with other populations, Asians, at lower BMI, have a high prevalence of OSA and have a higher body fat percentage.[7,8] Due to differences in morphology of the Asian population, the World Health Organization recommended alternate BMI thresholds (BMI of 23, 27.5, 32.5, and 37.5 kg/m^2) as indicators of additional health risks for Asians.[7] Therefore, a modified BMI for the Asian population needs to be evaluated with the STOP-Bang questionnaire. A number of studies reported the diagnostic performance of the STOP-Bang questionnaire in different Asian ethnic groups using either the standard BMI (35 kg/m^2) or a lower BMI threshold.[9–21] These studies followed younger patients, most of whom had been referred to sleep clinics. The diagnostic performance of the STOP-Bang questionnaire in the older surgical patients of the different Asian groups remained unknown. The objective of this study was to determine the diagnostic performance of the STOP-Bang questionnaire, using modified BMI threshold, as an OSA screening tool for surgical patients in different ethnic groups. We hypothesized that using a modified BMI threshold in different Asian ethnic groups would improve the diagnostic performance of the STOP-Bang questionnaire.

METHODS

Study design

The study was a planned, post-hoc analysis from a multicenter prospective cohort study on postoperative vascular complications in patients with unrecognized OSA undergoing major noncardiac surgery [Postoperative Vascular Complications in Unrecognized Obstructive Sleep Apnea study (POSA)].[22] Data were collected in 5 countries at 8 hospitals from January, 2012, to July, 2017. Approval was obtained from all participating institutions and written informed consent was given by all the patients. (ClinicalTrials.gov Identifier: NCT01494181)

Participants

The inclusion criteria of the study were: (1) age 45 years or older undergoing major noncardiac surgery (intraperitoneal, major orthopedic, or vascular) and (2) 1 or more risk factors for postoperative cardiovascular events (ie, history of coronary artery disease, heart failure, stroke, or transient ischemic attack, diabetes requiring treatment, and renal impairment with preoperative plasma creatinine concentration > 175 μmol/L). The exclusion criteria were: (1) prior diagnosis or undergoing corrective surgery for OSA and (2) patients requiring more than 2 days of mechanical lung ventilation after surgery.[22]

Procedure

Before surgery, the baseline characteristics and comorbidities of the patients were recorded by the research staff. Patients reported their ethnicity as Arab, Black, Chinese, Indian, Malay, and Caucasian. All patients underwent a preoperative overnight sleep study at home or in the hospital using a type 3 portable sleep monitoring device (ApneaLink Plus; ResMed, San Diego, CA). The sleep-associated apnea and hypopnea events were scored according to American Academy of Sleep Medicine criteria.[23] Apnea was defined as airflow reduction of ≥ 90% for ≥ 10 seconds from baseline. Hypopnea was defined as reduction in airflow for ≥ 30% for ≥ 10 seconds from baseline. Patients with an apnea-hypopnea index (AHI) ≥ 15 events/h were considered to have moderate-to-severe OSA, and those with AHI ≥ 30 events/h were considered to have severe OSA.[23,24]

The STOP-Bang Questionnaire

Research staff assessed all patients for risk of OSA before surgery using the STOP-Bang questionnaire. The STOP-Bang questionnaire consists of 8 questions requiring either a "Yes'' or "No'' response. The questions are as follows: (1) Do you snore loudly (louder than talking or loud enough to be heard through closed doors)? (2) Do you often feel tired, fatigued, or sleepy during daytime? (3) Has anyone observed you stop breathing or choking during your sleep? (4) Do you have or are you being treated for high blood pressure? (5) BMI is more than 35 kg/m^2. (6) Age is over 50 years old. (7) Neck circumference is greater than 40 cm. (8) Sex is male. Scores ranged from 0 to 8. A score of 3 or greater indicates an increased risk for OSA,[4] and a score of 5 or greater indicates a high risk for OSA.[3,4] The English version of the STOP-Bang questionnaire was used mostly. The questionnaire was translated using a forward and backward translation for Chinese, Indian, and Malay patients who did not speak English.

Patients, health care, and research personnel were blinded to the results of the sleep studies and the STOP-Bang scores. After surgery, patients with abnormal sleep study findings were referred to their local sleep clinic for further care.

Statistical analysis

The analysis was performed using Stata/SE 14.2 (StataCorp, College Station, TX). Patient characteristics were summarized using descriptive statistics. The mean (± standard deviation) or median (interquartile range) was used for continuous variables, and frequency (percentage) was used for categorical variables. Characteristics were compared across ethnic groups and between patients with or without moderate-to-severe OSA. Continuous variables were analyzed using one-way analysis of variance or Kruskal-Wallis test and independent sample *t* test or Wilcoxon rank-sum test. The categorical variables were analyzed using chi-square test or Fisher's exact test, as appropriate. Normality of variables were tested by the Kolmogorov-Smirnov test.

The predictive performance of the STOP-Bang questionnaire for moderate-to-severe (AHI ≥ 15 events/h) and severe (≥ 30 events/h) OSA was assessed using sensitivity, specificity, positive predictive values, negative predictive values, and area under receiver operating characteristics curve (AUROC). All parameters were reported with 95% confidence interval (CI). To compare the parameters, the McNemar's test was used. DeLong's test was used to compare the AUROC of BMI thresholds.[25] Using logistic regression, predictive probabilities were calculated for different cut-offs of AHI at each score of the STOP-Bang. $P < .05$ was considered statistically significant. The sample size was estimated based on the primary outcome of the original study, which involved examining the association between unrecognized OSA and 30-day postoperative complications after the surgery.[22]

RESULTS

In POSA, a total of 1,364 patients were recruited, 1,218 patients were included for analysis, and 146 patients were excluded because of cancelled surgery, failure of sleep study, or study duration less than 4 hours. In the current study, 1,205 patients belonging to 4 ethnic groups were included. Thirteen patients (Arab or Black) were excluded due to the small number (**Figure S1** in the supplemental material). The ethnic distribution of 1,205 patients was as follows: 666 Chinese, 161 Indian, 195 Malay, and 183 Caucasian.

The mean ages of Chinese, Indian, Malay, and Caucasian were 68 ± 9, 66 ± 10, 64 ± 8, and 71 ± 10 years, respectively ($P < .001$).

Table 1—Characteristics of patients in each ethnic group (n = 1,205).

Characteristics	Chinese	Indian	Malay	Caucasian	*P* Value
n (%)	666 (55)	161 (13)	195 (16)	183 (15)	–
BMI, kg/m^2	24.9 ± 4.1	27.4 ± 5.1	27.9 ± 6.2	30.1 ± 5.5	< .001
BMI > 35, n (%)	12 (1.8)	14 (8.7)	23 (11.8)	32 (17.5)	< .001
BMI > 30, n (%)	68 (10.2)	46 (28.6)	63 (32.3)	79 (43.2)	< .001
BMI > 27.5, n (%)	155 (23.3)	81 (50.3)	86 (44.1)	115 (62.8)	< .001
Age, years	67.5 ± 8.8	65.9 ± 9.7	64.0 ± 8.3	70.7 ± 10.3	< .001
Age > 50 years, n (%)	649 (97.5)	151 (93.8)	180 (92.3)	181 (98.9)	< .001
Male sex, n (%)	441 (66.2)	76 (47.2)	101 (51.8)	103 (56.3)	< .001
Neck circumference, cm	38.4 ± 3.2	37.8 ± 3.7	38.8 ± 4.1	39.3 ± 3.4	.001
Neck > 40 cm, n (%)	161 (24.2)	38 (23.6)	59 (30.3)	54 (29.5)	.200
Waist circumference, cm	89.6 ± 11.4	95.5 ± 11.8	96.8 ± 13.9	95.7 ± 9.8	< .001
STOP	1.8 ± 0.98	1.7 ± 1.0	1.5 ± 0.9	1.98 ± 1.0	< .001
STOP-Bang	3.7 ± 1.3	3.4 ± 1.4	3.4 ± 1.3	4 ± 1.4	< .001
STOP-Bang ≥ 3, n (%)	545 (81)	117 (72.7)	146 (74.5)	150 (81.9)	.015
STOP-Bang ≥ 4, n (%)	359 (53.9)	73 (45.3)	79 (40.5)	114 (62.3)	< .001
STOP-Bang ≥ 5, n (%)	165 (24.8)	39 (24.2)	34 (17.4)	74 (40.4)	< .001
STOP-Bang ≥ 6, n (%)	52 (7.8)	10 (6.2)	13 (6.7)	27 (14.8)	.009
Comorbidities, n (%)					
Smoking	81 (12.2)	9 (5.6)	17 (8.7)	28 (15.3)	.018
Hypertension	579 (86.9)	136 (84.5)	169 (86.7)	144 (78.7)	.042
History of stroke	111 (9.2)	17 (1.4)	16 (1.3)	32 (2.7)	.007
COPD	28 (4.2)	4 (2.5)	7 (3.6)	21 (11.5)	< .001
Asthma	38 (5.7)	13(8.1)	10 (5.1)	10 (5.5)	.639
Diabetes	543 (81.5)	128 (79.5)	143 (73.3)	115 (62.8)	< .001
Type of surgery, n (%)					< .001
Intraperitoneal	307 (46.1)	38 (23.6)	53 (27.2)	24 (13.1)	–
Orthopedic	111 (16.7)	81 (50.3)	51 (26.2)	115 (62.8)	–
Vascular	65 (9.8)	18 (11.2)	54 (27.7)	29 (15.8)	–
Other	183 (27.5)	24 (14.9)	37 (19)	15 (8.2)	–
Sleep study parameters					
AHI, events/h	7 (3–15)	8 (4–16)	11 (3–22)	9 (4–19)	.002
ODI, events/h	8.1 (4–16)	8.7 (5.0–17.4)	11.7 (5.8–23)	9.6 (5.2–16.8)	.002
Average SpO_2, %	95.1 ± 1.7	94.6 ± 2.2	94.7 ± 2.2	92.7 ± 2.1	< .001
Lowest SpO_2, %	78 ± 10.3	73.5 ± 13	76 ± 11.2	77.6 ± 10.9	< .001
AHI ≥ 5, n (%)	430 (64.6)	116 (72.1)	133 (68.2)	137 (74.9)	.033
AHI ≥ 15, n (%)	176 (26.4)	46 (28.6)	82 (42.1)	63 (34.4)	< .001
AHI ≥ 30, n (%)	72 (10.8)	17 (10.6)	28 (14.4)	25 (13.7)	.440

Continuous variables are expressed as mean ± standard deviation or median (interquartile) as appropriate and categorical variables were presented as frequency (percentage). One-way analysis of variance or Kruskal-Wallis test and chi-square or Fisher's exact tests were conducted to examine differences in the characteristics of patients for ethnic groups. AHI = apnea-hypopnea index, BMI = body mass index, COPD = chronic obstructive pulmonary disease, ODI = oxygen desaturation index, SpO_2 = oxygen saturation.

The mean BMI of Chinese, Indian, Malay, and Caucasian were 25 ± 4, 27 ± 5, 28 ± 6, and 30 ± 6 kg/m^2, respectively ($P < .001$). **Table 1** shows the total demographic characteristics for each ethnic group.

Among Chinese and Indian patients, compared to patients with AHI < 15, those with AHI ≥ 15 had significantly higher mean BMI [(24.3 ± 3.9 vs 26.3 ± 4.3 kg/m^2, $P < .001$) and (26.7 ± 4.8 vs 29.4 ± 5.5 kg/m^2, $P = 0.002$)] and neck circumference [(37.8 ± 3.0 vs 40.0 ± 3.2 cm, $P < .001$) and (37.3 ± 3.5 vs 39.0 ± 3.7 cm, $P = .007$)], respectively (**Table 2**). For Malay and Caucasian patients, mean BMI was not significantly different for patients with or without moderate-to-severe apnea (**Table 3**).

The prevalence of hypertension was 85% or greater in the Chinese, Indian, and Malay population, and the history of stroke was

Table 2—Characteristics of Chinese and Indian patients with moderate-to-severe sleep apnea (n = 1,205).

Characteristics	Chinese AHI < 15	Chinese AHI ≥ 15	*P* Value	Indian AHI < 15	Indian AHI ≥ 15	*P* Value
n (%)	490 (40.1)	176 (14.6)	–	115 (9.5)	46 (3.8)	–
BMI, kg/m^2	24.3 ± 3.9	26.3 ± 4.3	< .001	26.7 ± 4.8	29.4 ± 5.5	.002
BMI > 35, n (%)	4 (0.8)	8 (4.5)	.001	6 (5.2)	8 (17.4)	.013
BMI > 30, n (%)	37 (7.6)	31 (17.6)	< .001	26 (22.6)	20 (43.5)	.008
BMI > 27.5, n (%)	94 (19.2)	61 (34.7)	< .001	49 (42.6)	32 (69.6)	.002
Age, years	67.2 ± 8.6	68.3 ± 9.1	.132	65.9 ± 9.9	65.9 ± 9.3	.984
Age > 50 years, n (%)	478 (97.6)	171 (97.2)	.777	107 (93.0)	44 (95.7)	.536
Male sex, n (%)	305 (62.2)	136 (77.3)	< .001	50 (43.5)	26 (56.5)	.134
Neck circumference, cm	37.8 ± 3.0	40.0 ± 3.2	< .001	37.3 ± 3.5	39.0 ± 3.7	.007
Neck > 40 cm, n (%)	75 (15.3)	86 (48.9)	< .001	23 (20)	15 (32.6)	.089
Waist circumference, cm	88.3 ± 11.1	92.8 ± 12.2	< .001	95.2 ± 11.7	96.2 ± 12.3	.636
STOP	1.7 ± 0.96	2.1 ± 0.94	< .001	1.5 ± 0.9	2.1 ± 1.1	.0002
STOP-Bang	3.4 ± 1.2	4.4 ± 1.4	< .001	3.1 ± 1.3	4.2 ± 1.4	< .001
STOP-Bang ≥ 3, n (%)	385 (78.6)	160 (90.9)	< .001	77 (67.0)	40 (87.0)	.010
STOP-Bang ≥ 4, n (%)	226 (46.1)	133 (75.6)	< .001	42 (36.5)	31 (67.4)	< .001
STOP-Bang ≥ 5, n (%)	85 (17.3)	80 (45.5)	< .001	15 (13.0)	24 (52.2)	< .001
STOP-Bang ≥ 6, n (%)	15 (3.1)	37 (21)	< .001	5 (4.3)	5 (10.9)	.121
Comorbidities, n (%)						
Smoking	58 (11.8)	23 (13.1)	.687	7 (6.1)	2 (4.3)	1.000
History of stroke	78 (15.9)	33 (18.8)	.387	13 (11.3)	4 (8.7)	.780
Hypertension	414 (84.5)	165 (93.8)	.002	94 (81.7)	42 (91.3)	.130
COPD	19 (3.9)	9 (5.1)	.483	2 (1.7)	2 (4.3)	.322
Asthma	29 (5.9)	9 (5.1)	.693	9 (7.8)	4 (8.7)	1.000
Diabetes	398 (81.2)	145 (82.4)	.733	90 (78.3)	38 (82.6)	.537
Type of surgery, n (%)			.021			.325
Intraperitoneal	238 (48.6)	69 (39.2)	–	30 (26.1)	8 (17.4)	–
Orthopedic	77 (15.7)	34 (19.3)	–	57 (49.6)	24 (52.2)	–
Vascular	39 (8.0)	26 (14.8)	–	14 (12.2)	4 (8.7)	–
Other	136 (27.8)	47 (26.7)	–	14 (12.2)	10 (21.7)	–
Sleep study parameters						
AHI, events/h	5 (2–8)	25 (19–37)	< .001	6 (2–9)	26 (18–43)	< .001
ODI, events/h	6 (3–9.1)	25.2 (18.9–35.9)	< .001	6.5 (3.8–9.5)	24.7 (19–34)	< .001
Average SpO_2, %	95.4 ± 1.6	94.3 ± 1.9	< .001	95.1 ± 1.8	93.2 ± 2.6	< .001
Lowest SpO_2, %	80.0 ± 8.9	72.6 ± 11.9	< .001	76.7 ± 10.4	65.4 ± 15.1	< .001

Continuous variables are expressed as mean ± standard deviation or median (interquartile) as appropriate and categorical variables were presented as frequency (percentage). *t* test or Wilcoxon rank-sum test and Chi-square or Fisher's exact tests were conducted to examine differences in the patients with or without moderate-to-severe OSA for ethnic groups. AHI = apnea-hypopnea index, BMI = body mass index, COPD = chronic obstructive pulmonary disease, ODI = oxygen desaturation index, SpO_2 = oxygen saturation.

higher in the Chinese population at 9%. The prevalence of smoking was highest in the Caucasian (15%) and the Chinese (12%) populations, but the diagnosis of COPD was highest in the Caucasian population at 12%. The commonly performed surgical procedures were intraperitoneal or major orthopedic. Other variables for different ethnic groups are shown in **Table 1**, **Table 2**, and **Table 3**.

Optimal BMI threshold

AUROC across BMI values from > 23 to > 35 kg/m^2 was determined for different ethnic groups. In Chinese and Indian patients, a BMI threshold of > 27.5 kg/m^2 achieved a better predictive performance for moderate-to-severe and severe OSA. For predicting moderate-to-severe OSA, the AUROC values at BMI > 27.5 kg/m^2 for Chinese and Indian were 0.709 [95% CI, 0.665–0.753] and 0.722 (95% CI, 0.635–0.808), respectively (**Table S1** in the supplemental material). The AUROC for predicting severe OSA for Chinese and Indian were 0.756 (95% CI, 0.697–0.816) and 0.849 (95% CI, 0.765–0.932), respectively (**Table S1**). There was no significant difference in the AUROC vs other BMI thresholds. Despite no

Table 3—Characteristics of Malay and Caucasian patients with moderate-to-severe sleep apnea (n = 1,205).

Characteristics	Malaysian AHI < 15	Malaysian AHI ≥ 15	*P* Value	Caucasian AHI < 15	Caucasian AHI ≥ 15	*P* Value
n (%)	113 (9.4)	82 (6.8)	–	120 (9.6)	63 (5.2)	–
BMI, kg/m^2	27.9 ± 5.7	28.0 ± 6.7	.956	29.6 ± 5.1	31.0 ± 6.2	.104
BMI > 35, n (%)	11 (9.7)	12 (14.6)	.295	18 (15)	14 (22.2)	.222
BMI > 30, n (%)	38 (33.6)	25 (30.4)	.643	48 (40)	31 (49.2)	.232
BMI > 27.5, n (%)	55 (48.6)	31 (37.8)	.131	73 (60.8)	42 (66.7)	.438
Age, years	62.6 ± 8.4	65.9 ± 7.9	.007	70.3 ± 10.4	71.7 ± 10.1	.383
Age > 50 years, n (%)	101 (89.3)	79 (96.3)	.072	119 (99.2)	62 (98.4)	.641
Male sex, n (%)	47 (41.6)	54 (65.9)	.001	60 (50)	43 (68.3)	.018
Neck circumference, cm	38.5 ± 4.1	39.2 ± 4.1	.255	38.7 ± 3.4	40.3 ± 3.2	.004
Neck > 40 cm, n (%)	34 (30.1)	25 (30.5)	.952	31 (25.8)	23 (36.5)	.132
Waist circumference, cm	95.4 ± 12.6	98.8 ± 15.5	.095	95.2 ± 9.3	96.6 ± 10.9	.343
STOP	1.4 ± 0.8	1.6 ± 1.0	.055	1.8 ± 1.0	2.3 ± 1.0	.004
STOP-Bang	3.1 ± 1.2	3.7 ± 1.2	.0007	3.7 ± 1.4	4.5 ± 1.3	.0002
STOP-Bang ≥ 3, n (%)	76 (67.3)	70 (85.4)	.004	91 (75.8)	59 (93.7)	.003
STOP-Bang ≥ 4, n (%)	35 (31.0)	44 (53.7)	.001	65 (54.2)	49 (77.8)	.002
STOP-Bang ≥ 5, n (%)	14 (12.4)	20 (24.4)	.029	40 (33.3)	34 (54.0)	.007
STOP-Bang ≥ 6, n (%)	5 (4.4)	7 (8.5)	.238	13 (10.8)	14 (22.2)	.039
Comorbidities, n (%)						
Smoking	7 (6.2)	10 (12.2)	.198	17 (14.2)	11 (17.5)	.666
History of stroke	8 (7.1)	8 (9.8)	.501	16 (13.3)	16 (25.4)	.041
Hypertension	96 (84.9)	73 (89)	.409	90 (75)	54 (85.7)	.093
COPD	3 (2.7)	4 (4.9)	.457	12 (10)	9 (14.3)	.387
Asthma	8 (7.1)	2 (2.4)	.196	9 (7.5)	1 (1.6)	.168
Diabetes	85 (75.2)	58 (70.7)	.484	76 (63.3)	39 (61.9)	.849
Type of surgery, n (%)			.002			.796
Intraperitoneal	38 (33.6)	15 (18.3)	–	14 (11.7)	10 (15.9)	–
Orthopedic	33 (29.2)	18 (22.0)	–	78 (65.0)	37 (58.7)	–
Vascular	20 (17.7)	34 (41.5)	–	19 (15.8)	10 (15.9)	–
Other	22 (19.5)	15 (18.3)	–	9 (7.5)	6 (9.5)	–
Sleep study parameters						
AHI, events/h	4 (2–8)	25 (18–32)	< .001	6 (3–9)	24 (19–36)	< .001
ODI, events/h	6 (3.9–8.6)	25.1 (17.8–32.1)	< .001	6.4 (3.9–9.6)	22(15.8–29.6)	< .001
Average SpO_2, %	95.1 ± 1.9	94.2 ± 2.6	.005	93.0 ± 1.9	92.0 ± 2.2	.0023
Lowest SpO_2, %	80.1 ± 9.5	70.3 ± 11.0	< .001	80.1 ± 8.0	72.8 ± 13.7	< .001

Continuous variables are expressed as mean ± standard deviation or median (interquartile) as appropriate, and categorical variables were presented as frequency (percentage). *t* test or Wilcoxon rank-sum test and Chi-square or Fisher's exact tests were conducted to examine differences in the patients with or without moderate-to-severe OSA for ethnic groups. AHI = apnea-hypopnea index, BMI = body mass index, COPD = chronic obstructive pulmonary disease, ODI = oxygen desaturation index, SpO_2 = oxygen saturation.

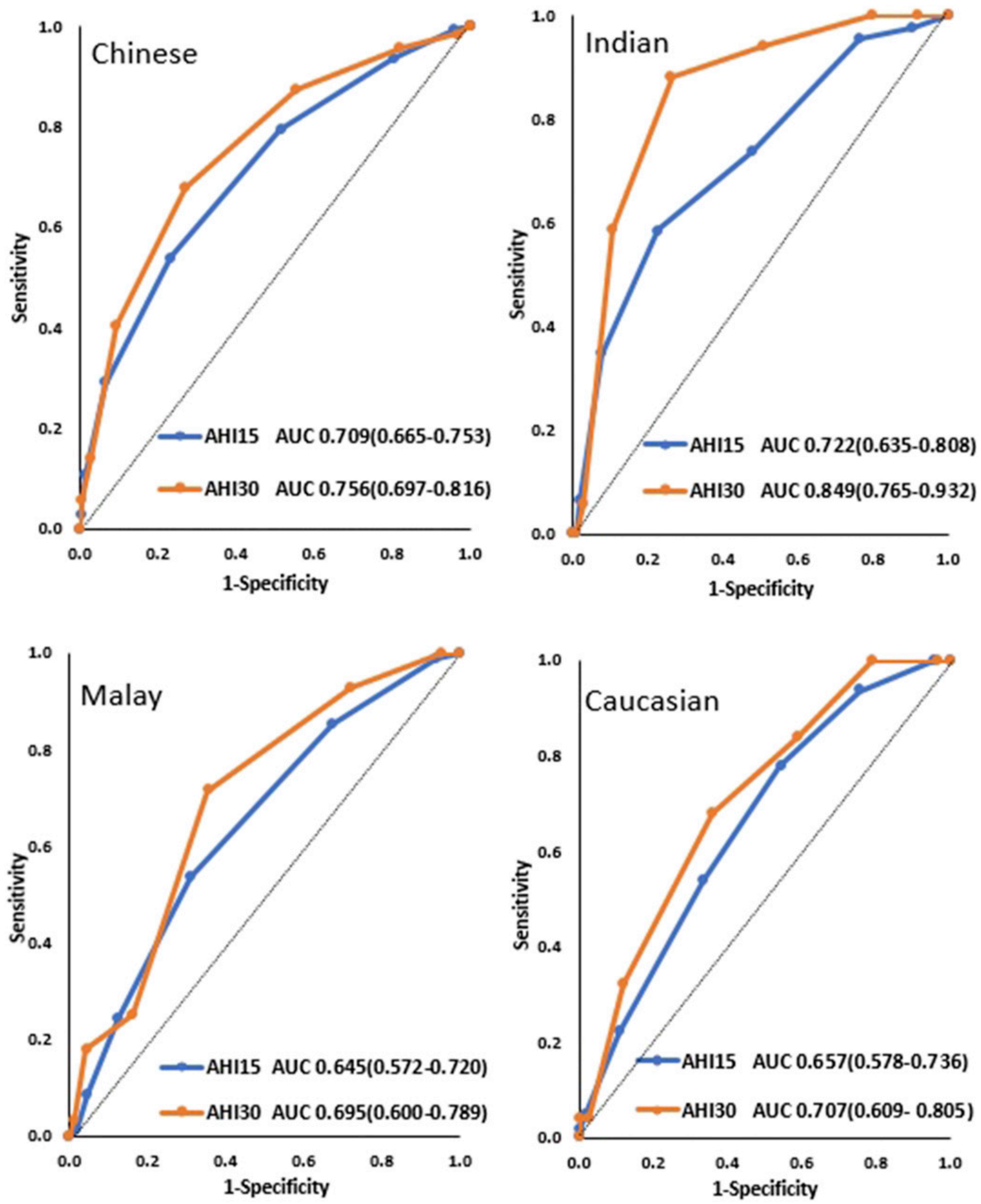
significant improvement, we chose 27.5 kg/m^2 for Chinese and Indian patients since the mean BMI for patients with moderate-to-severe OSA was lower (**Table 2**). Additionally, there were only 12 Chinese and 14 Indian patients with BMI > 35 kg/m^2 (**Table 1**).

In Malay patients, the best predictive performance was at BMI > 35 kg/m^2. The AUROC values at BMI > 35 kg/m^2 for predicting moderate-to-severe and severe OSA were 0.645 (95% CI, 0.572–0.720) and 0.695 (95% CI 0.600–0.789), respectively. There was a significant difference in the AUROC compared with other BMI thresholds (**Table S1**). The receiver operating curve analysis showed the AUC using optimal BMI thresholds for 4 different ethnic groups for predicting moderate-to-severe or severe OSA (**Figure 1**).

Chinese population

Based on an equipoise decision that privileged neither sensitivity nor specificity, using the > 27.5 kg/m^2 BMI threshold, the best discrimination score of the STOP-Bang for moderate-to-severe or severe OSA was 4 (**Table 4**). Comparing

Figure 1—Receiver operating curve for the STOP-Bang questionnaire using optimal BMI of 27.5 kg/m^2 for Chinese and Indian patients, and optimal BMI of 35 kg/m^2 for Malay and Caucasian patients for predicting moderate-to-severe and severe OSA.



Moderate-to-severe OSA defined as AHI ≥ 15 events/h and severe OSA defined as AHI ≥ 30 events/h. AH = apnea-hypopnea index, AUC, area under curve.

BMI > 27.5 kg/m^2 with > 35 kg/m^2, using a STOP-Bang score 4 or greater for predicting moderate-to-severe OSA increased the sensitivity significantly from 75.6% (95% CI, 69.3–81.1) to 79.5% (95% CI, 73.5–84.7) (*P* = .008), and the specificity decreased significantly from 53.9% (95% CI, 51.6–55.9) to 48.6% (95% CI, 46.4–50.4) (*P* = .001) (**Table 4**). This showed that the lower BMI threshold of > 27.5 kg/m^2 increased sensitivity but decreased specificity. The number of true positives increased from 133 to 140, although there was no significant improvement in AUROC when BMI threshold was > 27.5 kg/m^2.

Indian population

Based on the balance between optimal sensitivity and specificity with > 27.5 kg/m^2 BMI threshold, the STOP-Bang score 4 or greater was chosen as the best discrimination score to predict moderate-to-severe and severe OSA (**Table 5**). Comparing BMI > 27.5 kg/m^2 with > 35 kg/m^2 using the STOP-Bang score 4 or greater for predicting moderate-to-severe OSA, the sensitivity increased significantly from 67.4% (95% CI, 54.2–78.8) to 73.9% (95% CI, 60.8–84.5), *P* =.086, and the specificity decreased significantly from 63.5% (95% CI, 58.2–68.0) to 52.2% (95% CI, 46.9–56.4), *P* = .0003 (**Table 5**). Similarly,

Table 4—Diagnostic parameters of the STOP-Bang questionnaire using BMI > 27.5 kg/m^2 and 35 kg/m^2 for Chinese patients (n = 666).

	Score			
	≥ 3	≥ 4	≥ 5	≥ 6
BMI > 27.5 kg/m^2				
AHI ≥ 15 (moderate–to–severe sleep apnea) AUC: 0.709 AHI (0.665–0.753)				
n (%)	165 (24.8)	140 (21)	95 (14.3)	51 (7.7)
Sensitivity (%)	93.8 (89.4–96.6)	79.5 (73.5–84.7)	54 (47.6–60.1)	29 (24–33.5)
Specificity (%)	19.8 (18.2–20.8)	48.6 (46.4–50.4)	76.5 (74.2–78.7)	93.3 (91.5–94.9)
PPV (%)	29.6 (28.2–30.5)	35.7 (33.0–38.0)	45.2 (39.9–50.4)	60.7 (50.4–70.3)
NPV (%)	89.8 (82.7–94.5)	86.9 (83.0–90.2)	82.2 (79.8–84.6)	78.5 (77.0–79.9)
AHI ≥ 30 (severe sleep apnea) AUC: 0.756 AHI (0.697–0.816)				
n (%)	69 (10.3)	63 (9.6)	49 (7.4)	29 (4.4)
Sensitivity (%)	95.8 (87.9–98.9)	87.5 (77.6–93.7)	68.1 (56.7–77.9)	40.3 (30.2–50.7)
Specificity (%)	17.7 (16.7–18.1)	44.6 (43.4–45.4)	72.9 (71.5–74.1)	90.7 (89.5–92)
PPV (%)	12.49 (11.3–12.8)	16.1 (14.2–17.2)	23.3 (19.4–26.7)	34.5 (25.9–43.4)
NPV (%)	97.2 (92–99.3)	96.7 (94.1–98.3)	95.0 (93.2–96.5)	92.6 (91.4–93.9)
BMI > 35 kg/m^2				
AHI ≥ 15 (moderate–to–severe sleep apnea) AUC: 0.701 AHI (0.656–0.746)				
n (%)	160 (24)	133 (20)	80 (12)	37 (5.6)
Sensitivity (%)	90.9 (86.1–94.4)	75.6 (69.3–81.1)	45.5 (39.4–51.4)	21.0 (17.0–24.3)
Specificity (%)	21.4 (19.7–22.7)	53.9 (51.6–55.9)	82.7 (80.5–84.8)	96.9 (95.5–98.1)
PPV (%)	29.4 (27.8–30.5)	37.0 (34–39.8)	48.5 (42–54.8)	71.2 (57.5–82.2)
NPV (%)	86.8 (79.8–91.9)	86.0 (82.4–89.2)	80.8 (78.7–82.9)	77.4 (76.2–78.3)
AHI ≥ 30 (severe sleep apnea) AUC: 0.751 AHI (0.691–0.811)				
n (%)	68 (10.2)	61 (9.2)	44 (6.6)	19 (2.9)
Sensitivity (%)	94.4 (86.1–98.2)	84.7 (74.4–91.7)	61.1 (49.8–71.5)	26.4 (17.9–35.7)
Specificity (%)	19.7 (18.7–20.2)	49.8 (48.6–50.7)	79.6 (78.3–80.9)	94.4 (93.4–95.6)
PPV (%)	12.5 (11.4–13)	17.0 (14.9–18.4)	26.7 (21.7–31.2)	36.5 (24.8–49.4)
NPV (%)	96.7 (91.7–98.9)	96.4 (94–98)	94.4 (92.8–95.9)	91.4 (90.4–92.5)

AHI = apnea-hypopnea index, AUC = area under curve, BMI = body mass index, NPV = negative predictive value, PPV = positive predictive value, STOP-Bang = snoring, tiredness, observed apnea, pressure, BMI, age, neck circumference, and gender.

lowering BMI threshold in the Indian group increased the sensitivity and maximized the number of true positives, although there was no significant improvement in the AUC.

Malay population

Based on the optimal sensitivity and specificity with > 35 kg/m^2 BMI threshold, the STOP-Bang score 4 or greater can be chosen as the best discrimination score to predict moderate-to-severe and severe OSA (**Table 6**). For the Malay patients, when BMI threshold > 35 kg/m^2 was used, the sensitivity and specificity of the STOP-Bang score ≥ 4 for predicting moderate-to-severe OSA was 53.7% (95% CI, 45.0–61.9) and 69.0% (95% CI, 62.7–75.0), respectively (**Table 6**).

Caucasian population

Based on the optimal sensitivity and specificity with > 35 kg/m^2 BMI threshold, a STOP-Bang score 4 or greater can be chosen as the best discrimination score to predict moderate-to-severe and severe OSA in Caucasian patients (**Table 6**). Using BMI of > 35 kg/m^2 for the STOP-Bang questionnaire, the sensitivity and specificity at a score 4 or greater for predicting moderate-to-severe OSA was 77.7% (95%CI, 67.5–86.2) and 45.8% (95% CI, 40.4–50.3), respectively (**Table 6**).

Probabilities of moderate-to-severe and severe OSA

The predicted probabilities of moderate-to-severe and severe OSA increased with a higher STOP-Bang score. The trend was similar across each ethnic group. For Chinese, Indian, Malay, and Caucasian, at a STOP-Bang score of 4, the probability of moderate-to-severe OSA was 25%, 28%, 48%, and 33%, respectively. For severe OSA, the probabilities were 8%, 6%,

Table 5—Diagnostic parameters of the STOP-Bang questionnaire using BMI > 27.5 kg/m^2 and > 35 kg/m^2 for Indian patients (n = 161).

	Score			
	≥ 3	≥ 4	≥ 5	≥ 6
BMI > 27.5 kg/m^2				
AHI ≥ 15 (moderate–to–severe sleep apnea) AUC: 0.722 AHI (0.635–0.808)				
n (%)	44 (27.3)	34 (21.1)	27 (16.8)	16 (9.9)
Sensitivity (%)	95.7 (85.7–99.2)	73.9 (60.8–84.5)	58.7 (45.8–70.3)	34.8 (24.2–43.6)
Specificity (%)	23.5 (19.5–24.9)	52.2 (46.9–56.4)	77.4 (72.2–82.0)	92.2 (87.9–95.7)
PPV (%)	33.3 (29.9–34.6)	38.2 (31.4–43.7)	50.9 (39.8–61.0)	64 (44.5–80.3)
NPV (%)	93.1 (77.4–98.8)	83.3 (75.0–90.1)	82.4 (76.9–87.4)	77.9 (74.4–80.9)
AHI ≥ 30 (severe sleep apnea) AUC: 0.849 AHI (0.765–0.932)				
n (%)	17 (10.5)	16 (9.9)	15 (9.3)	10 (6.2)
Sensitivity (%)	100 (78.8–100)	94.1 (70.5–99.7)	88.2 (63.8–97.9)	58.8 (35.4–79)
Specificity (%)	20.1 (17.6–20.1)	49.3 (46.5–50.0)	73.6 (70.7–74.8)	89.6 (86.8–92)
PPV (%)	12.9 (10.2–12.9)	18.0 (13.5–19.0)	28.3 (20.5–31.4)	40 (24.1–53.7)
NPV (%)	100 (87.6–100)	98.6 (93–99.9)	98.1 (94.3–99.7)	94.9 (91.9–97.4)
BMI > 35 kg/m^2				
AHI ≥ 15 (moderate–to–severe sleep apnea) AUC 0.714 AHI (0.624–0.804)				
n (%)	40 (24.8)	31 (19.3)	24 (14.9)	5 (3.1)
Sensitivity (%)	87.0 (75.2–94.4)	67.4 (54.2–78.8)	52.2 (40.1–62.8)	10.9 (4.5–17.3)
Specificity (%)	33.0 (28.3–36.0)	63.5 (58.2–68.0)	87.0 (82.1–91.2)	95.7 (93.1–98.2)
PPV (%)	34.2 (29.6–37.1)	42.5 (34.1–49.7)	61.5 (47.3–74.0)	50.0 (20.6–79.4)
NPV (%)	86.4 (74.1–94.1)	83.0 (76.0–88.9)	82.0 (77.4–86.0)	72.8 (70.9–74.8)
AHI ≥ 30 (severe sleep apnea) AUC: 0.833 AHI (0.757–0.909)				
n (%)	17 (10.6)	16 (9.9)	12 (7.4)	3 (1.9)
Sensitivity (%)	100 (78.4–100)	94.1 (70.5–99.7)	70.6 (45.8–88.2)	17.6 (4.9–36.5)
Specificity (%)	30.6 (28.0–30.6)	60.4 (57.6–61.1)	81.3 (78.3–83.3)	95.1 (93.6–97.4)
PPV (%)	14.5 (11.4–14.5)	21.9 (16.4–23.2)	30.8 (20.0–38.5)	30.0 (8.3–62.1)
NPV (%)	100 (91.7–100)	98.9 (93.9–99.9)	95.9 (92.4–98.4)	90.7 (89.3–92.9)

AHI = apnea-hypopnea index, AUC = area under curve, BMI = body mass index, NPV = negative predictive value, PPV = positive predictive value, STOP-Bang = snoring, tiredness, observed apnea, pressure, BMI, age, neck circumference, and gender.

17%, and 11%, respectively (**Figure 2**). At a STOP-Bang score of 5, the probability of moderate-to-severe OSA for Chinese, Indian, Malay, and Caucasian, was 38%, 40%, 58%, and 43%, respectively. For severe OSA, the probabilities were 16%, 15%, 25%, and 18%, respectively (**Figure 2**). Using the STOP-Bang scores, Malay had the highest probability for predicting moderate-to-severe and severe OSA.

DISCUSSION

Our study examined the diagnostic performance of the STOP-Bang questionnaire by comparing different BMI thresholds for 4 ethnic groups: Chinese, Indian, Malay, and Caucasian. Our results showed that BMI > 27.5 kg/m^2 for Chinese and Indian had one of the higher AUROC for predicting moderate-to-severe and severe OSA. For the Malay, BMI > 35 kg/m^2 had the higher AUROC for predicting moderate-to-severe and severe OSA. Additionally, we found that when comparing the diagnostic performance for predicting moderate-to-severe or severe OSA, the Indian patients had the best diagnostic parameters compared to Chinese and Malay patients.

Balancing the optimal sensitivity and specificity, the optimal STOP-Bang threshold for the Chinese, Indian, Malay, and Caucasian was 4. Previously in Caucasian obese surgical patients, we recommended using a STOP-Bang score of 4 as the optimal threshold.[26] For all the different ethnic groups, the probabilities of moderate-to-severe and severe OSA increased with a higher STOP-Bang score. At each STOP-Bang score, the Malay patients had the highest probability for predicting moderate-to-severe and severe OSA compared with other ethnic groups. In the surgical population with a low prevalence of severe OSA, a higher score of 4 may be useful to reduce false positive rate. This

Table 6—Diagnostic parameters of the STOP-Bang questionnaire for Malay (n = 195) and Caucasian (n = 183) patients using BMI > 35 kg/m^2.

	Score			
	≥ 3	≥ 4	≥ 5	≥ 6
Malay patients				
AHI ≥ 15 (moderate–to–severe sleep apnea) AUC: 0.645 (0.572–0.720)				
n (%)	70 (35.9)	44 (22.5)	20 (10.2)	7 (3.5)
Sensitivity (%)	85.4 (77.7–91.4)	53.7 (45.0–61.9)	24.4 (17.5–30.6)	8.5 (4.3–12.2)
Specificity (%)	32.7 (27.2–37.1)	69.0 (62.7–75.0)	87.6 (82.6–92.1)	95.6 (92.5–98.2)
PPV (%)	47.9 (43.6–51.3)	55.7 (46.7–64.2)	58.8 (42.3–73.9)	58.3 (29.1–83.2)
NPV (%)	75.5 (62.7–85.6)	67.2 (61.1–73.0)	61.5 (580–64.7)	59 (57.1–60.6)
AHI ≥ 30 (severe sleep apnea) AUC: 0.695 (0.600–0.789)				
n (%)	26 (13.3)	20 (10.2)	7 (3.6)	5 (2.5)
Sensitivity (%)	92.9 (76.5–98.7)	71.4 (52.6–85.6)	25.0 (11.9–42.5)	17.9 (7.3–30.0)
Specificity (%)	28.1 (25.4–29.1)	64.7 (61.5–67.1)	83.8 (81.6–86.8)	95.8 (94.0–97.8)
PPV (%)	17.8 (14.7–18.9)	25.3 (18.6–30.4)	20.6 (9.8–35.0)	41.7 (17.0–70.1)
NPV (%)	95.9 (86.6–99.3)	93.1 (88.6–96.5)	87.0 (84.7–90.0)	87.4 (85.8–89.3)
Caucasian patients				
AHI ≥ 15 (moderate–to–severe sleep apnea) AUC: 0.657 (0.578–0.736)				
n (%)	59 (32.2)	49 (26.8)	34 (18.6)	14 (7.7)
Sensitivity (%)	93.7 (85.5–97.9)	77.7 (67.5–86.2)	54.0 (43.0–64.0)	22.2 (14.4–29.9)
Specificity (%)	24.2 (19.9–26.4)	45.8 (40.4–50.3)	66.7 (61.1–72.0)	89.2 (85.0–93.2)
PPV (%)	39.3 (35.9–41.1)	43.0 (37.3–41.6)	45.9 (36.9–54.6)	51.9 (33.5–69.7)
NPV (%)	87.9 (72.4–96.0)	79.7 (70.3–87.4)	73.4 (67.2–79.3)	68.6 (65.4–71.7)
AHI ≥ 30 (severe sleep apnea) AUC: 0.707 (0.609– 0.805)				
n (%)	25 (13.6)	21 (11.5)	17 (9.3)	8 (4.4)
Sensitivity (%)	100 (84.8–100)	84.0 (64.5–94.7)	68.0 (47.9–83.8)	32.0 (16.6–50.1)
Specificity (%)	20.9 (18.5–20.9)	41.1 (38.1–42.8)	63.9 (60.7–66.4)	88.0 (85.5–90.8)
PPV (%)	16.7 (14.1–16.7)	18.4 (14.2–20.8)	23.0 (16.2–28.3)	29.6 (15.3–46.4)
NPV (%)	100 (88.5–100)	94.2 (87.2–98.1)	92.7 (88.0–96.3)	89.1 (86.6–92.0)

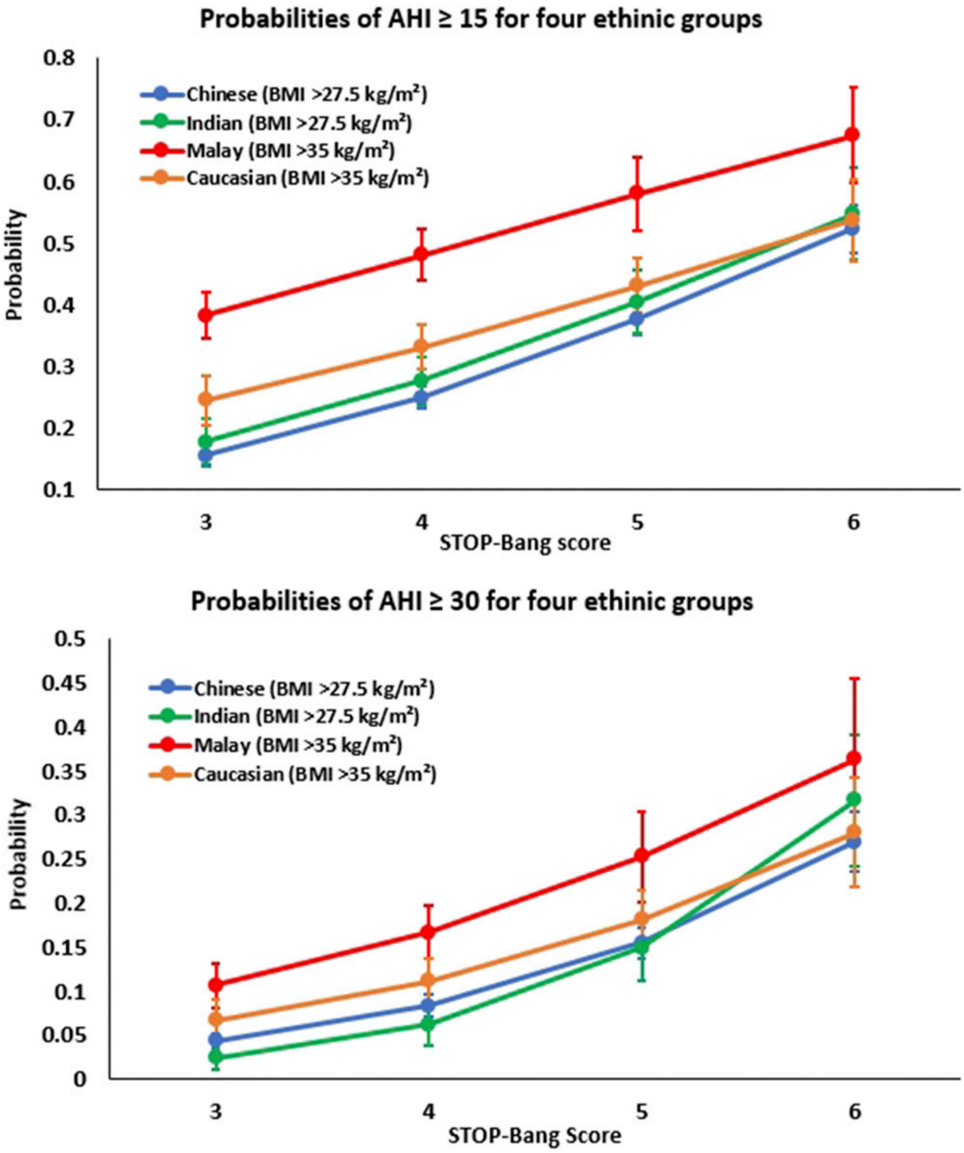
AHI = apnea-hypopnea index, AUC = area under curve, BMI = body mass index, NPV = negative predictive value, PPV = positive predictive value, STOP-Bang = snoring, tiredness, observed apnea, pressure, BMI, age, neck circumference, and gender.

enables identification of patients who are in urgent need of evaluation and to mitigate possible harm due to unrecognized OSA.[27]

In previous studies on the Asian population, most patients were from sleep clinics, where they had been referred for sleep-disordered breathing.[10–15] Patients who were referred to sleep clinics for sleep issues have a higher prevalence of OSA, and the results are therefore prone to selection bias. In our study on surgical populations with cardiovascular risk factors, we found that the prevalence of moderate-to-severe OSA was 26% to 42% and severe OSA was 11% to 14% in the 4 ethnic groups, which is much lower than the prevalence of moderate-to-severe (49% to 80%) and severe (32% to 64%) OSA in the studies involving Asian sleep clinic patients.[10–15] By including a surgical population with lower prevalence of OSA, our findings might be better representative of the general population and allow the results to be generalized to the wider community.

In 2 previous studies, 3 Asian groups (Chinese, Indian, and Malay) were assumed to have similar characteristics and were treated as 1 group.[9,10] Our study found differences among the 3 Asian ethnic groups. Post-hoc analysis showed that Chinese patients had significantly lower mean BMI and waist circumference compared with Indian and Malay patients. In contrast to the Chinese and Indians, the Malays had a significantly higher proportion of patients with BMI > 35 kg/m^2. Also, the Malays had a significantly higher proportion of patients with moderate-to-severe OSA. These characteristics may account for the higher BMI (> 35 kg/m^2) as the optimal threshold for the Malay group. Due to these differences in the characteristics of the 3 Asian ethnic groups, we analyzed each ethnic group independently instead of grouping them as one. Our findings showed different performance of the STOP-Bang questionnaire among Chinese, Indian, and Malay, indicating that diagnostic

Figure 2—The predicted probabilities for sleep apnea using the STOP-Bang score with the optimal BMI thresholds for Chinese, Indian, Malay, and Caucasian patients for moderate-to-severe and severe OSA.



Vertical bars represent standard errors of the mean. Moderate-to-severe OSA defined as AHI ≥ 15 events/h and severe OSA defined as AHI ≥ 30 events/h. AHI = apnea-hypopnea index, BMI = body mass index, OSA = obstructive sleep apnea.

performance of the screening tool needs to be examined in each ethnic population independently.

Sensitivity and specificity

An ideal screening tool should have both high sensitivity and specificity at the same threshold value. However, this is a rare situation. For most screening tools, there is a trade-off between sensitivity and specificity.[28] Among Chinese and Indian patients, a lower BMI threshold increased the sensitivity but decreased the specificity of the STOP-Bang questionnaire with small improvement in AUROC. High sensitivity is desirable for a screening tool, as it will enable identification of most patients with OSA. For instance, in the Indian population, when using BMI > 35 kg/m^2 vs > 27.5 kg/m^2, the sensitivity of the STOP-Bang score ≥ 4 for predicting moderate-to-severe OSA increased from 67.4% (95% CI, 54.2–78.8) to 73.9% (95% CI, 60.8–84.5), enabling more people with moderate-to-severe OSA to be identified. In addition to identifying moderate-to-severe OSA, it is important that those stratified to be at low risk do actually have a low risk of OSA. When using BMI > 35 kg/m^2 vs > 27.5 kg/m^2 for Indian patients, at a score of ≥ 3, the negative predictive value increased from 86.4% (95% CI, 74.1–94.1) to 93.1% (95% CI, 77.4–98.8) for moderate-to-severe OSA. A high negative predictive value assures the physician that the possibility of moderate-to-severe OSA may be safely excluded.

A screening tool should also have adequate specificity to minimize the false positives. In our study, using a lower BMI threshold in the Asian patients, the specificity decreased. In the

Asian patients, the phenotypes of craniofacial features, such as retrognathia, long soft palate, tongue position, are contributing factors for OSA.[29,30] In the Asian population, the anthropometric factors may play an important role beyond the contribution of BMI in the underlying causation of OSA. Some studies had recommended using additional criteria, for instance, using the STOP questionnaire with male or BMI only, or adding waist-to-height ratio or serum bicarbonate level to the STOP-Bang questionnaire. These measures improve the specificity and diagnostic performance of a screening tool.[11,28,31,32]

Probability

A concise and easy-to-use screening tool is useful in the preoperative assessment of patients with unrecognized OSA. Correctly identifying patients at high risk of OSA is the first step for the perioperative care of patients and prevention of adverse events.[33–35] Recent systematic reviews and reports showed that patients with OSA had a higher risk of postoperative complications, death, or near-death.[36–38] A recent large prospective cohort study showed that patients with a STOP-Bang score 5 or greater was significantly associated with an increased rate of postoperative vascular events. Patients with a STOP-Bang score 3 and 4 was significantly associated with intensive care readmission and wound infection.[22] Health professionals should use the probability of severe OSA and the severity of surgery in each ethnic group as thresholds to determine those most in need of further evaluation.

Limitation

Our study has potential limitations. Patients underwent type 3 portable sleep monitoring instead of in-laboratory polysomnography. The total sleep time may have been inaccurate, leading to underestimation of the AHI. Also, there may be rather high misclassification of obstructive sleep apnea by single-night studies; repeat studies may improve these predictive analytics. However, there is a good agreement between polysomnography and home sleep apnea testing in estimating AHI when predicting severe OSA.[39,40] The prevalence of obstructive sleep apnea in our surgical population was higher than reported in the general population.[2] Since the data were collected in surgical patients with cardiovascular risk factors, the results may not be applicable to other populations.

CONCLUSIONS

Our study showed that lowering BMI thresholds in the Chinese and Indian populations increased the sensitivity and maximized the number of true positives with no significant change in the AUC. In clinical situations when there is a high risk associated with an undiagnosed condition, a tool with high sensitivity should be strongly considered. For predicting moderate-to-severe and severe OSA in patients above the age of 45, we recommend the BMI threshold of 27.5 kg/m^2 for the Chinese and Indian populations, and 35 kg/m^2 for Malay and Caucasian patients. Balancing the optimal sensitivity and specificity, the optimal STOP-Bang threshold for the Chinese, Indian, Malay, and Caucasian surgical patients was determined to be 4 or greater. The Malay had the highest probabilities of moderate-to-severe and severe OSA compared to the other ethnic groups at each STOP-Bang score.

ABBREVIATIONS

AHI, apnea-hypopnea index
AUC, area under curve
AUROC, area under the receiver operating characteristic curve
BMI, body mass index
CI, confidence interval
OSA, obstructive sleep apnea
POSA, Postoperative Vascular Complications in Unrecognized Obstructive Sleep Apnea study
STOP-Bang, snoring, tiredness, observed apnea, pressure, BMI, age, neck circumference, and gender

REFERENCES

1. Benjafield AV, Ayas NT, Eastwood PR, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. *Lancet Respir Med.* 2019;7(8):687–698.
2. Senaratna CV, Perret JL, Lodge CJ, et al. Prevalence of obstructive sleep apnea in the general population: A systematic review. *Sleep Med Rev.* 2017;34:70–81.
3. Chung F, Subramanyam R, Liao P, Sasaki E, Shapiro C, Sun Y. High STOP-Bang score indicates a high probability of obstructive sleep apnoea. *Br J Anaesth.* 2012;108(5):768–775.
4. Chung F, Yegneswaran B, Liao P, et al. Validation of the Berlin questionnaire and American Society of Anesthesiologists checklist as screening tools for obstructive sleep apnea in surgical patients. *Anesthesiology.* 2008;108(5):822–830.
5. Chiu HY, Chen PY, Chuang LP, et al. Diagnostic accuracy of the Berlin questionnaire, STOP-BANG, STOP, and Epworth sleepiness scale in detecting obstructive sleep apnea: A bivariate meta-analysis. *Sleep Med Rev.* 2017;36:57–70.
6. Nagappa M, Liao P, Wong J, et al. Validation of the STOP-Bang questionnaire as a screening tool for obstructive sleep apnea among different populations: a systematic review and meta-analysis. *PLoS One.* 2015;10(12):e0143697.
7. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet.* 2004;363(9403):157–163.
8. Ko GT, Tang J, Chan JC, et al. Lower BMI cut-off value to define obesity in Hong Kong Chinese: an analysis based on body fat assessment by bioelectrical impedance. *Br J Nutr.* 2001;85(2):239–242.
9. Tan A, Yin JD, Tan LW, van Dam RM, Cheung YY, Lee CH. Predicting obstructive sleep apnea using the STOP-Bang questionnaire in the general population. *Sleep Med.* 2016;27–28:66–71.
10. Ong TH, Raudha S, Fook-Chong S, Lew N, Hsu AA. Simplifying STOP-BANG: use of a simple questionnaire to screen for OSA in an Asian population. *Sleep Breath.* 2010;14(4):371–376.
11. Banhiran W, Durongphan A, Saleesing C, Chongkolwatana C. Diagnostic properties of the STOP-Bang and its modified version in screening for obstructive sleep apnea in Thai patients. *J Med Assoc Thai.* 2014;97(6):644–654.
12. Abdullah B, Idris AI, Mohammad ZW, Mohamad H. Validation of Bahasa Malaysia STOP-BANG questionnaire for identification of obstructive sleep apnea. *Sleep Breath.* 2018;22(4):1235–1239.
13. Luo J, Huang R, Zhong X, Xiao Y, Zhou J. STOP-Bang questionnaire is superior to Epworth sleepiness scales, Berlin questionnaire, and STOP questionnaire in screening obstructive sleep apnea hypopnea syndrome patients. *Chin Med J (Engl).* 2014;127(17):3065–3070.
14. Hu YY, Yu Y, Wang ZB, Liu C, Cui YH, Xiao WM. Reliability and validity of simplified Chinese STOP-BANG questionnaire in diagnosing and screening obstructive sleep apnea hypopnea syndrome. *Curr Med Sci.* 2019;39(1):127–133.
15. Prasad KT, Sehgal IS, Agarwal R, et al. Assessing the likelihood of obstructive sleep apnea: a comparison of nine screening questionnaires. *Sleep Breath.* 2017;21(4):909–917.
16. Devaraj U, Rajagopala S, Kumar A, Ramachandran P, Devereaux PJ, D'Souza GA. Undiagnosed obstructive sleep apnea and postoperative outcomes: a prospective observational study. *Respiration.* 2017;94(1):18–25.

17. Ha SC, Lee DL, Abdullah VJ, van Hasselt CA. Evaluation and validation of four translated Chinese questionnaires for obstructive sleep apnea patients in Hong Kong. *Sleep Breath*. 2014;18(4):715–721.
18. Jeon HJ, Bang YR, Yoon IY. A validation study on three screening questionnaires for obstructive sleep apnea in a Korean community sample. *Sleep Breath*. 2019;23(3):969–977.
19. Kim B, Lee EM, Chung YS, Kim WS, Lee SA. The utility of three screening questionnaires for obstructive sleep apnea in a sleep clinic setting. *Yonsei Med J*. 2015;56(3):684–690.
20. Xia M, Liu S, Ji N, et al. BMI 35 kg/m^2 does not fit everyone: a modified STOP-Bang questionnaire for sleep apnea screening in the Chinese population. *Sleep Breath*. 2018;22(4):1075–1082.
21. Rong Y, Wang S, Wang H, et al. Validation of the NoSAS score for the screening of sleep-disordered breathing in a sleep clinic. *Can Respir J*. 2020;2020:4936423.
22. Chan MTV, Wang CY, Seet E, et al. Postoperative Vascular Complications in Unrecognized Obstructive Sleep Apnea (POSA) Study Investigators. Association of unrecognized obstructive sleep apnea with postoperative cardiovascular events in patients undergoing major noncardiac surgery. *JAMA*. 2019;321(18):1788–1798.
23. Collop NA, Tracy SL, Kapur V, et al. Obstructive sleep apnea devices for out-of-center (OOC) testing: technology evaluation. *J Clin Sleep Med*. 2011;7(5):531–548.
24. Berry RB, Budhiraja R, Gottlieb DJ, et al. Deliberations of the Sleep Apnea Definitions Task Force of the American Academy of Sleep Medicine. Rules for scoring respiratory events in sleep: update of the 2007 AASM Manual for the Scoring of Sleep and Associated Events. *J Clin Sleep Med*. 2012;8(5):597–619.
25. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*. 1988;44(3):837–845.
26. Chung F, Yang Y, Liao P. Predictive performance of the STOP-Bang score for identifying obstructive sleep apnea in obese patients. *Obes Surg*. 2013;23(12):2050–2057.
27. Farney RJ, Walker BS, Farney RM, Snow GL, Walker JM. The STOP-Bang equivalent model and prediction of severity of obstructive sleep apnea: relation to polysomnographic measurements of the apnea/hypopnea index. *J Clin Sleep Med*. 2011;7(5):459–65B.
28. Chung F, Yang Y, Brown R, Liao P. Alternative scoring models of STOP-bang questionnaire improve specificity to detect undiagnosed obstructive sleep apnea. *J Clin Sleep Med*. 2014;10(9):951–958.
29. Xu L, Keenan BT, Wiemken AS, et al. Differences in three-dimensional upper airway anatomy between Asian and European patients with obstructive sleep apnea. *Sleep*. 2020;43(5):zsz273. .
30. Lee RW, Vasudavan S, Hui DS, et al. Differences in craniofacial structures and obesity in Caucasian and Chinese patients with obstructive sleep apnea. *Sleep*. 2010;33(8):1075–1080.
31. Chung F, Chau E, Yang Y, Liao P, Hall R, Mokhlesi B. Serum bicarbonate level improves specificity of STOP-Bang screening for obstructive sleep apnea. *Chest*. 2013;143(5):1284–1293.
32. Chung F, Abdullah HR, Liao P. STOP-Bang questionnaire: a practical approach to screen for obstructive sleep apnea. *Chest*. 2016;149(3):631–638.
33. Chung F, Memtsoudis SG, Ramachandran SK, et al. Society of Anesthesia and Sleep Medicine Guidelines on Preoperative Screening and Assessment of Adult Patients With Obstructive Sleep Apnea. *Anesth Analg*. 2016;123(2):452–473.
34. American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Obstructive Sleep Apnea. Practice guidelines for the perioperative management of patients with obstructive sleep apnea: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Obstructive Sleep Apnea. *Anesthesiology.* 2014;120(2):268–286.
35. Olson E, Chung F, Seet E. Surgical risk and the preoperative evaluation and management of adults with obstructive sleep apnea. UpToDate 2018; wwwuptodatecom/home; accessed November 5, 2020.
36. Opperer M, Cozowicz C, Bugada D, et al. Does obstructive sleep apnea influence perioperative outcome? A qualitative systematic review for the Society of Anesthesia and Sleep Medicine Task Force on Preoperative Preparation of Patients with Sleep-Disordered Breathing. *Anesth Analg*. 2016;122(5):1321–1334.
37. Subramani Y, Nagappa M, Wong J, Patra J, Chung F. Death or near-death in patients with obstructive sleep apnoea: a compendium of case reports of critical complications. *Br J Anaesth*. 2017;119(5):885–899.
38. Nagappa M, Patra J, Wong J, et al. Association of STOP-Bang questionnaire as a screening tool for sleep apnea and postoperative complications: a systematic review and bayesian meta-analysis of prospective and retrospective cohort studies. *Anesth Analg*. 2017;125(4):1301–1308.
39. El Shayeb M, Topfer LA, Stafinski T, Pawluk L, Menon D. Diagnostic accuracy of level 3 portable sleep tests versus level 1 polysomnography for sleep-disordered breathing: a systematic review and meta-analysis. *CMAJ*. 2014;186(1):E25–E51.
40. Erman MK, Stewart D, Einhorn D, Gordon N, Casal E. Validation of the ApneaLink for the screening of sleep apnea: a novel and simple single-channel recording device. *J Clin Sleep Med*. 2007;3(4):387–392.

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