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CHEST Original Research
SLEEP MEDICINE

Association of Sleep-Disordered Breathing With Postoperative Complications*

Dennis Hwang, MD, FCCP; Nawaid Shakir, MD; Baba Limann, MD; Cristina Sison, PhD; Sumeet Kalra, MD; Lawrence Shulman, DO, FCCP; Andre de Corla Souza, MD; and Harly Greenberg, MD, FCCP

Background: **Obstructive sleep apnea (OSA) is associated with increased perioperative risk, but the incidence of postoperative complications and the severity of OSA associated with increased risk have not been established. We investigated the relationship between intermittent hypoxemia measured by home nocturnal oximetry with the occurrence of postoperative complications in patients with clinical signs of OSA identified during preoperative assessment for elective surgery.**

Methods: **This study was performed at a tertiary care hospital. Home nocturnal oximetry was performed on elective surgical patients with clinical features of OSA. The number of episodes per hour of oxygen desaturation (or oxygen desaturation index) of ≥ 4% (ODI4%) was determined. Subjects with five or more desaturations per hour (ODI4%≥ 5) were compared to those with less than five desaturations per hour (ODI4%< 5). Hospital records were reviewed to assess the incidence and type of postoperative complications.**

Results: **A total of 172 patients were investigated as part of this study. No significant differences were observed between groups in terms of age, body mass index, number of medical comorbidities, or smoking history. Patients with an ODI4%≥ 5 had a significantly higher rate of postoperative complications than those with ODI4%< 5 (15.3% vs 2.7%, respectively [$p < 0.01$]; adjusted odds ratio, 7.2; 95% confidence interval, 1.5 to 33.3 [$p = 0.012$]). The complication rate also increased with increasing ODI severity (patients with an ODI4% of 5 to 15 events per hour, 13.8%; patients with an ODI4% of ≥ 15 events per hour, 17.5%; $p = 0.01$) Complications were respiratory (nine patients), cardiovascular (five patients), GI (one patient), and bleeding (two patients). The hospital length of stay was similar in both groups.**

Conclusion: **An ODI4%≥ 5, determined by home nocturnal oximetry, in patients with clinical features of OSA is associated with an increased rate of postoperative complications.**

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Key words: oximetry; postoperative complications; sleep apnea syndromes; sleep-disordered breathing; surgery

Abbreviations: BMI = body mass index; CPAP = continuous positive airway pressure; ODI = oxygen desaturation index; ODI4% = oxygen desaturation index of ≥ 4%; ODI4%< 5 = oxygen desaturation index of ≥ 4% with less than five desaturations per hour; ODI4%≥ 5 = oxygen desaturation index of ≥ 4% with five or more desaturations per hour; OSA = obstructive sleep apnea; PACU = postanesthesia care unit; SDB = sleep-disordered breathing; T90% = time spent with an oxygen saturation of < 90%

Obstructive sleep apnea (OSA) is a common form of sleep-disordered breathing (SDB) that has significant consequences in the perioperative setting.[1,2] However, strategies to reduce postoperative risk are difficult to implement since many patients with SDB and OSA have not received a formal diagnosis at the time of surgery.[3] Published guidelines regarding the role of various screening modalities for OSA, and the management of patients with known OSA undergoing surgery, have been based largely on expert opinion, reflecting the relative lack of evidence derived from clinical studies.[4] We sought to determine whether a simple screening protocol for OSA-related signs and symptoms performed at the time of preoperative assessment for elective surgery, followed by home nocturnal oximetry in selected cases, could identify patients who are at increased risk of perioperative complications.

Materials and Methods

Patients

We reviewed the medical records of elective surgery patients who were at least 18 years of age (performed on an inpatient or outpatient basis) who underwent preoperative screening for SDB based on an established clinical protocol at North Shore University Hospital, a tertiary care hospital in New York, between July 2004 and November 2006. During preoperative assessment in the preanesthesia testing unit, patients without a prior diagnosis of OSA but with at least two clinical features suggestive of OSA on a standardized screening questionnaire and physical examination (*eg*, snoring, excessive daytime somnolence, witnessed apneas, or crowded oropharynx) were selected for home nocturnal oximetry testing. The results were interpreted by sleep medicine-trained physicians prior to the scheduled surgery. Studies that did not provide at least 4 h of adequate recording time were excluded. The results of the oximetry studies were made available to the anesthesia and surgical teams, as well as to the primary care physician. Because subsequent medical care was provided at the discretion of the patients' usual physicians, further follow-up beyond the surgical period delineated in the charts was not available to the research team; therefore, the results of formal polysomnography, which may have been performed after this hospitalization for further evaluation of oximetry results was not available for review. Oximeters were programmed to average measurements over 8-s intervals. This study was approved by the hospital institutional review board.

Protocol

Chart reviewers were blinded to the results of the oximetry testing. Demographic information, comorbidities, nocturnal oximetry results, and surgical outcome data were collected. Demographic variables included age, sex, race, type of surgery, height, and weight. For this study, patients were defined as overweight if they had a body mass index (BMI) of ≥ 27 kg/m^2. Variables from nocturnal oximetry testing included the number of episodes per hour of oxygen desaturation (or oxygen desaturation index [ODI]) of $\geq 4\%$ (ODI4%) and the percentage of study time spent with an oxygen saturation of $< 90\%$ (T90%). An oxygen desaturation of $\geq 4\%$ was used to determine the ODI since this degree of oxygen desaturation has been used in previous studies.[5] Outcomes included the presence or absence of postoperative complications and hospital length of stay. A complication was defined as an adverse event affecting a major organ system that required further monitoring, additional diagnostic testing, or direct therapeutic intervention. Hospital protocol mandated that patients with SDB determined by an abnormal nocturnal oximetry test result and patients with an established diagnosis of OSA undergo prolonged postanesthesia care unit (PACU) monitoring. Subjects with an ODI4% of ≥ 5 were compared to those with an ODI4% of <5. Nocturnal oxygen desaturation severity was rated as follows: mild (ODI4%, 5 to 20); moderate (ODI4%, 20 to 40); and severe (ODI4%, ≥ 40).

*From the Division of Pulmonary, Critical Care, and Sleep Medicine (Drs. Hwang, Shakir, Limann, de Corla-Souza, Shulman, and Greenberg), the Biostatistics Unit (Dr. Sison), and the Department of Anesthesiology (Dr. Kalra), North Shore Long Island Jewish Health Systems, Mahasset, NY.
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Correspondence to: Dennis Hwang, MD, Division of Pulmonary, Critical Care, and Sleep Medicine, North Shore Long Island Jewish Health Systems, 410 Lakeville Rd, Suite 107, New Hyde Park, NY 11040; e-mail: dennis.hwang@nyumc.org
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Statistical Analysis

The Fisher exact test was used to determine whether there was a statistically significant difference in perioperative complication rates between the ODI4% ≥ 5 and ODI4% < 5 groups. The Fisher exact test and Mann-Whitney test were used to determine which of the candidate risk factors were individually associated with a perioperative complication. The Cochran-Armitage trend test was used to test for trends across the ODI4% severity groups. The asymptotic test for the Somer D(C/R), which measures association between complication (outcome) and ODI4% severity as the predictor, was also calculated. Spearman correlations were used to determine the strength of association between variables (such as ODI and BMI). A logistic regression analysis was subsequently carried out to determine which of the significant risk factors found from the univariate screening process were jointly associated with a complication. A backward-selection algorithm was applied to arrive at a parsimonious model. In order to adjust for multiple comparisons, we arbitrarily used $p < 0.03$ to conclude significance, rather than the usual $p < 0.05$.

Results

A total of 172 patients aged 27 to 85 years were evaluated. The overall mean ($\pm$ SD) age was 54.5 ± 13.6 years. Other relevant demographics are included in Tables 1 and 2; the categories of surgical procedures are included in Table 3.

Home nocturnal oximetry testing revealed that 98 patients (57%) had an ODI4% with five or more desaturations per hour (ODI4%≥ 5) and 74 patients (43%) had an ODI4% with less than five desaturations per hour (ODI4%< 5). There were 58 patients (33.7%) with an ODI in the mild range, 30 patients (17.4%) with an ODI in the moderate range, and 10 patients (5.8%) with an ODI in the severe range. Due to the small numbers of subjects in the latter group, data from the severe and moderate ODI4% groups were combined for analysis. The mean ODI in the ODI4%≥ 5 group was 21.9 ± 17.4, and the mean ODI in the ODI4%< 5 group was 1.9 ± 1.4. The T90% was $2.1 \pm 4.8\%$ in the ODI4%< 5 group, and $17.7 \pm 25.0\%$ in the ODI4%≥ 5 group ($p < 0.0001$). Overall, 17 patients (9.9%) experienced a perioperative complication. Fifteen of these complications (88%) occurred among the 98 patients with an ODI4%≥ 5, while only 2 of the complications (12%) occurred among those patients with an ODI4%< 5. The T90% was also greater in patients who experienced a complication compared to those without a complication (20.8 ± 25.6 vs 9.9 ± 19.8, respectively; $p = 0.03$). However, all patients with an increased

Table 1—*Demographics and Clinical Characteristics of the Study Patients**

Variables	ODI4% < 5	ODI4% ≥ 5	Total
Gender			
Male	30 (40.5)	55 (56.1)	85
Female	44 (59.5)	43 (43.9)	87
Race			
White	48 (66.7)	56 (57.1)	104
Nonwhite	24 (33.3)	42 (42.9)	66
Age group			
≥ 65 yr	14 (18.9)	27 (27.6)	41
< 65 yr	60 (81.1)	71 (72.4)	131
BMI group			
≥ 27 kg/m^2	54 (73.0)	86 (87.8)	140
< 27 kg/m^2	20 (27.0)	12 (12.2)	32
Smoking status†			
Positive smoking history‡	42 (57.5)	40 (50.6)	82
Negative smoking history	31 (42.5)	39 (49.4)	70
Comorbidities			
Hypertension	37 (45.9)	61 (62.2)	
Diabetes	9 (12.2)	20 (20.4)	
History of MI or stroke	3 (4.1)	3 (3.1)	
COPD	4 (5.4)	3 (3.1)	
Asthma	13 (17.6)	16 (16.3)	
ESRD	1 (1.4)	0 (0)	
Total in each ODI group	74	98	172

*Values are given as No. (% of ODI group), unless otherwise indicated. MI = myocardial infarction; ESRD = end-stage renal disease.
†Smoking status could not be obtained for several patients; the analysis was performed only on the 152 patients with an available smoking history.
‡Current or previous smoker.

T90% also had an increased ODI4%; therefore, the T90% essentially reflected the degree of intermittent hypoxia. The categories of complications are shown in Figure 1, and detailed information on the patients who experienced a complication is given in Table 4. A hypoxemic complication was defined by a decrease in oxygen saturation that required an addition or increase in supplemental oxygen. An atelectasis event was identified if it had been recorded in the clinical or radiographic record. An increased rate of complications was observed as the severity of SDB increased. The rate of complications increased from 2.7% among patients without nocturnal oxygen desaturation to 13.8% in patients with a mild ODI4%, and to 17.5% in patients with a moderate-to-severe ODI4% ($p = 0.01$).

A trend toward a higher BMI was observed in the ODI4%≥ 5 group compared with the ODI4%< 5 group (36.5 ± 8.7 vs 34.0 ± 9 kg/m^2, respectively; $p = 0.054$). The former group also had a higher proportion of patients who were classified as being overweight with a BMI of ≥ 27 kg/m^2 (88% vs 73%, respectively; $p = 0.02$); more overweight patients had an ODI4%≥ 5 than nonoverweight patients (61% vs 37.5%, respectively; $p = 0.02$). There were no significant differences between the two groups in age, height, smoking history, type of surgery, number of inpatient days, and number of medical comorbidities. There was no significant difference in the presence of respiratory diseases between the two groups, and none of the patients in our study were receiving

Table 2—*Demographics**

Variables	ODI4% < 5	ODI4% ≥ 5	p Value
ODI	1.9 ± 1.4	21.9 ± 17.4	
Age, yr	52.7 ± 14.3	55.9 ± 12.9	NS
Weight, kg	97.4 ± 26.3	106.6 ± 27.1	0.02
BMI, kg/m^2	34.0 ± 9.0	36.5 ± 8.7	0.054
Complication rate, %	2.7	15.3	0.008

*Values are given as the mean ± SD or %, unless otherwise indicated. NS = not significant.

Table 3—*Categories of Surgery**

Categories	ODI4% < 5	ODI4% ≥ 5	Total
Abdominal	32 (43.2)	35 (35.7)	67
Thoracic	5 (6.8)	3 (3.1)	8
Gynecologic	7 (9.5)	15 (15.3)	22
Vascular	3 (4.1)	3 (3.1)	6
Neurosurgical	5 (6.8)	10 (10.2)	15
Urologic	14 (18.9)	19 (19.4)	33
Cardiothoracic	2 (2.7)	4 (4.1)	6
Orthopedic	3 (4.1)	4 (4.1)	7
ENT (non-UPPP)	2 (2.7)	3 (3.1)	5
Other	1 (1.4)	2 (2.0)	3
Total	74	98	172

*Values are given as No. (% of ODI group), unless otherwise indicated. ENT = ear, nose, and throat; UPPP = uvulopalatopharyngoplasty.

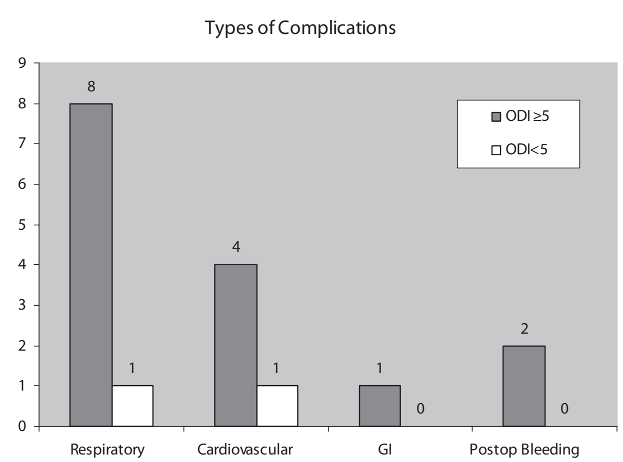

FIGURE 1. Tabulation of the types of complications based on ODI grouping. A higher number of complications occurred in patients with an ODI4%≥5, the majority of which were respiratory or cardiovascular in nature.

Table 4—*Patients With Adverse Events**

Variables	ODI4%	Age, yr	Sex	BMI, kg/m^2	Type of Surgery	Complication
ODI 4%< 5	0.2	27	F	46.7	Laparoscopic gastric bypass surgery	Transient episodes of unspecified tachyarrhythmia during the first 3 postoperative days
	3.0	52	F	59.4	Laparoscopy with conversion to open ventral herniorrhaphy and adhesiolysis	Hypoxemia treated with supplemental oxygen and BPAP
ODI 4%≥ 5	5.5	49	F	26.2	Total abdominal hysterectomy and right salpingoophorectomy cystoscopy with placement of ureteral catheters	Hypoxemia was observed on postoperative day 3 and treated with oxygen supplementation; atelectasis was noted
	6.0	49	F	39.1	Total abdominal hysterectomy and bilateral oophorectomy	Intraperitoneal bleeding was treated with embolization
	6.2	39	F	44.9	Laparoscopic gastric bypass surgery	Intraperitoneal bleeding which resolved without surgery
	7.6	61	M	33.5	Sigmoid colon resection	Hypoxemia and hypotension.
	12.9	64	M	37.0	Mitral valve replacement	Hypotension and junctional escape rhythm
	13.0	57	M	38.9	Laparoscopic colonic polypectomy	Atelectasis
	14.5	58	F	41.6	Total abdominal hysterectomy and bilateral oophorectomy	Atelectasis
	18.6	62	M	37.3	Left inguinal herniorrhaphy	Wheezing observed which required treatment with bronchodilators
	24.6	49	F	28.1	Total abdominal hysterectomy and bilateral oophorectomy	Pneumonia
	26.3	53	F	47.9	Gastric bypass surgery	GI bleeding
	31.9	50	M	29.6	Radical prostatectomy	Hypoxemia treated with CPAP
	34.1	62	F	31.4	Total abdominal hysterectomy and bilateral oophorectomy	Atelectasis
	34.2	69	M	36.9	Laparoscopic right hemicolectomy	Pulmonary embolism; superior mesenteric vein thrombosis
	36.4	55	F	49.5	Exploratory laparotomy, adhesiolysis, small bowel resection, partial hepatic resection, gastric bypass	Chest pain (MI was ruled out)
	82.4	66	F	46.8	Total abdominal hysterectomy and bilateral oophorectomy	Hypoxemia treated with CPAP

*F = female; M = male; BPAP = bilevel positive airway pressure. See Table 1 for abbreviation not used in the text.

long-term oxygen therapy. Men had a significantly higher prevalence of ODI4%≥ 5 than women (64.7% vs 49.5%, respectively; p = 0.05). Spearman correlations revealed a significant association between BMI and ODI4% ($r = 0.23$; p = 0.003), and between BMI and T90% ($r = 0.22$; p = 0.004).

The number of PACU hours was greater in the ODI4%≥ 5 group than in the ODI4%< 5 group (11.1 ± 9.5 vs 6.3 ± 7.3 h, respectively; p < 0.001), but this observation was consistent with the existing hospital protocol requiring that patients with known OSA or an abnormal nocturnal oximetry test result to be observed for an extended duration in the PACU.

A cross-tabulation of categoric variables was performed, and revealed a significant difference in the complication rates between the ODI4%≥ 5 and ODI4%< 5 groups (15.3% vs 2.7%, respectively; p = 0.008). Logistic regression analysis was performed to determine which factors were significant contributors to the complication rate. Factors considered were ODI4% group (*ie*, ODI4%≥ 5 vs ODI4%< 5), sex, and BMI group (≥ 27 or < 27 kg/m^2). Only the ODI4% grouping was a significant determinant of the rate of perioperative complications. The odds ratio for a postoperative complication was 6.5 in the ODI4%≥ 5 group compared with the ODI4%< 5 group (95% confidence interval, 1.4 to 29.4; p = 0.015). After adjusting for sex and BMI grouping, the adjusted odds ratio of a perioperative complication increased to 7.2 in the ODI4%≥ 5 group (95% confidence interval, 1.5 to 33.3; p = 0.012).

Discussion

While OSA is a prevalent condition with the potential to cause significant adverse effects in the perioperative setting, the majority of patients remain without a diagnosis.[3] This necessitates screening during preoperative assessment to facilitate the implementation of strategies to minimize the postoperative risk. Since clinical history is an unreliable indicator of the presence of OSA, a more effective screening modality is necessary.[6] Overnight polysomnography is the "gold standard" for the diagnosis of OSA but may be impractical during preoperative assessment. Home nocturnal oximetry has been studied as a potential screening tool, although a wide range of sensitivity and specificity for OSA has been reported.[7–21] Furthermore, prior studies using this modality did not correlate the results of home oximetry testing with perioperative outcomes. In the present study, we directly compared the results of home nocturnal oximetry with the incidence of complications after elective surgery. The ODI4% was the primary metric used to assess SDB. We demonstrated that an ODI4% $\geq$ 5, in patients with clinical features of OSA, independently predicts an increased rate of postoperative complications, with an adjusted odds ratio of 7.2 compared to subjects with an ODI4% $<$ 5.

The cardiorespiratory consequences of OSA may be exacerbated in the perioperative setting due to the adverse effects of anesthetics and analgesics on ventilatory control and upper airway muscle tone, particularly during the early postoperative period.[22–26] In addition, sleep disturbances, including sleep deprivation and fragmentation as well as rebound increases in rapid eye movement sleep during later postoperative days, may have additional adverse effects on the cardiac and respiratory systems.[27–30] Potential clinical consequences of SDB in the perioperative setting include upper airway collapse with obstructive apnea, exacerbation of hypoxemia and hypercapnia, cardiac arrhythmias and ischemia, airway management difficulties, encephalopathy, increased rate of postoperative infections, as well as other adverse effects.[31–46] Case series have suggested that the perioperative use of continuous positive airway pressure (CPAP) reduces the rate of complications in OSA patients.[42,47] CPAP stabilizes fluctuations in BP, improves upper airway patency and ventilation, reduces myocardial ischemia, and decreases the incidence of cardiac arrhythmias.[42,48–50] Mooe et al[50] demonstrated that an apnea-hypopnea index of more than five events per hour was an independent risk factor for postoperative atrial fibrillation in patients undergoing coronary artery bypass surgery. Gupta et al[51] found an increased incidence of postoperative complications, an elevated rate of transfers to an ICU, and a prolonged overall length of hospital stay in patients with OSA compared with control subjects matched for age, sex, and BMI. Receiving CPAP therapy prior to surgery appeared to reduce the rate of serious complications and shorten the average length of hospital stay by about 1 day. The choice of postoperative analgesia is also an important consideration since narcotics and benzodiazepines have been shown to adversely affect SDB.[25,27]

Some of the adverse postoperative events that we observed can be directly attributed to underlying SDB. Two patients had oxygen desaturations during the postoperative period that resolved with CPAP therapy. The eight other postoperative respiratory complications consisted of hypoxemia, atelectasis, pneumonia, bronchospasm, and pulmonary embolism. Cardiac complications included chest pain and a case of junctional arrhythmia. While the etiology of these complications is not known, SDB may be a contributing factor. Of the 15 postoperative complications observed in the subjects with SDB, only three complications (intraperitoneal bleeding, two instances; GI bleeding, one instance) may be considered to have been unrelated to SDB.

Our study focused on patients with clinical features of OSA and nocturnal intermittent hypoxia as assessed by the ODI4%. While T90% was also greater in the group with postoperative complications, this variable was closely associated with the ODI; therefore, the T90% essentially reflected the severity of intermittent hypoxia. Thus, conclusions cannot be made regarding patients with sustained hypoxia that may occur as a result of underlying pulmonary dysfunction or hypoventilation. Furthermore, it is worth noting that nocturnal oximetry and the metrics used in its assessment are insensitive to forms of SDB that are not associated with decreases of $\geq$ 4% in saturation such as inspiratory flow limitation and apneas/hypopneas that induce lesser declines in oxygen saturation. Despite these restrictions, this study suggests that even a mild ODI4% rate, at levels frequently not considered clinically significant, may confer an increased risk of postoperative complications. This is consistent with the previous observations of Mooe et al[50] that an apnea-hypopnea index of at least five events per hour was associated with an increased risk of atrial fibrillation after coronary artery bypass surgery. Furthermore, our study also suggests that the rate of postoperative complications increases with increasing severity of SDB.

The limitations of this study include the lack of polysomnographic confirmation of the nocturnal oximetry findings, which prevents determination of the sensitivity and specificity of nocturnal oximetry for OSA in this setting. As a result, in this study nocturnal oximetry is more accurately described as a surrogate marker for SDB rather than as a metric for the presence of OSA and its severity. However, numerous studies have previously correlated oximetry testing with the assessment of OSA, and Gyulay et al[11] have suggested that a positive oximetry test result has a high positive predictive value for OSA. In addition, the primary variable assessed in our study is the ODI, which detects a pattern of deoxygenation and reoxygenation that is most consistent with sleep apnea-type syndromes, of which OSA is the most common.[52] Therefore, we propose that our use of nocturnal oximetry testing has strong relevance in the assessment of OSA. A second limitation includes the use of nocturnal oximetry only in patients who were preselected with clinical features of OSA during a preoperative evaluation. Thus, the usefulness of nocturnal oximetry as a screening tool in unselected preoperative patients cannot be assessed. Despite these limitations, we demonstrated the potential usefulness of home nocturnal oximetry in preoperative assessment as the results of this test are independently correlated to postoperative complications. However, we cannot prove a causal relationship between nocturnal oxygen desaturation and the observed postoperative complications. This issue can only be resolved by a randomized controlled trial designed to determine whether the perioperative treatment of SDB, potentially with CPAP, in patients with abnormal nocturnal oximetry findings reduces the incidence of complications. Finally, it is worth noting that technical factors such as oximetry sampling and averaging rates may affect determination of the ODI4%.[21] This parameter must be standardized in future studies.

In conclusion, we demonstrated that an ODI4% $\geq$ 5, measured during home nocturnal oximetry, is independently associated with an increased rate of postoperative complications. Future studies are needed to evaluate the effect of perioperative treatment of SDB in patients who are identified to be at risk for this disorder during preoperative assessment.

References

1 Young T, Palta M, Dempsey J, et al. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 1993; 328:1230–1235

2 Kyzer S, Charuzi I. Obstructive sleep apnea in the obese. World J Surg 1998; 22:998–1001

3 Young T, Evans L, Finn L, et al. Estimation of the clinically diagnosed proportion of sleep apnea syndrome in middle-aged men and women. Sleep 1997; 20:705–706

4 Gross JB, Bachenberg KL, Benumof JL, et al. Practice guidelines for the perioperative management of patients with obstructive sleep apnea: a report by the American Society of Anesthesiologists Task Force on Perioperative Management of patients with obstructive sleep apnea. Anesthesiology 2006; 104:1081–1093

5 Shahar E, Whitney CW, Redline S, et al. Sleep-disordered breathing and cardiovascular disease: cross-sectional results of the Sleep Heart Health Study. Am J Respir Crit Care Med 2001; 163:19–25

6 Hoffstein V, Szalai JP. Predictive value of clinical features in diagnosing obstructive sleep apnea. Sleep 1993; 16:118–122

7 Farney RJ, Walker LE, Jensen RL, et al. Ear oximetry to detect apnea and differentiate rapid eye movement (REM) and non-REM (NREM) sleep: screening for the sleep apnea syndrome. Chest 1986; 89:533–539

8 Series F, Marc I, Cormier Y, et al. Utility of nocturnal home oximetry for case finding in patients with suspected sleep apnea hypopnea syndrome. Ann Intern Med 1993; 119:449–453

9 Epstein LJ, Dorlac GR. Cost-effectiveness analysis of nocturnal oximetry as a method of screening for sleep apnea-hypopnea syndrome. Chest 1998; 113:97–103

10 Golpe R, Jimenez A, Carpizo R, et al. Utility of home oximetry as a screening test for patients with moderate to severe symptoms of obstructive sleep apnea. Sleep 1999; 22:932–937

11 Gyulay S, Olson LG, Hensley MJ, et al. A comparison of clinical assessment and home oximetry in the diagnosis of obstructive sleep apnea. Am Rev Respir Dis 1993; 147:50–53

12 Williams AJ, Yu G, Santiago S, et al. Screening for sleep apnea using pulse oximetry and a clinical score. Chest 1991; 100:631–635

13 Sano K, Nakano H, Ohnishi Y, et al. Screening of sleep apnea/hypopnea syndrome by home pulse oximetry. Nihon Kokyuki Gakkai Zasshi 1998; 36:948–952

14 Magalang UJ, Dmochowski J, Veeramachaneni S, et al. Prediction of the apnea-hypopnea index from overnight pulse oximetry. Chest 2003; 124:1694–1701

15 Chiner E, Signes-Costa J, Arriero JM, et al. Nocturnal oximetry for the diagnosis of the sleep apnoea hypopnoea syndrome: a method to reduce the number of polysomnographies? Thorax 1999; 54:968–971

16 Levy P, Pepin JL, Deschaux-Blanc C, et al. Accuracy of oximetry for detection of respiratory disturbances in sleep apnea syndrome. Chest 1996; 109:395–399

17 Olson LG, Ambrogetti A, Gyulay SG. Prediction of sleep-disordered breathing by unattended overnight oximetry. J Sleep Res 1999; 8:51–55

18 Whitelaw WA, Brant RF, Flemons WW. Clinical usefulness of home oximetry compared with polysomnography for assessment of sleep apnea. Am J Respir Crit Care Med 2005; 171:188–193

19 Takeda T, Nishimura Y, Satouchi M, et al. Usefulness of the oximetry test for the diagnosis of sleep apnea syndrome in Japan. Am J Med Sci 2006; 331:304–308

20 Brouillette RT, Morielli A, Leimanis A, et al. Nocturnal pulse oximetry as an abbreviated testing modality for pediatric obstructive sleep apnea. Pediatrics 2000; 105:405–412

21 Wiltshire N, Kendrick AH, Catterall JR. Home oximetry studies for diagnosis of sleep apnea/hypopnea syndrome: limitation of memory storage capabilities. Chest 2001; 120:384–389

22 Kaw R, Michota F, Jaffer A, et al. Unrecognized sleep apnea in the surgical patient: implications for the perioperative setting. Chest 2006; 129:198–205

23 Leiter JC, Knuth SL, Krol RC, et al. The effect of diazepam on genioglossal muscle activity in normal human subjects. Am Rev Respir Dis 1985; 132:216–219

24 White DP, Douglas NJ, Pickett CK, et al. Sleep deprivation and the control of ventilation. Am Rev Respir Dis 1983; 128:984–986

25 Moote C, Knill RL, Skinner MI. Morphine disrupts nocturnal sleep in a dose-dependent fashion [abstract]. Anesth Analg 1989; 68:S200

26 Rapoport DM, Greenberg HE, Goldring RM. Differing effects of the anxiolytic agents buspirone and diazepam on

control of breathing. Clin Pharmacol Ther 1991; 49:394–401
27 Leiter JC, Knuth SL, Bartlett D Jr. The effect of sleep deprivation on activity of the genioglossus muscle. Am Rev Respir Dis 1985; 132:1242–1245
28 Knill RL, Moote CA, Skinner MI, et al. Anesthesia with abdominal surgery leads to intense REM sleep during the first postoperative week. Anesthesiology 1990; 73:52–61
29 Series F, Roy N, Marc I. Effects of sleep deprivation and sleep fragmentation on upper airway collapsibility in normal subjects. Am J Respir Crit Care Med 1994; 150:481–485
30 Orr WC, Stahl ML. Sleep disturbances after open heart surgery. Am J Cardiol 1977; 39:196–201
31 Kaw R, Golish J, Ghamande S, et al. Incremental risk of obstructive sleep apnea on cardiac surgical outcomes. J Cardiovasc Surg (Torino) 2006; 47:683–689
32 Eastwood PR, Platt PR, Shepherd K, et al. Collapsibility of the upper airway at different concentrations of propofol anesthesia. Anesthesiology 2005; 103:470–477
33 Eastwood PR, Szollosi I, Platt PR, et al. Collapsibility of the upper airway during anesthesia with isoflurane. Anesthesiology 2002; 97:786–793
34 Eastwood PR, Szollosi I, Platt PR, et al. Comparison of upper airway collapse during general anaesthesia and sleep. Lancet 2002; 359:1207–1209
35 Sharma VK, Galli W, Haber A, et al. Unexpected risks during administration of conscious sedation: previously undiagnosed obstructive sleep apnea. Ann Intern Med 2003; 139:707–708
36 Rosenberg J, Rasmussen GI, Wojdemann KR, et al. Ventilatory pattern and associated episodic hypoxaemia in the late postoperative period in the general surgical ward. Anaesthesia 1999; 54:323–328
37 Gentil B, Lienhart A, Fleury B. Enhancement of postoperative desaturation in heavy snorers. Anesth Analg 1995; 81:389–392
38 Isono S, Sha M, Suzukawa M, et al. Preoperative nocturnal desaturations as a risk factor for late postoperative nocturnal desaturations. Br J Anaesth 1998; 80:602–605
39 Rosenberg J, Wildschiodtz G, Pedersen MH, et al. Late postoperative nocturnal episodic hypoxaemia and associated sleep pattern. Br J Anaesth 1994; 72:145–150
40 Hanly P, Sasson Z, Zuberi N, et al. ST-segment depression during sleep in obstructive sleep apnea. Am J Cardiol 1993; 71:1341–1345
41 Mooe T, Franklin KA, Wiklund U, et al. Sleep-disordered breathing and myocardial ischemia in patients with coronary artery disease. Chest 2000; 117:1597–1602
42 Peled N, Abinader EG, Pillar G, et al. Nocturnal ischemic events in patients with obstructive sleep apnea syndrome and ischemic heart disease: effects of continuous positive air pressure treatment. J Am Coll Cardiol 1999; 34:1744–1749
43 Kanagala R, Murali NS, Friedman PA, et al. Obstructive sleep apnea and the recurrence of atrial fibrillation. Circulation 2003; 107:2589–2594
44 Mehra R, Benjamin EJ, Shahar E, et al. Association of nocturnal arrhythmias with sleep-disordered breathing: the Sleep Heart Health Study. Am J Respir Crit Care Med 2006; 173:910–916
45 Guilleminault C, Connolly SJ, Winkle RA. Cardiac arrhythmia and conduction disturbances during sleep in 400 patients with sleep apnea syndrome. Am J Cardiol 1983; 52:490–494
46 Shepard JW Jr, Garrison MW, Grither DA, et al. Relationship of ventricular ectopy to oxyhemoglobin desaturation in patients with obstructive sleep apnea. Chest 1985; 88:335–340
47 Rennotte MT, Baele P, Aubert G, et al. Nasal continuous positive airway pressure in the perioperative management of patients with obstructive sleep apnea submitted to surgery. Chest 1995; 107:367–374
48 Reeder MK, Goldman MD, Loh L, et al. Postoperative obstructive sleep apnoea: haemodynamic effects of treatment with nasal CPAP. Anaesthesia 1991; 46:849–853
49 Hers V, Liistro G, Dury M, et al. Residual effect of nCPAP applied for part of the night in patients with obstructive sleep apnoea. Eur Respir J 1997; 10:973–976
50 Mooe T, Gullsby S, Rabben T, et al. Sleep-disordered breathing: a novel predictor of atrial fibrillation after coronary artery bypass surgery. Coron Artery Dis 1996; 7:475–478
51 Gupta RM, Parvizi J, Hanssen AD, et al. Postoperative complications in patients with obstructive sleep apnea syndrome undergoing hip or knee replacement: a case-control study. Mayo Clin Proc 2001; 76:897–905
52 Kryger M, Roth T, Dement W. Principles and practice of sleep medicine. 3rd ed. Philadelphia, PA: Saunders, 2000; 827