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Identification of Patients at Risk for Postoperative Respiratory Complications Using a Preoperative Obstructive Sleep Apnea Screening Tool and Postanesthesia Care Assessment

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Background: **Patients with obstructive sleep apnea are at risk for perioperative morbidity. The authors used a screening prediction model for obstructive sleep apnea to generate a sleep apnea clinical score (SACS) that identified patients at high or low risk for obstructive sleep apnea. This was combined with postanesthesia care unit (PACU) monitoring with the aim of identifying patients at high risk of postoperative oxygen desaturation and respiratory complications.**

Methods: **In this prospective cohort study, surgical patients with a hospital stay longer than 48 h who consented were enrolled. The SACS (high or low risk) was calculated; all patients were monitored in the PACU for recurrent episodes of bradypnea, apnea, desaturations, and pain–sedation mismatch. All patients underwent pulse oximetry postoperatively; complications were documented. Chi-square, two-sample *t* test, and logistic regression were used for analysis. The oxygen desaturation index (number of desaturations per hour) was calculated. Oxygen desaturation index and incidence of postoperative cardiorespiratory complications were primary endpoints.**

Results: **Six hundred ninety-three patients were enrolled. From multivariable logistic regression analysis, the likelihood of a postoperative oxygen desaturation index greater than 10 was increased with a high SACS (odds ratio = 1.9, $P < 0.001$) and recurrent PACU events (odds ratio = 1.5, $P = 0.036$). Postoperative respiratory events were also associated with a high SACS (odds ratio = 3.5, $P < 0.001$) and recurrent PACU events (odds ratio = 21.0, $P < 0.001$).**

Conclusions: **Combination of an obstructive sleep apnea screening tool preoperatively (SACS) and recurrent PACU respiratory events was associated with a higher oxygen desaturation index and postoperative respiratory complications. A two-phase process to identify patients at higher risk for perioperative respiratory desaturations and complications may be useful to stratify and manage surgical patients postoperatively.**

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PATIENTS with obstructive sleep apnea (OSA) are at risk for perioperative morbidity, and many patients who present for surgical procedures may have undiagnosed OSA.[1–5] In 1993, approximately 4% of men and 2% of women in the age group of 30–60 yr were presumed to have OSA, and it is now known to be an independent risk factor for increased mortality.[6,7] It is estimated that between 1990 and 1998, there was a 12-fold increase in the diagnosis of OSA in surgical outpatients.[8] Anesthetic and analgesic agents used during the perioperative period can decrease pharyngeal tone and depress ventilatory responses to hypoxia and hypercapnia.[1,9] These effects can exacerbate the underlying anatomical and physiologic abnormality associated with OSA. In one recent study, 24% of patients with OSA had significant postoperative complications, compared with 9% of patients in the control group.[3] The American Academy of Sleep Medicine 2003 practice guidelines state that "there is insufficient information to develop an American Academy of Sleep Medicine standards of practice recommendation" and recommended careful attention to perioperative airway management and appropriate monitoring.[10] The American Society of Anesthesiologists (ASA) addressed this issue in 2006 with practice guidelines including assessment of patients for possible OSA before surgery and careful postoperative monitoring for those suspected to be at high risk.[11]

Despite improved awareness and increased frequency of diagnosis, it is certain that numerous patients still undergo surgery with undiagnosed OSA. In population studies, a high proportion (24% men, 9% women) had a respiratory distress index of 5 or greater. Based on such data, an estimated 82% of men and 93% of women with OSA are yet to be diagnosed.[12] Many of these patients present for surgery and anesthesia.

The ASA guidelines include recommendations to assess patients who may be at high risk based on clinical suspicion preoperatively.[10] Determining how best to identify patients before surgery and assessing how to best manage their postoperative care continues to be unclear. Clinical prediction formulas can be used to help recognize patients at higher risk for OSA and have good sensitivities (> 85%) but low specificities (< 55%).[13] The

Flemons criteria (appendix 1) is a clinical prediction formula used by sleep physicians to identify patients who will likely be diagnosed with OSA.[14] This requires measurement of neck circumference, history of hypertension, and reported clinical symptoms to generate a likelihood ratio. With these criteria, a sleep apnea clinical score (SACS) is generated, and a score greater than 15 has a likelihood ratio of 5.17 and a posttest probability of 81% in identifying OSA patients subsequently confirmed by formal sleep study. When used to evaluate patients undergoing evaluation for sleep apnea in the outpatient setting, the Flemons criteria have a sensitivity of 76% and a positive predictive value of 77%.[13]

Polysomnography is the gold standard for diagnosis of OSA, but it is expensive and a limited resource. The oxygen desaturation index (ODI) has been used as an inexpensive marker for postoperative apnea-related events.[15] It has been evaluated in the outpatient setting, and ODI $>$ 10 has been reported to have sensitivities of 71–85% with specificities of 90–95%.[16–18] ODI, or respiratory distress index (with same definition), has been shown to show a close estimate of apnea–hypopnea index derived from polysomnography in patients suspected of having OSA[19] and is a sensitive indicator to screen for mild to moderate OSA.[20]

Use of cardiopulmonary monitoring in the postanesthesia care unit (PACU) may help to determine which patients are at risk for postoperative respiratory events.[21] Respiratory complications in the immediate postoperative period can lead to increased morbidity and mortality, and PACU nurses play an important role in the assessment of patients during this time.[22–24] Vigilant recovery care is emphasized in the training and ongoing education of PACU nurses.[25] It is possible that patients who experience respiratory problems in the PACU are more likely to have similar difficulties in the postoperative period after leaving the PACU. By combining the preoperative application of the Flemons criteria with observations of respiratory behavior in the PACU, we propose that we can predict those patients at risk for adverse events after PACU discharge and institute more intensive monitoring protocols to prevent serious postoperative morbidity.[19,26]

Because of the limited data available regarding management of patients who may have undiagnosed OSA, there is not a defined pathway or protocol to determine who requires closer monitoring. Our aim was to identify patients thought to be at high risk for perioperative respiratory and other complications, including those with undiagnosed OSA. We used a two-step approach to determine which patients were at high risk for these complications; a preoperative screening tool for OSA and a postanesthesia care unit assessment for specific respiratory events. We hypothesized that the combination of these two tools would identify those patients at highest risk of postoperative respiratory and other complications. Our secondary aim was to determine whether this combination of tools would also identify those patients with higher numbers of pulse oximetry events, as determined by the oxygen desaturation index.

Materials and Methods

Following institutional review board (Mayo Clinic Rochester, Minnesota) approval, patients seen in our preoperative evaluation clinic between October 2005 and September 2007 were screened for study eligibility. Patients without a known diagnosis of OSA based on history who were scheduled to undergo inpatient surgery requiring a hospital stay longer than 48 h were considered eligible, and those who consented to participate were enrolled (with written/informed consent) in this prospective cohort study. All patients were evaluated preoperatively with the Flemons criteria, also known as SACS, an (established prediction model for OSA) (appendix 1).

All providers of clinical care were blinded to the results of the Flemons instrument. Anesthetic management was at the discretion of the attending anesthesiologist, including the decision to provide regional or general anesthesia. In the PACU, all study patients were monitored continuously for recurrent PACU events of apnea, bradypnea, desaturations, and pain–sedation mismatch (see appendix 2 for event definitions). Data were recorded for three 30-min evaluation periods. Pain–sedation mismatch refers to a high pain score on the visual analog scale with a high level of sedation, and thus concern with further administration of analgesics causing apnea, bradypnea, or desaturations. If a patient had any events in two or more of the three evaluation periods, the patient was considered to have experienced recurrent events. The type of event (apnea, bradypnea, desaturations, or pain–sedation mismatch) did not need to be the same at each evaluation period. For example, a patient who experienced apnea in the initial 30 min and desaturations in the second 30 min would have been considered to have experienced recurrent PACU events. Recurrence of events during the 90 min after PACU admission resulted in overnight intermediate care admission, as per our institutional protocol. The rationale for this protocol is that single PACU events could be related to emergence from anesthesia or administration of bolus of intravenous opioid, but continued respiratory events are less likely to be due to those events.

All patients underwent monitoring with recording of pulse oximetry for 48 h after PACU discharge while in bed. Oxygen therapy, if required, was administered by nasal cannula, based on need to maintain oxygen saturation greater than 90% on discharge from the PACU. After 48 h from admission to the floor, recording was

discontinued. Patients who had adverse intraoperative events that require prolonged ventilation were excluded from final analysis.

Patients were followed up for evidence of cardiorespiratory complications during their hospital stay. Respiratory complications were defined as follows: intensive care unit admission for a new respiratory indication (*e.g.*, respiratory failure), the need for respiratory therapy beyond standard postoperative clinical practice, the need for noninvasive ventilatory support (*e.g.*, continuous positive airway pressure or bilevel positive airway pressure), and the development of postoperative pneumonia (new infiltrate on chest x-ray, leukocytosis, and temperature > 38°C). Use of bronchodilators was considered standard practice and did not qualify as respiratory therapy beyond standard practice. Cardiac complications were defined as follows: the development of a new arrhythmia requiring treatment, evidence of myocardial ischemia on electrocardiogram with or without symptoms, or myocardial infarction (troponin elevation according to local laboratory standards with or without symptoms or electrocardiogram changes). Major events of any cause, including in-hospital cardiac arrest or mortality, were also documented.

All patients underwent recording pulse oximetry for 48 h postoperatively while in bed with Nellcor 595 oximeters (Nellcor, Pleasanton, CA), with sampling rates of 2 s. Data were analyzed with Score Analysis Software (version 1.1a; Mallinckrodt Inc., St. Louis, MO). ODI was calculated with ODI defined as number of desaturations per hour of recording. A desaturation was defined as a decrease in saturation of 4% or greater for 10 s or more. An ODI for the first 24 h was calculated, in addition to ODI over the entire recording period. ODI > 10 was chosen to indicate a high frequency of oxygen desaturation.

Statistical Analyses

Patient and procedural characteristics are summarized using mean ± SD for continuous variables and frequency percentages for categorical variables. These characteristics were compared between those with low (< 15) *versus* high (≥ 15) SACS using the two-sample *t* test or chi-square test as appropriate. The frequency of PACU events was also summarized according to SACS group (low *vs.* high) and compared between groups using the chi-square test. Patients were classified as experiencing recurrent PACU events if they experienced one or more events in at least two of the PACU evaluation periods. Postoperative outcomes are summarized separately for the four groups defined by the combination of SACS group (low *vs.* high) and recurrent PACU events (no *vs.* yes). Postoperative outcomes were analyzed using multiple logistic regression for binary outcomes and analysis of covariance for continuous outcomes. In all cases, the explanatory variables of interest were SACS group (low *vs.* high) and recurrent PACU events (no *vs.* yes). Initial analyses were performed that included the SACS group by recurrent event interaction term. Given the absence of significant interaction effects, subsequent analyses were performed using models that included only main effect terms. The primary purpose of our investigation was to assess whether SACS (high *vs.* low) and recurrent PACU events (yes *vs.* no) were useful for identifying patients at increased risk for postoperative events. For this reason, no covariate adjustment was included in our primary analyses. However, it is also of interest to know whether an association of SACS group and recurrent events with postoperative outcomes is independent of other patient demographic variables. For this reason, a series of supplemental analyses were performed using a hierarchical modeling approach. For each outcome of interest, an initial base model was constructed which included age, sex, and body mass index (BMI) as explanatory variables. SACS group (high *vs.* low) was then added to these models to assess whether SACS group was significantly associated with the given outcome after adjusting for the demographic variables. Recurrent events (yes *vs.* no) was then included as an additional explanatory variable in these models to assess the association of both SACS group and recurrent events with postoperative outcomes after adjusting for baseline demographics. Analyses were performed using SAS software (version 9; SAS Institute Inc., Cary, NC), and in all cases, two-tailed *P* values of 0.05 or less were considered statistically significant.

The sample size for this investigation was determined by the number of eligible patients who provided consent and enrolled in the study during the predetermined 2-yr recruitment period. For the analyses assessing the association of SACS group (low *vs.* high) and recurrent PACU events (no *vs.* yes) with the endopoint of ODI > 10 (which has an overall incidence of 22%), the effective sample sizes for this study provide statistical power of approximately 80% to detect an association consistent with a difference of 10% points between patients with and without a given risk factor.

Results

Analysis included 693 patients with data available for the entire study period. Table 1 shows demographics. There were no significant differences in age between the groups that had high SACS and low SACS derived from the Flemons criteria. There was a significantly higher percentage of males in the high SACS group than in the low SACS group (86% *vs.* 43%; $P < 0.001$). BMI was significantly different between the low SACS and high

Table 1. Patient and Procedural Characteristics

Characteristic	Overall, n = 693	SACS Group		*P* Value*
		Low, n = 472	High, n = 221	
Age	58.8 ± 11.3	58.2 ± 11.6	59.9 ± 10.5	0.067
Sex				< 0.001
Male	393 (57%)	203 (43%)	190 (86%)	
Female	300 (43%)	269 (57%)	31 (14%)	
BMI, kg/m^2	31.9 ± 6.9	30.4 ± 6.7	35.1 ± 6.0	< 0.001
Neck circumference, cm	40.4 ± 4.6	38.2 ± 3.7	44.9 ± 2.7	< 0.001
Flemons score	12.9 ± 14.9	5.5 ± 4.2	28.8 ± 17.0	< 0.001
High blood pressure				< 0.001
No	333 (48%)	291 (62%)	42 (19%)	
Yes	360 (52%)	181 (38%)	179 (81%)	
Type of surgery†				< 0.001
Orthopedics	386 (56%)	271 (57%)	115 (52%)	
Gynecologic	51 (7%)	46 (10%)	5 (2%)	
Urology	104 (15%)	52 (11%)	52 (24%)	
Thoracic	6 (1%)	5 (1%)	1 (0%)	
ENT	12 (2%)	8 (2%)	4 (2%)	
Plastics	7 (1%)	6 (1%)	1 (0%)	
General abdominal	34 (5%)	28 (6%)	6 (3%)	
Neurosurgical	82 (12%)	52 (11%)	30 (14%)	
Other	11 (2%)	4 (1%)	7 (3%)	
ASA physical status‡				< 0.001
I	27 (4%)	26 (6%)	1 (0%)	
II	461 (67%)	328 (69%)	133 (60%)	
III	203 (29%)	117 (25%)	86 (39%)	
IV	2 (0%)	1 (0%)	1 (0%)	
Duration of anesthesia, min	256.2 ± 109.0	254.3 ± 111.5	260.3 ± 103.6	0.495
Type of anesthesia				0.194
General	594 (86%)	399 (85%)	195 (88%)	
Regional	99 (14%)	73 (15%)	26 (12%)	

* Characteristics were compared between Flemons groups (high *vs.* low) using the two-sample *t* test for continuous variables and the chi-square test for categorical variables. † For analysis purposes, the following surgery types were combined into one category: thoracic; ear, nose, and throat (ENT); plastics; general abdominal; and other. ‡ For analysis purposes, American Society of Anesthesiologists (ASA) physical status was dichotomized as ≤ II *vs.* ≥ III.

BMI = body mass index; SACS = sleep apnea clinical score.

SACS groups ($P < 0.001$). Neck circumference and hypertension, which are both included in SACS, were both significantly higher in the high SACS group ($P < 0.001$). Types of surgical procedures are also presented in table 1, with some differences in SACS based on surgical type ($P < 0.001$). ASA status was also different ($P < 0.001$) between the groups, with higher percentages of low SACS patients classified as ASA I (6% *vs.* 0%) or II (69% *vs.* 60%) compared with ASA III (25% *vs.* 39%). There was no difference between the low and high SACS groups in duration of anesthesia (254.3 ± 111.5 *vs.* 260.3 ± 103.6; $P = 0.495$) or type of anesthesia (general *vs.* regional).

Postanesthesia care unit events were more common in the high SACS group ($P = 0.043$), with individual events presented in table 2. There was no significant difference in duration of oximetry between the low and high SACS groups or between those with and without recurrent PACU events. Postoperative outcomes after PACU discharge are presented in table 3. Overall, there were 168 patients (24%) with ODI > 10 over the period of oximetry. Of the patients with ODI > 10, 13% had oxygen saturation measured by pulse oximetry (Spo_2) less than 89% for 10% or more of the time monitored, whereas only 3% of those with ODI < 10 had Spo_2 less than 89% for 10% or more of the time monitored ($P < 0.001$). Similarly, the minimum Spo_2 recorded was lower for patients with ODI > 10 *versus* ODI < 10 (72.2 ± 6.0 *vs.* 76.1 ± 6.1; $P < 0.001$). Mean ODI over the entire period of oximetry and the frequency of patients with ODI > 10 were higher for patients with high SACS ($P < 0.001$) and also higher in the patients who had recurrent PACU events ($P = 0.018$ for ODI, $P = 0.036$ for ODI > 10). Mean ODI and number of patients with ODI > 10 over the first 24-h period was significantly higher in the high SACS group ($P < 0.001$). Patients with recurrent PACU events had a higher mean ODI over the first 24 h ($P = 0.034$), but the frequency of ODI > 10 over the first 24 h ($P = 0.700$) was not associated with recurrent PACU events.

There were cardiac events in 9 patients (of 472) in the low SACS group and 4 patients (of 221) in the high SACS group, which was not significantly different. The likelihood of postoperative respiratory events was increased with high SACS (odds ratio = 3.5, $P < 0.001$) and recurrent PACU events (odds ratio = 21.0, $P < 0.001$) (fig. 1). Similarly, the risk for any postoperative compli-

Table 2. Postanesthesia Care Unit Events

Event Type and Number	SACS Low, n = 472	SACS High, n = 221	*P* Value*
Hypopnea			0.126
0	385 (82)	181 (82)	
1	49 (10)	21 (10)	
2	28 (6)	8 (4)	
3	10 (2)	11 (5)	
Apnea			0.657
0	389 (82)	181 (82)	
1	41 (9)	15 (7)	
2	26 (6)	15 (7)	
3	16 (3)	10 (5)	
Desaturations			< 0.001
0	418 (89)	159 (72)	
1	33 (7)	34 (15)	
2	16 (3)	18 (8)	
3	5 (1)	10 (5)	
Pain–sedation mismatch			0.235
0	427 (90)	196 (89)	
1	31 (7)	16 (7)	
2	10 (2)	3 (1)	
3	4 (1)	6 (3)	
Any type event			0.043
0	306 (65)	128 (58)	
1	75 (16)	41 (19)	
2	59 (12)	24 (10)	
3	32 (7)	28 (13)	

Hypopnea, apnea, desaturations, and pain–sedation mismatch were assessed at 30, 60, and 90 min after admission to the postanesthesia care unit. The data presented correspond to the number (%) of patients with 0, 1, 2, and 3 (or more) occurrences of the given event.

* Chi-square test.

SACS = sleep apnea clinical score.

cation was found to be significantly associated with a high SACS (odds ratio = 2.7, $P = 0.004$) and recurrent PACU events (odds ratio = 13.4, $P < 0.001$).

To further assess whether the associations of SACS and recurrent PACU events with postoperative outcomes were independent of patient demographics, a series of supplemental analyses was performed. Table 4 summarizes the *P* values for the effects of SACS and recurrent PACU events that were obtained from these supplemental analyses. The association between SACS group and postoperative complications was no longer statistically significant after adjusting for baseline demographics. In all other cases, effects found to be statistically significant in unadjusted analyses remained statistically significant after adjusting for baseline demographics.

Discussion

Use of the SACS preoperatively identified patients who were at higher risk of postoperative complications and those with higher ODI by recording pulse oximetry. The PACU assessment also found recurrent events associated with more postoperative complications and higher ODI. Our two-phase screening tool helped designate patients who may need closer monitoring in the immediate postoperative period.

Our study identified 31.9% of patients as high risk for OSA based on SACS, which had previously been verified for the outpatient sleep disorder evaluation setting. This is somewhat higher than that reported in recent studies looking at other preoperative screening tools, with incidences of 24–27.5%.[27,28] Significantly more patients in our high-risk group were male, and more males are presumed to have OSA in the general population.[12] A majority of our patients underwent orthopedic surgery (55.7%; $P < 0.001$), and this is due to the population that is seen in our preoperative evaluation clinic. Specific surgical services are more likely to send patients to the preoperative evaluation clinic before surgery in our practice; these include gynecologic, urologic, plastics, neurosurgical, and otorhinolaryngologic, in addition to orthopedic specialties.

There were significantly more patients with ASA physical status III in our high SACS group ($P < 0.001$). This may be due to the association of OSA with other medical conditions such as hypertension, cardiovascular events, and cerebrovascular disease.[29] There were similar numbers of patients in other ASA categories. No difference was seen in duration of anesthesia between patients with high SACS and low SACS.

Table 3 reveals no difference in duration of recording pulse oximetry postoperatively. From multivariable models that include both SACS group (low *vs.* high) and recurrent PACU events (no *vs.* yes) as explanatory variables, the likelihood of having ODI over the first 24 h were found to be significantly higher in patients with high SACS ($P < 0.001$). Similar results were obtained for the analysis of ODI over the entire recording period.

After adjusting for SACS group, recurrent PACU events were also associated with higher mean ODI and an increased likelihood of experiencing ODI > 10 over the entire recording period ($P = 0.018$ and $P = 0.036$), but not with experiencing ODI > 10 over the first 24 h. This may indicate that longer than 24 h is necessary to determine whether patients may have desaturations postoperatively when deeper sleep returns. It is known that sleep patterns are altered in the immediate postoperative period, and this may have impacted our patients in the first 24-h period.[30,31] The combination of the preoperative SACS and PACU assessment seems to be likely to capture more patients at risk of significant desaturations.

Perioperative complications, including respiratory events, were more frequent in patients with high SACS and also in those with recurrent events on PACU assessment. Among patients with low SACS and no recurrent PACU events, the rate of respiratory complications was less than 1% (3 in 381). For patients with high SACS and no recurrent PACU events, the rate of respiratory complications was 2% (3 in 169). However, 11% of patients (10 of 91) with recurrent PACU events and low SACS had

Table 3. Postoperative Outcomes

	Low SACS, n = 472		High SACS, n = 221		*P* Value	
	No Recurrent Events, n = 381	Recurrent Events, n = 91	No Recurrent Events, n = 169	Recurrent Events, n = 52	SACS Group	Recurrent Events
Duration of study oximetry, h	37.2 ± 9.6	38.9 ± 8.0	37.2 ± 9.4	38.4 ± 7.5	0.872	0.073
ODI over entire period						
Mean ± SD	6.8 ± 4.7	7.4 ± 4.9	8.3 ± 5.7	10.6 ± 8.5	< 0.001	0.018
ODI > 10	74 (19%)	22 (24%)	49 (29%)	23 (44%)	< 0.001	0.036
ODI over first 24 h						
Mean ± SD	6.3 ± 5.0	7.1 ± 5.8	7.8 ± 6.0	9.7 ± 8.7	< 0.001	0.034
ODI > 10	71 (19%)	16 (18%)	48 (28%)	18 (35%)	< 0.001	0.700
Perioperative complications						
ICU admission for respiratory indication	2 (1%)	7 (8%)	2 (1%)	14 (27%)	—	—
Respiratory therapy beyond clinical standards	1 (0%)	3 (3%)	1 (1%)	5 (10%)	—	—
Noninvasive ventilatory support	0 (0%)	3 (3%)	1 (1%)	8 (15%)	—	—
Pneumonia	1 (0%)	1 (1%)	0 (0%)	0 (0%)	—	—
Respiratory arrest	0 (0%)	0 (0%)	0 (0%)	0 (0%)	—	—
New cardiac arrhythmia requiring treatment	4 (1%)	3 (3%)	2 (1%)	0 (0%)	—	—
Electrocardiographic changes	2 (1%)	0 (0%)	0 (0%)	2 (4%)	—	—
Hospital death	0 (0%)	0 (0%)	0 (0%)	0 (0%)	—	—
Any cardiac event	6 (2%)	3 (3%)	2 (1%)	2 (4%)	0.869	0.118
Any respiratory event	3 (1%)	10 (11%)	3 (2%)	17 (33%)	0.001	< 0.001
Any event	7 (2%)	12 (13%)	4 (2%)	19 (37%)	0.004	< 0.001

Data were analyzed using multiple logistic regression (binary outcomes) or analysis of covariance (continuous outcomes). For complications, analyses were only performed for the three cumulative endpoints of any event, any respiratory event, and any cardiac event. In all cases, the explanatory variables included in the model were sleep apnea clinical score (SACS) group (high *vs.* low) and recurrent postanesthesia care unit events (yes *vs.* no). Initial analyses were performed that included the group–by–recurrent event interaction term. No significant interactions were detected. In all cases, the *P* values presented are from a multivariable model that includes main effect terms for SACS group (high *vs.* low) and recurrent events (yes *vs.* no).

ICU = intensive care unit; ODI = oxygen desaturation index.

postoperative respiratory complications. Patients with both factors (high SACS and recurrent events) had the most notable likelihood of respiratory complications at 33% (17 of 52), again attesting to the benefit of the combined assessment. Figure 1 compares respiratory complications in all four groups, those with low and high SACS and those with and without recurrent PACU events. The differences in percent of complications per group reveals a much higher incidence in those with high SACS compared with low SACS in those without recurrent events, and both low and high SACS in those with recurrent PACU events.

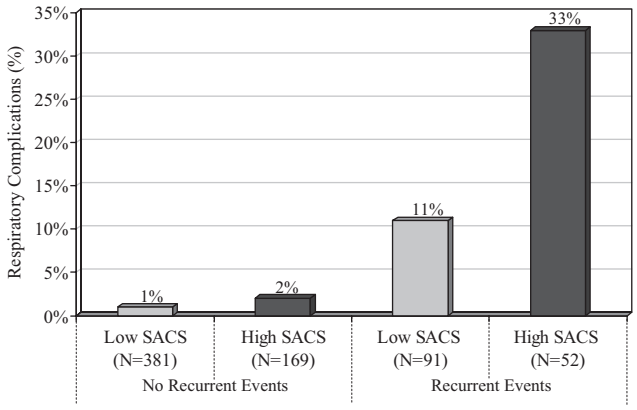

Fig. 1. The frequency of postoperative respiratory events is displayed according to the four patient groups defined by the combination of sleep apnea clinical score (SACS) (low/high) and recurrent postanesthesia care unit (PACU) events (no/yes). From a multiple logistic regression analysis, which included SACS group and recurrent PACU events as explanatory variables, the likelihood of postoperative respiratory events was found to be significantly associated with high SACS (odds ratio = 3.5, $P = 0.001$) and recurrent PACU events (odds ratio = 21.0, $P < 0.001$).

The lack of significance between SACS and complications after adjustment for demographics is likely due to a correlation between SACS and BMI (table 4). Another issue is that there were only 42 patients who experienced any complications (and 33 who experienced respiratory complications). There should be approximately 10 events for potential explanatory variables assessed. For the models that we report in the article (with only two explanatory variables), this is appropriate. However, this really is not enough events to adequately fit multivariable models that include five explanatory variables (SACS, recurrent events, age, sex, and BMI).

Cardiac complications were not found to be significantly associated with SACS group or recurrent PACU events. This may be due to our low overall incidence of cardiac events, with 13 events in all 693 patients. It is possible that concerns regarding patients in the PACU may have prompted caregivers to send patients to higher levels of care, thus impacting the number of cardiac events seen. More intensive monitoring may have impacted the neural mechanisms and vascular responses that are thought to be involved in cardiovascular risk in the OSA population.[29] This may have led to intervention during episodes of obstruction or desaturation in the

Table 4. Supplemental Models Assessing Association of SACS and Recurrent Events with Postoperative Outcomes after Adjusting for Baseline Demographics

	Model 1*	Model 2†	
	SACS Group	SACS Group	Recurrent Events
ODI over entire period			
Mean ± SD	0.010	0.009	0.026
ODI > 10	0.039	0.037	0.044
ODI over first 24 h			
Mean ± SD	0.024	0.022	0.045
ODI > 10	0.043	0.043	0.765
Perioperative complications			
Any cardiac event	0.870	0.823	0.082
Any respiratory event	0.128	0.081	< 0.001
Any event	0.173	0.136	< 0.001

In all cases, data were analyzed using multiple logistic regression (binary outcomes) or analysis of covariance (continuous outcomes). The values presented in the table correspond to the *P* values for the effects of sleep apnea clinical score (SACS) group and recurrent postanesthesia care unit events from these models. In all cases, the direction and magnitude of the effects from the adjusted analyses were consistent with that found from the unadjusted analysis (table 3).

* Multivariable analysis assessing SACS group (high *vs.* low) after adjusting for age, sex, and body mass index. † Multivariable analysis assessing SACS group (high *vs.* low) and recurrent events (yes *vs.* no) after adjusting for age, sex, and body mass index.

ODI = oxygen desaturation index.

monitored setting that would not occur in a floor setting, which may have impacted cardiac events.

The ASA guidelines regarding perioperative management for OSA recommend careful assessment preoperatively to identify patients at high risk postoperatively. There are many screening tools available but limited information on which tool to use. Recently, the Snoring, Tiredness during daytime, Observed apnea, and high blood Pressure (STOP)-Bang model and Berlin questionnaire were used.[28,32] The recent publication that described an approach to specifically identify patients with OSA using the STOP questionnaire combined BMI, neck circumference, and sex. The authors showed sensitivities of 84, 93, and 100% for apnea–hypopnea index of greater than 5, greater than 15, and greater than 30, respectively, for detecting OSA. In our study, a definitive diagnosis of OSA (using polysomnography) was not performed because we had a different goal, namely to identify patients at high risk of postoperative complications. As such, direct comparison to this study is not easily done. Neither of these studies commented on the postoperative course of their patients. Indeed, a clinician is more interested in identifying potential postoperative complications of the disease than merely making a diagnosis requiring further outpatient management. We used a different screening tool that has a sensitivity of 76% for OSA[13] combined with a PACU assessment to identify patients at risk of adverse postoperative events. We found that both the preoperative and PACU assessments were associated with patients at high risk of postoperative complications and desaturations by recording pulse oximetry (ODI). Both SACS and PACU events are independent predictors of perioperative complications, respiratory complications, and high ODI.

A major limitation of our study is the inability to directly compare our findings suggesting the presence of OSA with polysomnography results attesting to this process. Our patients may be at high risk for postoperative events without having OSA. It has been found that the first 24 h is high risk for respiratory events in surgical patients, and this may not be related to diagnosis of OSA.[33] Our findings suggest that the combination of preoperative SACS and PACU monitoring can be used to identify patients at risk for postoperative respiratory and overall complications, in addition to desaturations. Our tools may have capability of identifying patients at risk for respiratory complications independent of the presence of OSA. Further studies will be important to help determine whether this population is likely to have OSA and require not only closer perioperative management but longer-term follow-up and intervention. In addition, it would be important to identify other patient factors that make the perioperative period higher risk, and ultimately, we should develop outcome studies to verify how to successfully modify our care for this group of patients.

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Appendix 1: Sleep Apnea Clinical Score

Historic features:

1. Do you have high blood pressure or have you been told to take medication for high blood pressure? ☐ Yes ☐ No

2. People who have shared (or are sharing) my bedroom tell me that I snore:
(Please pick the best response for the frequency of your snoring)
☐ Usually (3–5 times/week) [= 1 historic feature]
☐ Always (every night) [= 1 historic feature]

3. I have been told by other people that I gasp, choke, or snort while I am sleeping:
(Please pick the best response for the frequency of any of these symptoms)
☐ Usually (3–5 times/week) [= 1 historic feature]
☐ Always (every night) [= 1 historic feature]

4. Neck measurement (We will measure you) ___ ___ cm

Prediction of obstructive sleep apnea based on linear regression model using above factors:
Low = sleep apnea clinical score < 15
High = sleep apnea clinical score ≥ 15

Prediction of Obstructive Sleep Apnea
(Circle the patient's score.)

	Sleep Apnea Clinical Score					
	Not Hypertensive Historic Features*			Hypertensive Historic Features*		
Neck Circumference, cm	None	One	Both	None	One	Both
< 30	0	0	1	0	1	2
30–31	0	0	1	1	2	4
32–33	0	1	2	1	3	5
34–35	1	2	3	2	4	8
36–37	1	3	5	4	6	11
38–39	2	4	7	5	9	16
40–41	3	6	10	8	13	22
42–43	5	8	14	11	18	30
44–45	7	12	20	15	25	42
46–47	10	16	28	21	35	58
48–49	14	23	38	29	48	80
> 49	19	32	53	40	66	110

* Historic features: (1) habitual snoring; (2) partner reports of gasping, choking, or snorting.

Probability of sleep apnea:
Low = sleep apnea clinical score < 15
High = sleep apnea clinical score ≥ 15

Total sleep apnea clinical score: _____

Appendix 2: Postanesthesia Care Unit Evaluation for Recurrent Respiratory Events

	Evaluation Period		
Bradypnea: < 8 respirations/min (3 episodes needed for yes) Apnea: ≥ 10 s (only 1 episode needed for yes) Desaturations: pulse oximetry < 90% with nasal cannula (3 episodes needed for yes) Pain–sedation mismatch: RASS score −3 through −5 and pain scale score > 5 (only 1 episode needed for yes)	Initial 30 min after Extubation or PACU Admit (Whichever Occurs Later)	Second 30 min after Initial Evaluation (60 min after Extubation or PACU Admit)	Third 30 min after Second Evaluation (90 min after Extubation or PACU Admit)

Recurrent events if any event occurs at more than one evaluation period (not necessary to be same event).

PACU = postanesthesia care unit; pain scale score = visual analog score; RASS = Richmond Agitation–Sedation Scale.