



## Original Article

## Prevalence of undiagnosed obstructive sleep apnea among adult surgical patients in an academic medical center

Kevin J. Finkel<sup>a</sup>, Adam C. Searleman<sup>a</sup>, Heidi Tymkew<sup>a</sup>, Christopher Y. Tanaka<sup>a</sup>, Leif Saager<sup>a</sup>, Elika Safer-Zadeh<sup>a</sup>, Michael Bottros<sup>a</sup>, Jacqueline A. Selvidge<sup>a</sup>, Eric Jacobsohn<sup>b</sup>, Debra Pulley<sup>a</sup>, Stephen Duntley<sup>c</sup>, Colleen Becker<sup>d</sup>, Michael S. Avidan<sup>a,\*</sup>

<sup>a</sup> Washington University School of Medicine, Department of Anesthesiology, 660 S Euclid Ave, Campus Box 8054, St. Louis, MO 63110, USA

<sup>b</sup> University of Manitoba, Department of Anesthesia, Lennox Bell Lodge, LB315, 60 Pearl St., Man., Canada R3E1X2

<sup>c</sup> Washington University School of Medicine, Sleep Medicine Center, 212 N Kings Highway Suite 237, St. Louis, MO 63108, USA

<sup>d</sup> Barnes-Jewish Hospital, Perioperative Services, One Barnes-Jewish Hospital Plaza, #90-72-408, St. Louis, MO 63110, USA

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## ABSTRACT

**Background:** Obstructive sleep apnea (OSA) affects approximately 20% of US adults, of whom about 90% are undiagnosed. While OSA may increase risk of perioperative complications, its prevalence among surgical patients is unknown. We tested the feasibility of screening surgical patients for OSA and determined the prevalence of undiagnosed OSA.

**Methods:** In a prospective, observational study adult surgical patients were screened for OSA in an academic hospital. Patients without an OSA diagnosis who screened high-risk were offered a home sleep study to determine if they had OSA. The results were compared with polysomnography (PSG) when available. Charts of high-risk patients were examined for postoperative complications. High-risk patients received targeted interventions as part of a hospital safety initiative.

**Results:** There were 2877 patients screened; 661 (23.7%) screened high-risk for OSA, of whom 534 (81%) did not have diagnosed OSA. The portable sleep study detected OSA in 170/207 (82%) high-risk patients without diagnosed OSA. Twenty-six PSGs confirmed OSA in 19 of these patients. Postoperatively there were no respiratory arrests, two unanticipated ICU admissions, and five documented respiratory complications.

**Conclusion:** Undiagnosed OSA is prevalent in adult surgical patients. Implementing universal screening is feasible and can identify undiagnosed OSA in many surgical patients. Further investigation is needed into perioperative complications and their prevention for patients with undiagnosed OSA.

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## 1. Introduction

Obstructive sleep apnea (OSA) refers to a condition where those affected periodically have obstruction to breathing while they sleep. Twenty-five percent of the US adult population is thought to be at high-risk for having OSA [1], and the estimated prevalence of OSA in the US adult population is 20% [2]. Some risk factors for OSA are male gender [3,4], smoking [5], age >40 [4] and obesity [4,6]. The prevalence of OSA is expected to rise as an increasing proportion of Americans are obese and elderly [7]. It is estimated that up to 90% of people with OSA are undiagnosed [8], which is likely owing to poor awareness of OSA [9], a lack of

routine screening, and the limited number of diagnostic sleep study facilities [10].

Much of the preoperative assessment before surgery has focused on the diagnosis and management of heart and lung diseases. There has been little emphasis on screening for or diagnosing sleep-disordered breathing prior to surgery [11]. However, patients with OSA may be more vulnerable during the perioperative period, particularly if they receive general anesthesia and opioid analgesia. These medications could diminish the protective arousal reflex and may thereby increase the risk for prolonged periods of apnea and respiratory arrest [12]. In addition, these medications can worsen existing OSA by increasing upper airway resistance by decreasing pharyngeal muscle tone [12]. These outcomes may be more likely to happen when the care providers are unaware of their diagnosis and cannot properly identify these patients to take preventative precautions.

\* Corresponding author. Tel.: +1 314 747 4155; fax: +1 314 747 3977.

E-mail addresses: [avidanm@wustl.edu](mailto:avidanm@wustl.edu), [avidanm@msnotes.wustl.edu](mailto:avidanm@msnotes.wustl.edu) (M.S. Avidan).

Outcome studies on specific surgical populations have shown that patients with OSA have a higher incidence of postoperative complications [13–17] such as unplanned ICU admissions, longer hospital stay, longer ICU stay, postoperative encephalopathy, and postoperative infection [15,16]. Even patients who are suspected to have OSA based on screening questionnaires may have increased postoperative respiratory complications [13,14]. OSA is also associated with numerous comorbidities such as diabetes [18], hypertension [19], stroke [20], heart failure [21], and coronary artery disease [21]. Furthermore, OSA is associated with an increased risk of mortality independent of these comorbidities [20].

Recently the American Society of Anesthesiologists (ASA) published guidelines on caring for surgical patients with OSA which state that perioperative risk directly increases with severity of OSA [22]. For this reason, the guidelines stress the importance of screening all surgical patients for risk factors for OSA and then modifying perioperative care and increasing vigilance for surgical patients at risk for OSA. The ASA has proposed an OSA risk stratification screen, based predominantly on the severity of OSA, the risks of surgery and the likely administration of sedative and analgesic medications [22]. However, no studies have demonstrated the feasibility of universal screening in the preoperative setting to identify those with undiagnosed OSA and to implement changes in identifying and monitoring these patients.

The proportion of adult surgical patients who have undiagnosed OSA has not been well established. We therefore conducted a single-center, prospective, observational study to establish the prevalence of undiagnosed OSA among adult surgical patients with a preoperative OSA screening program.

## 2. Materials and methods

The Human Research Protection Office (HRPO) at Washington University School of Medicine approved this study. A waiver of written consent was granted for the voluntary screening portion of this study as completion of the questionnaire gave implied consent. All participants who agreed to use the home testing device for OSA signed written, informed consent.

All participants undergoing elective surgery at our urban tertiary care referral center attended the preoperative assessment clinic. Adult surgical patients at the preoperative assessment clinic who were older than 18 were included in the study. Participants completed an OSA risk screening questionnaire as a voluntary part of their preoperative medical assessment. The apnea risk evaluation system (ARES) OSA screening questionnaire (Advanced Brain Monitoring, Inc., Carlsbad, CA) is a validated questionnaire [23] that combines features of three established screens: the Berlin questionnaire [24], Flemons' Index [25], and the Epworth sleepiness scale [26]. It assesses daytime somnolence, frequency of snoring, witnessed episodes of choking or apnea, body mass index (BMI), neck circumference, and associated comorbidities. The sensitivity and specificity of the questionnaire for predicting sleep apnea (apnea-hypopnea index >5) is 0.94 and 0.79, respectively; the positive and negative predictive values were 0.91 and 0.86 [23]. The results of the questionnaire were analyzed by a computer program to identify OSA risk level [23]. Similar to the ASA's recommended preoperative risk stratification system, this program assigned patients to the OSA risk levels of no, low, moderate, or high-risk for OSA [22]. For the purposes of this study, we compared those at high-risk for OSA to the remainder not at high-risk for OSA (no, low, and moderate risks). A copy of the screening questionnaire is shown in Appendix A.

All available consecutive patients who screened high-risk for OSA were offered a home testing device for OSA. Those patients who consented to home testing were instructed in the use of the ARES Unicorder (Advanced Brain Monitoring, Inc., Carlsbad, CA), a validated home testing device for OSA [27,28]. The device is fitted to the patient's forehead where it records oxygen saturation, pulse rate, snoring level, head position (patient positioning), sudden movement (surrogate for arousal), and airflow using a pressure-transducing nasal cannula. Patients were excluded if they had a prior diagnosis of OSA, required home oxygen, were allergic to synthetic material, or were unable to use the sleep apnea detection device.

Patients were instructed to wear the home testing device for two nights and then return it on the day of surgery. At least two hours of valid recording time was necessary to make a diagnosis. On the day of surgery, the data were downloaded from the device to generate a report detailing the Apnea-hypopnea index (AHI), which is the number of apneic and hypopneic events per hour of valid recording time. Apneic events were defined as complete cessation of airflow for at least 10 s. Hypopneic events required at least 50% reduction in air flow, 3% decrease in saturation, and a confirmatory arousal detected by a sudden change in head position, heart rate, or snoring volume [27]. In this study, we used the ASA's recommended stratification of OSA severity: AHI 5 or less is normal, 6 to 20 is mild OSA, 21–40 is moderate OSA, and  $\geq 41$  is severe OSA [22]. Patients were given the results of their screening questionnaires and home sleep studies. In addition, a letter was sent to their primary care physician informing them of the findings and advising a referral for PSG testing. The research team obtained all available PSG tests completed within one year of study participation. Charts were reviewed for postoperative respiratory complications including respiratory arrests, unplanned ICU admissions, and evidence of respiratory distress (oxygen saturation <90%, or hypercapnia requiring CPAP, BiPAP, or intubation).

In addition, as a safety precaution, all patients who were at high-risk for OSA received an "OSA Risk" notification. This included identifying wrist bands, signs on their hospital beds, stamps in their charts, and notifications in the operating room schedule.

### 2.1. Statistical analysis

Patient characteristics were compared using Fisher's exact test for categorical data and the Wilcoxon rank-sum test for continuous data. Confidence intervals (CI) for proportions were calculated according to Newcombe's method with continuity correction [29]. The CIs for prevalence of OSA were computed using a parametric bootstrap by obtaining 10,000 estimates after re-sampling from the maximum likelihood empirical binomial distributions for the proportion of patients with a prior diagnosis of OSA, the proportion of patients at high-risk for OSA without a prior diagnosis, and the proportion of these high-risk patients with positive home sleep studies. These analyses were conducted in the *R* statistical environment (Vienna, Austria). A *p*-value of less than 0.05 was considered statistically significant.

## 3. Results

We screened 2877 adult patients in the preoperative assessment clinic (Fig. 1). Of the 2778 patients who completed the screening questionnaire, 661 (23.7%) screened high-risk for OSA. There were 173 (6.2%) patients who had a previous

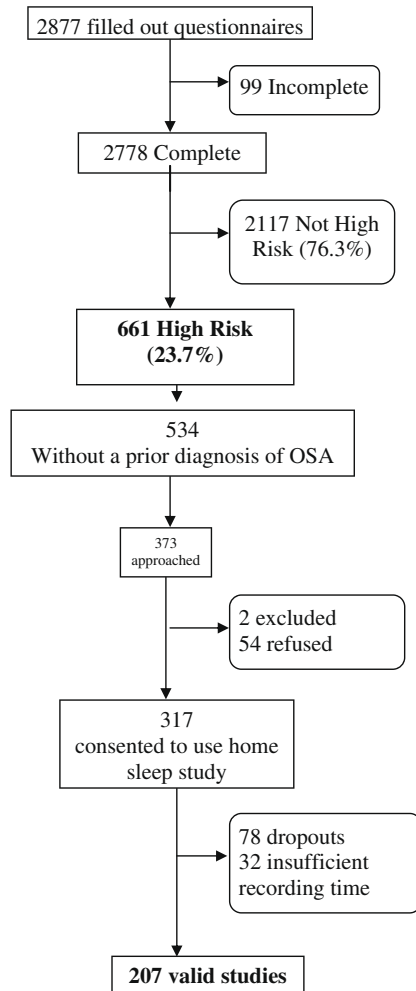


Fig. 1. Flow diagram of the study.

diagnosis of OSA: 127 of them screened high-risk and 46 did not screen high-risk. These patients were excluded from analysis.

There were 534 patients who screened high-risk for OSA and were without a previous diagnosis of OSA. Patient characteristics of our surgical population stratified by OSA risk are shown in Table 1. Among the patients who screened high-risk and who had no prior diagnosis of OSA, 207 had valid home sleep studies detecting mild OSA in 97 patients, moderate OSA in 40 patients, and severe OSA in 33 patients (Table 2). In total, 170 of these patients had OSA, resulting in a prevalence of 82.1% (95% CI: 76.1–87.0%) of undiagnosed OSA in this high-risk population. For the high-risk patients, there were no significant differences in the patient characteristics and comorbidities between those who had a valid home sleep study ( $n = 207$ ) and those who either had invalid (sleep study time <2 h) ( $n = 110$ ) or no ( $n = 217$ ) home sleep studies (Table 3).

The types of surgeries performed on patients with previously undiagnosed OSA are shown in Table 4. There were five (2.9%) patients who had postoperative respiratory distress. Two patients were transferred to the ICU unexpectedly – one for oxygen desaturations and the other for reintubation after developing a neck hematoma subsequent to a neck dissection. The average hospital

Table 2

Severity of OSA in the high-risk patients ( $n = 207$ ) without a prior diagnosis of OSA as measured by home sleep studies.

OSA severity	Number	Percentage
No OSA (0–5)	37	18.0%
Mild OSA (6–20)	97	47.1%
Moderate OSA (21–40)	40	18.9%
Severe OSA (>40)	33	16.0%
Mild to severe OSA	170	82.0%

The numbers in parentheses represent the apnea–hypopnea index range defining the OSA classification. OSA, obstructive sleep apnea.

Table 1

Patient characteristics and comorbidities of all patients who completed the questionnaire compared between those at high-risk and those not at high-risk for OSA.

	Not high-risk ( $n = 2117$ )	High-risk ( $n = 661$ )	<i>p</i> - Value
<i>Patient characteristics</i>			
Age (years) <sup>a</sup>	56 (44–68)	53 (43–62)	<0.001
Male gender	1218 (57.5%)	334 (50.5%)	0.002
BMI <sup>a</sup>	26.6 (23.7–29.7)	36.9 (33.5–42.0)	<0.001
Neck circumference (cm) <sup>a</sup>	38.1 (35.6–40.6)	43.2 (40.6–45.7)	<0.001
Caucasian	1624 (76.7%)	482 (72.9%)	<0.001
African American	429 (20.3%)	175 (26.5%)	
Other	64 (3.0%)	4 (0.6%)	
<i>Comorbidities</i>			
Hx hypertension	850 (40.2%)	386 (58.4%)	<0.001
Hx CAD or valvular disease	275 (13.0%)	104 (15.7%)	0.080
Hx diabetes	222 (10.5%)	164 (24.5%)	<0.001
Hx stroke	80 (3.8%)	15 (2.3%)	0.066
Hx OSA	46 (2.2%)	127 (19.2%)	<0.001

<sup>a</sup> Median (interquartile range), analyzed by unpaired Wilcoxon rank-sum. All others are number (percentage) analyzed by Fisher's exact test. OSA, obstructive sleep apnea; BMI, body mass index; cm, centimeters; CAD, coronary artery disease; Hx, history.

Table 3

Comparison of patient characteristics and comorbidities of high-risk patients without a prior diagnosis of OSA between patients with valid home sleep studies and those with either invalid or no home sleep studies.

	Valid study ( $n = 207$ )	Other high-risk ( $n = 327$ )	<i>p</i> - Value
<i>Patient characteristics</i>			
Age (years) <sup>a</sup>	52 (44–61)	53 (42–62)	0.96
Male gender	113 (54.6%)	165 (50.4%)	0.37
BMI <sup>a</sup>	37.4 (33.4–42.4)	36.4 (33.2–41.0)	0.36
Neck circumference (cm) <sup>a</sup>	43.2 (40.6–45.7)	43.2 (40.6–45.7)	0.60
Caucasian	152 (73.4%)	233 (71.3%)	0.24
African American	52 (25.1%)	93 (28.4%)	
Other	3 (1.4%)	1 (0.3%)	
<i>Comorbidities</i>			
Hx hypertension	116 (56.0%)	181 (55.4%)	0.93
Hx CAD or valvular disease	22 (10.6%)	47 (14.4%)	0.23
Hx diabetes	49 (23.7%)	73 (22.3%)	0.75
Hx stroke	3 (1.4%)	8 (2.4%)	0.54

<sup>a</sup> Median (interquartile range), analyzed by unpaired Wilcoxon rank-sum. All others are number (percentage) analyzed by Fisher's exact test. OSA, obstructive sleep apnea; BMI, body mass index; cm, centimeters; CAD, coronary artery disease; Hx, History.

**Table 4**  
Surgery types of patients with previously undiagnosed obstructive sleep apnea.

Surgery	#
Bariatric	3
Cardiothoracic	2
ENT	16
General	49
Gynecology	25
Neurosurgery	12
Ophthalmology	16
Orthopedic	52
Urology	16
Vascular	7
Cancelled	4
Unknown	4

**Table 5**  
Comparison of ARES Unicorder diagnoses of OSA against formal PSG in patients at high-risk for OSA without a prior OSA diagnosis.

	PSG AHI > 5	PSG AHI < 5
Unicorder AHI > 5	19	4
Unicorder AHI < 5	1	2

AHI, apnea-hypopnea index; OSA, obstructive sleep apnea; PSG, Polysomnography; ARES, apnea risk evaluation system.

length of stay was 3 days for those with undiagnosed OSA (range 0–20 days).

Formal PSGs conducted within one year of enrollment were obtained for 26 patients at high-risk for OSA who did not have a prior diagnosis of OSA and who had valid home sleep studies (Table 5). The PSGs confirmed the diagnosis of OSA in 73% of this subset, thus giving the home sleep study a sensitivity of 95.0% (95% CI: 73.1–99.7%) and a specificity of 33.3% (95% CI: 6.0–75.9%).

#### 4. Discussion

Almost a quarter of adult patients presenting for surgery at a tertiary care referral center screened high-risk for OSA. The majority of those who screened high-risk and underwent home testing were found to have OSA. Most of the patients who screened high-risk had not previously been diagnosed with OSA; only 6% of all patients had a prior diagnosis of OSA.

The validity of this study rests on a number of assumptions. The first is that the home studies are accurate in diagnosing OSA and determining its severity. This is a reasonable assumption: the Unicorder has been validated in prior studies in which it was compared with PSG, the accepted standard for OSA diagnosis [27,30]. Moreover, the diagnosis of OSA was confirmed in 73% of patients who also received a PSG. While the studies were not done contemporaneously, the high level of agreement supports this assumption.

The second assumption is that the high-risk patients who had valid home sleep studies are representative of the entire high-risk group. This supposition is supported by the lack of significant differences between the high-risk patients with valid studies and all other high-risk patients and that all available, consecutive high-risk patients were approached to use home studies. These facts suggest that our group of patients at high-risk for OSA with valid home sleep studies represent a random sample of the entire high-risk population. Nonetheless, there may have been selection bias attributable to an unidentified factor.

Another assumption is that the ARES OSA Screening Questionnaire is valid for detecting OSA in adult surgical patients. The screen has been shown to have a sensitivity of 94% with a specificity of 79% [23] in a non-surgical population. We are unable to estimate the sensitivity of the ARES screen in this population as we did not estimate the number of patients with OSA who did not screen high-risk, but the fact that there were 46 patients with known OSA who were not detected by the ARES screen suggests that it was not 100% sensitive. Thus, it is possible that this study underestimated the prevalence of undiagnosed OSA among adult surgical patients at high-risk for OSA at our institution.

Assuming that the patients who had valid home sleep studies were representative of the high-risk group without known OSA, we would expect OSA in 438 patients (82% of 534) at high-risk without a prior diagnosis of OSA. Combining these patients with the 173 patients with known OSA would give an estimated prevalence of OSA of 22.0% (611/2778) in the adult surgical population, with a bootstrapped 95% CI of 20.2–23.8%. It is worth noting that more than 70% of patients with OSA were undiagnosed. This is corroborated by an estimated prevalence of 15.7% (438/2778) of undiagnosed OSA, with a bootstrapped 95% CI of 14.2–17.4%. We recognize the limitations in extrapolating a prevalence based on a specific subgroup. However, it was not feasible to give home sleep studies to patients not at high-risk for OSA. It is reassuring that our results are consistent with a recent Canadian study that had a very similar approach [13,31].

It is important to emphasize that the patients in this study were adults in the Midwest who were scheduled for surgery at an urban academic hospital. These patients may have important demographic differences, such as a high prevalence of obesity, from patients in other geographical regions and those attending other types of healthcare facilities.

Our study showed a lower number of postoperative respiratory complications in patients with OSA than many previous studies [13,16]. There may be several reasons for this finding. The complication data were gathered via a retrospective chart review and thus relied upon proper documentation of the events. Additionally, while most of the people at high-risk for OSA were encouraged to have continuous pulse oximetry postoperatively as part of the safety initiative, this was up to the clinician's discretion. The pulse oximetries were not recording the data and oxygen desaturation would only be detected if a health care provider noticed and documented the event. Thus, desaturation events may be underreported. On the other hand, the low incidence of respiratory complications may be due to the simultaneous implementation of the safety initiative to prevent perioperative OSA-related complications in those at high-risk for OSA. Continuous pulse oximetry, improved identification and improved monitoring may have prevented respiratory complications in some of these patients. However, we recognize the limitations of reporting these complications as we did not monitor complications for patients not at high-risk for OSA.

OSA is common in the adult surgical population, and is frequently undiagnosed. Given the high estimated prevalence of undiagnosed OSA, each year approximately 5000 patients at our institution alone may undergo surgery without the surgeon's or anesthesiologist's knowledge that they have OSA. We have demonstrated the feasibility of universal screening for OSA in a preoperative assessment clinic. The screen correctly identified a large number of surgical patients with undiagnosed OSA undergoing a wide range of surgical procedures. Screening questionnaires may be useful in identifying patients in the preoperative period that may be at risk for OSA. The role of home testing devices requires further study.

**Appendix A**

A copy of the sleep apnea screening questionnaire.

First Name		Middle Name		Last Name	
Age		<b>Date of Birth</b>	Month	Day	Year
Gender	Male	Female	<b>Neck circumference</b>		Inches
<b>Height</b>	Feet	Inches	<b>Weight</b>		Pounds

Have you been diagnosed or treated for any of the following conditions? Circle Yes or No.					
High Blood Pressure	Yes	No	Currently Pregnant	Yes	No
Heart Disease	Yes	No	Sleep Apnea	Yes	No
Diabetes	Yes	No	Nasal or Mask Oxygen Use	Yes	No
Stroke	Yes	No			

On average in the past month, how often have you snored or been told that you snored?				
Never	Rarely 0 - 1 times per week	Sometimes 1-2 times per week	Frequently 3-4 times per week	Almost always 5-7 times per week

Do you wake up choking or gasping?				
Never	Rarely 0 - 1 times per week	Sometimes 1-2 times per week	Frequently 3 - 4 times per week	Almost always 5 - 7 times per week

Have you been told that you stop breathing in your sleep or wake up choking or gasping?				
Never	Rarely 0 - 1 times per week	Sometimes 1-2 times per week	Frequently 3 - 4 times per week	Almost always 5 - 7 times per week

<b>Epworth Sleepiness Scale: How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to circle the most appropriate number for each situation. (M.W. Johns, Sleep 1991)</b>				
0 = would never doze    1 = slight chance of dozing    2 = moderate chance of dozing    3 = high chance of dozing				
Sitting and reading	0	1	2	3
Watching TV	0	1	2	3
Sitting, inactive, in a public place (theater, meeting, etc)	0	1	2	3
As a passenger in a car for an hour without a break	0	1	2	3
Lying down to rest in the afternoon when circumstances permit	0	1	2	3
Sitting and talking to someone	0	1	2	3
Sitting quietly after lunch without alcohol	0	1	2	3
In a car, while stopped for a few minutes in traffic	0	1	2	3

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