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REPORTS OF ORIGINAL INVESTIGATIONS

Postoperative complications in patients with obstructive sleep apnea: a retrospective matched cohort study

Complications postopératoires chez des patients souffrant d'apnée obstructive du sommeil: une étude de cohorte appariée rétrospective

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Abstract

Purpose *Obstructive sleep apnea (OSA) is presumed to be a risk factor for postoperative morbidity and mortality, but the current evidence is incomplete. This retrospective matched cohort study tested the hypothesis that OSA is a risk factor for the development of postoperative complications.*

Methods *Hospital ethics approval was obtained for the conduct of this study. The patients who were selected for the study were >18 yr of age, diagnosed preoperatively with OSA, and scheduled to undergo elective surgery. A cohort of surgical patients without OSA was used as a comparator group based on a one-to-one match. Matching criteria included gender, age difference <5 yr, type of surgery, and a <5 yr difference between two surgery dates. Summary data are presented and conditional logistic regression was used to identify risk factors for postoperative complications.*

Results *The 240 pairs of study subjects aged 57 ± 13 yr included 184 (77%) males and 56 (23%) females. The OSA patients had a higher mean body mass index relative to their non-OSA counterparts (35 ± 9 vs 28 ± 6 kg · m^{-2}, respectively) and a higher frequency of co-morbidities, including hypertension (48% vs 36%, respectively) and obesity (61% vs 23%, respectively). Also, the incidence of postoperative complications in the OSA patients was significantly greater (44% OSA group vs 28% non-OSA group; $P < 0.05$). The most commonly observed between-group difference was oxygen desaturation < 90% (17% OSA group vs 8% non-OSA group). The OSA patients who did not use home continuous positive airway pressure (CPAP) devices prior to scurgery but required the use of a CPAP device after surgery had the highest rate of complications. Conditional logistic regression was used to diagnose OSA and pre-existing stroke as significant risk factors for developing postoperative complications. The hazard ratio for OSA was 2.0 (1.25–3.19).*

Conclusion *Patients with diagnosed OSA have an increased incidence of postoperative complications, the most frequent being oxygen desaturation.*

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Résumé

Objectif *Il est présumé que l'apnée obstructive du sommeil (AOS) est un facteur de risque pour la morbidité et la mortalité postopératoires, mais les données probantes actuelles sont incomplètes. Cette étude de cohorte appariée rétrospective a testé l'hypothèse selon laquelle l'AOS est un facteur de risque pour l'apparition de complications postopératoires.*

Méthode *La réalisation de cette étude a été approuvée par le comité d'éthique de l'hôpital. Les patients sélectionnés pour participer à l'étude avaient > 18 ans, avaient reçu un diagnostic préopératoire d'AOS, et devaient subir une chirurgie non urgente. Une cohorte de patients chirurgicaux ne souffrant pas d'AOS a été utilisée comme groupe de comparaison, avec une correspondance injective. Les critères de correspondance incluaient le sexe, une différence d'âge < 5 ans, le type de chirurgie, et un délai < 5 ans entre les deux dates de chirurgie. Les données agrégées sont présentées et un modèle de régression*

logistique conditionnelle a été utilisé pour déterminer les facteurs de risque de complications postopératoires.

Résultats *Les 240 paires de patients à l'étude, âgés de 57 ± 13 ans, étaient composées de 184 (77 %) hommes et de 56 (23 %) femmes. Les patients souffrant d'AOS avaient un indice de masse corporelle moyen plus élevé par rapport à leurs pendants sans AOS (35 ± 9 vs 28 ± 6 kg·m^{-2}, respectivement) et une fréquence plus élevée de comorbidités, notamment l'hypertension (48 % vs 36 %, respectivement) et l'obésité (61 % vs 23 %, respectivement). De plus, l'incidence de complications postopératoires dans le groupe AOS était significativement plus élevée (44 % groupe AOS vs 28 % groupe non AOS; P < 0,05). La différence inter-groupe la plus communément observée était une désaturation en oxygène < 90 % (17 % groupe AOS vs 8 % groupe non AOS). Les patients AOS qui n'utilisaient pas d'appareil de ventilation en pression positive continue (PPC) à la maison avant la chirurgie mais qui ont nécessité l'utilisation d'un tel appareil après la chirurgie ont eu le taux de complications le plus élevé. La régression logistique conditionnelle a été utilisée pour diagnostiquer l'AOS et les accidents vasculaires cérébraux préexistants en tant que facteurs de risque significatifs pour l'apparition de complications postopératoires. Le taux de risque pour l'AOS était de 2,0 (1,25 – 3,19).*

Conclusion *Les patients pour lesquels un diagnostic d'AOS a été posé sont plus à risque de souffrir de complications postopératoires, la plus fréquente étant la désaturation en oxygène.*

Obstructive sleep apnea (OSA), the most prevalent breathing disturbance in sleep,[1] affects 2–26% of the general population, depending on sex, age, and the criteria of diagnosis.[2] A growing body of literature suggests that OSA has been implicated in the development of cardiorespiratory diseases.[3–10] OSA also has a significant impact on both acute and chronic cardiorespiratory function.[11]

Although no large epidemiologic studies have been undertaken to determine the prevalence of OSA in the general surgical population, reports of several studies suggest that the prevalence of OSA in the surgical population might be higher than in the general population, with variability among different surgical populations. In particular, as many as 29/41 (71%) of patients undergoing bariatric surgery were found to have OSA.[12] In the general surgical population, 24% of surgical patients were identified by the Berlin questionnaire as being at a high risk of having OSA.[13]

Physiological studies show that the upper airway muscles are more sensitive to neuromuscular blocking drugs than either the diaphragm or the peripheral muscles.[14] Patients with OSA are highly vulnerable to medications that suppress pharyngeal muscle activity.[15–17] In addition to compromising upper airway muscle function, general anesthesia and narcotics can depress the patients' ventilatory responses to obstruction and inhibit their normal arousal and awakening responses to hypoxia and hypercapnia.[18] A high incidence of early and late postoperative nocturnal hypoxemic episodes in healthy patients undergoing surgery has been reported in a number of studies.[19–21]

However, the currently available literature on the occurrence of perioperative respiratory complications among surgical patients with OSA is too limited to make any major correlations. The objective of this study was to test the hypothesis that OSA is a risk factor for the development of postoperative complications.

Methods

We undertook a retrospective matched cohort study of a large cross section of surgical patients at the University Health Network, Toronto. Following research ethics board approval, the study subjects were selected from the hospital administrative database. The institutional research ethics board waived the requirement for individual informed consent.

Surgical patients in the OSA group were selected based on the following criteria: (1) age > 18 yr; (2) diagnosis with OSA when discharged from hospital (the discharge diagnosis of OSA was coded according to the international classification of disease (ICD-9) codes; (3) undergoing elective surgery under general, regional, or local anesthesia with monitored anesthesia care at the University Health Network during the period January 1, 1990 to December 31, 2005. Exclusion criteria included patients who were undergoing surgical procedures involving the upper airway, including tonsillectomy, septoplasty, uvuloplasty, uvulopalatoplasty, uvulopharyngoplasty, or uvulopalatopharyngoplasty, as these procedures were most likely to have been indicated to cure the primary disease process (OSA) and, thus, would be impossible to match. The non-OSA patients (non-OSA group) were based on a one-to-one match with the OSA patients and were selected from a cohort of surgical patients without an OSA diagnosis at the time of hospital discharge. The match criteria included gender, age difference < 5 yr, same type of surgery, and <5 yr between the two surgery dates.

The primary outcome variable was the incidence of the total postoperative complications. Data collection was implemented through chart review. The charts of the selected patients were reviewed by a research anesthesiologist (S.V.). The following data were collected: demographic data (including gender and age at the time of surgery), ASA physical status, pre-existing medical conditions, concurrent medications, type of surgery and anesthesia, postoperative

complications and therapeutic interventions. The definitions of postoperative complications are shown in the Appendix.

Statistical considerations

In a previously published paper of a similar design,[22] the incidence of postoperative complications was 39% among OSA patients and 18% among non-OSA patients. Assuming a similar incidence of postoperative complications in our study, with $\alpha = 0.05$ and $\beta = 0.9$, we required 132 pairs of matching OSA and non-OSA patients.

The data collected were entered into a specifically designed Microsoft Access™ database (Microsoft Corporation, Redmond, WA, USA). SAS® 9.1.3 for Windows® (SAS Institute Inc., Cary, NC, USA) was used for data analysis. The demographic data and prevalence of the pre-existing co-morbidities were summarized. The incidence of postoperative complications and related treatments were compared between the OSA patients and the matched non-OSA patients. Testing of differences between the two groups was undertaken using the McNemar test for categorical data and Student's paired *t* tests for numerical data.

Conditional logistic regression was used to adjust for potential confounding variables.[23,24] The selection of potential risk factors was based mainly on the clinical relevance to the postoperative outcome. The correlation among the potential risk factors was also checked. When there was a correlation between two or more risk factors with a correlation coefficient >0.5, only one risk factor was retained. The chosen potential risk factors were used as independent variables, and the frequency of patients with one or more postoperative adverse events was used as the dependent variable for conditional logistic regression analysis. A backward automatic selection with $P < 0.2$ was used in conditional logistic regression. The appropriateness of the model was assessed based on fit statistics and testing for a global null hypothesis with $\beta = 0$.

Results

Two hundred ninety-four patients with an OSA diagnosis underwent different types of surgery; however, 19 of these were excluded from our study due to having upper airway surgical procedures. To establish matched pairs, 275 OSA patient records were compared with the records of patients without diagnosed OSA. Two hundred forty patients with OSA were successfully matched with 240 patients without diagnosed OSA. The analysis is based on the data from the 240 matched pairs.

The OSA group and the matched non-OSA group were similar with respect to gender distribution and type of surgery (Tables 1, 2), and both groups were similar in age (Table 1). However, compared with the matched non-OSA patients, the OSA patients had a higher prevalence of pre-existing co-morbidities, including obesity, hypertension, gastroesophageal reflux disease, diabetes, hypothyroidism, asthma, and chronic obstructive pulmonary disease. A larger proportion of the OSA patients were ASA physical status III and IV, and they had higher New York Heart Association (NYHA) classification scores. The OSA patients also had a higher mean body mass index (BMI), and 150 (63%) of them were on home continuous positive airway pressure (CPAP).

The types of anesthesia used were similar in the two groups (Table 2). However, a higher percentage of the

Table 1 Demographic data

	OSA	Non-OSA
Patients (*n*)	240	240
Age (yr)	57 (13)	57 (13)
Gender		
Male	184 (77)	184 (77)
Female	56 (23)	56 (23)
BMI ($kg \cdot m^{-2}$)	35 (9)	28 (6)
ASA physical status		
I	6 (3)	26 (11)
II	81 (34)	111 (47)
III	122 (51)	66 (28)
IV	30 (13)	31 (13)
NYHA classification		
I	195 (81)	220 (92)
II	9 (4)	3 (1.3)
III	33 (14)	15 (6)
IV	3 (1.3)	2 (0.8)
Home CPAP	150 (63)	0
Pre-existing co-morbidities		
Hypertension	116 (48)	87 (36)
CAD	64 (27)	64 (27)
Heart failure	10 (4)	6 (3)
Stroke or TIA	8 (3)	11 (5)
Asthma	46 (19)	19 (8)
COPD	21 (9)	10 (4)
Smoker	91 (8)	92 (38)
GERD	65 (27)	41 (17)
Obesity	146 (61)	56 (23)
Diabetes	49 (20)	26 (11)
Hypothyroidism	41 (19)	12 (5)

Age and BMI were presented as mean (SD). All other data presented as *n* (%)

ASA American Society of Anesthesiologists, *BMI* body mass index, *CAD* coronary artery disease, *TIA* transient ischemic attack, *COPD* chronic obstructive pulmonary disease, *CPAP* continuous positive airway pressure, *GERD* gastroesophageal reflux disease, *NYHA* New York Heart Association, *OSA* obstructive sleep apnea

Table 2 Type of surgery and anesthesia

	OSA *n* (%)	Non-OSA *n* (%)
Type of surgery		
Cardiac	48 (20)	48 (20)
ENT	44 (18)	44 (18)
Orthopedic	34 (14)	37 (14)
Spine	13 (5)	13 (5)
General	32 (13)	32 (13)
Urology	25 (10)	25 (10)
Gynecology	12 (5)	12 (5)
Plastic	2 (0.8)	2 (0.8)
Other	30 (13)	30 (13)
Type of anesthesia		
General	205 (85)	215 (90)
General + regional[a]	11 (5)	10 (4)
Regional[a]	23 (10)	12 (5)
Monitored anesthesia	1 (0.4)	3 (1)

OSA obstructive sleep apnea, *ENT* ear nose and throat

[a] Regional anesthesia includes spinal, epidural, and peripheral nerve block

Table 3 Airway assessment and tracheal intubation

	OSA *n* (%)	Non-OSA *n* (%)	*P* value
Laryngoscopic view			
1	130 (83)	140 (84)	0.034
2	14 (9)	23 (14)	
3	10 (6)	2 (1)	
4	3 (2)	1 (0.6)	
Total	157	166	
Intubation attempts			
1	162 (93)	159 (97)	0.184
2	8 (5)	2 (1)	
3	3 (2)	3 (2)	
Total	173	164	
Tracheal intubation			
Easy	170 (80)	202 (90)	0.003
Difficult	42 (20)	22 (10)	
Total	212	224	

OSA obstructive sleep apnea

OSA patients were ranked as class III and IV on laryngoscopic viewing (Table 3). More patients with OSA had difficult tracheal intubations (20% OSA group *vs* 10% non-OSA group; $P = 0.003$). There was no significant difference in the percentage of patients who were receiving opioid analgesics postoperatively, and mean doses of postoperative opioid were similar in the two groups (data not shown).

Postoperative complications

Table 4 summarizes the occurrence of postoperative complications in the OSA and non-OSA groups. There was a significantly greater overall incidence of postoperative complications in the OSA group compared with the non-OSA group (44% *vs* 28%, respectively; $P < 0.01$). The major contributor to the higher occurrence of postoperative complications in the OSA group was the increased incidence of respiratory complications (33% OSA group *vs* 22% non-OSA group). Desaturation with $SaO_2 < 90\%$ was the most common complication (17% OSA group *vs* 8% non-OSA group). The majority of the postoperative complications occurred after patients were transferred to the ward (25% OSA group *vs* 16% non-OSA group). Although the groups had similar numbers of minor cardiovascular and neurological complications, two patients in the OSA group and one patient in the non-OSA group suffered from cardiac arrest. The details of these patients are summarized in Table 5.

The OSA group experienced an increased number of treatments (Table 6). More OSA patients required prolonged oxygen therapy (23% OSA group *vs* 15% non-OSA group; $P < 0.05$). In the OSA group, 13% of patients required additional monitoring *vs* 6% of patients in the non-OSA group ($P < 0.01$). There were more intensive care unit (ICU) admissions among the OSA patients (40% OSA group *vs* 28% non-OSA group; $P < 0.01$), whereas the majority of ICU admissions were planned. Forty-nine percent of OSA patients received CPAP postoperatively.

Independent risk factors of postoperative complications

The following medical conditions were included in the conditional logistic regression analysis according to their clinical relevance as potential risk factors for the occurrence of postoperative complications: the diagnosis of OSA and co-morbidities, including hypothyroidism, stroke, coronary artery disease, diabetes, heart failure, asthma, chronic obstructive pulmonary disease (COPD), ASA physical status III–IV, and BMI > 35 kg $\cdot$ m^{-2}. In the final model obtained through a backward automatic selection with $P < 0.2$, the following medical conditions were retained in the model as risk factors for the occurrence of postoperative complications: the diagnosis of OSA, a high score on ASA physical status, pre-existing stroke, and asthma. Only the diagnosis of OSA and stroke were significant ($P < 0.05$). The P value for the hypothesis of $\beta = 0$ was 0.001 (Wald test) and <0.001 (Likelihood ratio test and Score test). The hazard ratios and P values of the risk factors are summarized in Table 7.

Table 4 Postoperative complications

	OSA *n* (%)	Non-OSA *n* (%)	*P* value
Patients (*n*)	240	240	
Total postoperative complications (case)[a]	104 (43)	67 (28)	<0.001
PACU	20 (8)	20 (8.3)	1.000
ICU	40 (17)	32 (13)	0.307
Ward	61 (25)	38 (16)	0.010
Total respiratory complication (case)[b]	78 (33)	53 (22)	0.010
Total desaturation	71 (30)	46 (19)	
Mild desaturation ($90\% < SaO_2 \leq 95\%$)	30 (13)	27 (11)	
Severe desaturation ($SaO_2 \leq 90\%$)	41 (17)	19 (8)	
Pulmonary edema	8 (3)	14 (6)	
Bronchospasm	5 (2)	3 (1)	
Pneumothorax	2 (0.8)	2 (0.8)	
Hypercapnea	2 (0.8)	1 (0.4)	
Laryngospasm	2 (08)	0	
Upper airway obstruction	1 (0.4)	0	
Arrive intubated in PACU	56 (23)	55 (23)	
Reintubated	1 (0.4)	1 (0.4)	
Total cardiac complication (case)[c]	36 (15)	27 (11)	0.224
Arrhythmia	32 (13)	23 (10)	
Bradycardia	9 (4)	4 (2)	
Tachycardia	6 (3)	4 (2)	
Dysrhythmia	20 (8)	17 (7)	
Ischemia	1 (0.4)	4 (2)	
Cardiac arrest	2 (0.8)	1 (0.4)	
Hypertension	16 (7)	10 (4)	0.226
Hypotension	9 (4)	24 (10)	0.007
Total neurology complication (case)[d]	15 (6)	12 (5)	0.553
Confusion	4 (2)	3 (1)	
Motor deficit	2 (0.8)	2 (0.8)	
Sensory deficit	2 (0.8)	0	
Agitation	9 (4)	6 (3)	
Stroke or TIA	1 (0.4)	0	

OSA obstructive sleep apnea, *PACU* postanesthesia care unit, *ICU* intensive care unit, *TIA* transient ischemic attack

[a] The number of patients with at least one postoperative adverse event

[b] The number of patients with at least one postoperative respiratory adverse event

[c] The number of patients with at least one postoperative cardiac adverse event

[d] The number of patients with at least one postoperative neurological adverse event

Postoperative complications and need for CPAP in OSA patients

To explore the relationship between CPAP utilization and the occurrence of postoperative complications in OSA patients, we examined the frequency of postoperative complications in OSA patients using different combinations of CPAP use at home and after surgery (Table 8). Of the 150 OSA patients who were on home CPAP, only 63% of patients received postoperative CPAP. Of the 90 patients who were not on home CPAP, 27% (24/90) received postoperative CPAP. This group of patients had the highest incidence of postoperative complications, mainly desaturation with $SaO_2 < 90\%$. The overall incidence of postoperative complications was 44% in OSA patients and 28% in non-OSA patients.

Discussion

This retrospective cohort study demonstrates that patients with OSA have a higher incidence of postoperative complications compared with matched non-OSA surgical patients. Oxygen desaturation with $SpO_2 < 90\%$ was the most common complication. The OSA patients who were not receiving home CPAP therapy before surgery and required CPAP after surgery had the highest incidence of postoperative complications. There was a need for a greater

Table 5 Detailed information of patients suffering cardiac arrest

Patient no.	Age	Gender	OSA	Home CPAP	Procedure	Type of anesthesia	Co-morbidities	Cardiac arrest
1	66	M	Yes	Yes	Transphenoidal resection of pituitary	General anesthesia	Hypertension asthma, hypothyroidism smoker	Occurred after induction of anesthesia, successfully resuscitated
2	62	F	Yes	Yes	Laparoscopic cholecystectomy	General anesthesia	Hypertension	Occurred after extubation, re-intubated and transferred to ICU. The patient was resuscitated and died 5 days later
3	60	M	No	No	Repair of colon parastomal hernia	General anesthesia with intubation	Hypertension, CAD, COPD, asthma, DM, acute MI	Acute MI induced cardiac arrest. The resuscitation was unsuccessful

OSA obstructive sleep apnea, *CPAP* continuous positive airway pressure, *ICU* intensive care unit, *CAD* coronary artery disease, *COPD* chronic obstructive pulmonary disease, *DM* diabetes mellitus, *MI* myocardial infarction

Table 6 Postoperative treatment and follow-up

	OSA	Non-OSA	*P* value
N	240	240	
Respiratory treatment	104 (43)	64 (27)	<0.001
FiO_2 increase	29 (12)	5 (2)	
Prolonged oxygen therapy	57 (24)	37 (15)	
Additional monitoring	32 (13)	14 (6)	
Pulmonary edema treatment	10 (4)	5 (2)	
Bronchospasm treatment	3 (1.3)	1 (0.4)	
CPAP used postop	118 (49)	0	<0.001
Total admission to ICU[a]	95 (40)	68 (28)	0.009
Unplanned	5 (2.1)	1 (0.4)	
Stay in ICU (hr)[b]	24 (46)	26 (45)	0.057
Total hospital stay (days)[b]	1.3 (3.2)	1.8 (3.2)	0.882
Re-admission within 7 days	1 (0.4)	1 (0.4)	
Re-admission within 8–30 days	0	5 (2.1)	
ER visit within 30 days	1 (0.4)	1 (0.4)	

OSA obstructive sleep apnea, *CPAP* continuous positive airway pressure, *NS* not significant

[a] ICU includes intensive care and neuron step-down

[b] Data for 'stay in ICU (hr)' and 'total hospital stay (day)' presented as median (interquartile range); all other data presented as *n* (%)

number of treatments and interventions in the OSA group, including prolonged oxygen therapy and additional monitoring. Multivariable logistic regression analysis demonstrated that the diagnosis of OSA and pre-existing stroke are risk factors for the occurrence of postoperative complications.

We recognize that this study has a number of important limitations. First, this was a retrospective analysis with all outcomes collected *post hoc*. The results must be considered as merely associations and causality cannot be implied. Second, patients with OSA were identified by using ICD-10 codes that are entered by non-physician coders after the patient has been discharged from hospital. Since the completion of this study, we have undertaken to quantitate the sensitivity and positive predictive value of ICD-10 codes to identify patients with OSA. During the year April 2008 to April 2009, there were 5542 elective non-cardiac surgical patients assessed prior to surgery. Of the 379 patients diagnosed with OSA (6.8%), 36 had an ICD-10 code which specified a preoperative diagnosis of OSA. Thus, the sensitivity of ICD-10 codes is 0.09 with a positive predictive value of 0.86. We are uncertain why only 10% of OSA patients were identified; perhaps our analysis preferentially identified a group of patients with severe OSA. Thus, our results may be applicable only to patients with moderate and severe OSA. Third, and related to the above point, there were no polysomnographic data available for the patients with OSA; thus, we could not quantitate the severity of OSA. Finally, our matching process was constructed so that age, gender, type of

Table 7 Risk factors for postoperative complications[a]

Risk factors	Parameter estimate	Standard error	Hazard ratio (95% confidence interval)	*P* value
OSA	0.69	0.24	2.00 (1.25–3.19)	0.003
ASA physical status	0.46	0.28	1.58 (0.92–2.72)	0.100
Asthma	0.81	0.49	2.26 (0.87–5.85)	0.094
Stroke	1.38	0.65	3.98 (1.12–14.17)	0.033

[a] The risk factors retained in the final model of conditional logistic regression by backward automatic selection with $P < 0.2$

Table 8 Use of CPAP and postoperative complications in OSA patients

	OSA patients not on home CPAP ($n = 90$)		OSA patients on home CPAP ($n = 150$)		Non-OSA
	No postoperative CPAP	Postoperative CPAP	No postoperative CPAP	Postoperative CPAP	
Patients (n)	66	24	56	94	240
Total postoperative complications (cases)	26 (39.4)	16 (66.7)*	19 (33.9)	42 (44.7)	67 (28)
Total respiratory complications (cases)	18 (27.3)	15 (62.7)	13 (23.3)	32 (34.0)	53 (22)
Total desaturation	18 (27.3)	14 (58.3)	11 (19.6)	28 (29.8)	46 (19)
Mild desaturation (SaO_2 91–92%)	6 (9.1)	5 (20.8)	6 (10.7)	13 (13.8)	27 (11)
Severe desaturation (SaO_2 90%)	12 (18.2)	9 (37.5)	5 (8.9)	15 (16.0)	19 (18)
Prolonged oxygen therapy	15 (22.7)	10 (41.7)	10 (17.9)	19 (20.0)	37 (15)
Additional monitoring	8 (12.2)	6 (25.0)	4 (7.4)	14 (14.9)	14 (6)
Total admissions to ICU	25 (37.9)	10 (41.7)	19 (33.9)	41 (43.6)	68 (28)
Unplanned admissions	2	1	0	2	1

All data are presented as n (%)

OSA obstructive sleep apnea, *CPAP* continuous positive airway pressure, *ICU* intensive care unit

* $P < 0.05$ *vs* the patients who were not on home or hospital CPAP

surgery, and surgery date were matched. However, this process did not match for individual patient characteristics, and our results show that there were more associated co-morbidities in the OSA patients, including higher ASA status, NYHA status, hypertension**,** diabetes, asthma, and gastroesophageal reflux disease (GERD). Thus, we cannot exclude the possibility that the associated co-morbidities may account for the higher complication rates rather than the diagnosis of OSA itself. Despite the above limitations, this study indicates that patients diagnosed with OSA had an increased incidence of postoperative adverse events, mainly oxygen desaturation with $SpO_2 < 90\%$. After adjusting for other confounding factors using conditional logistic regression, OSA remained a significant risk factor with an odds ratio of 2.00 (1.25–3.19).

Most previously published studies examining postoperative complications in OSA patients focused on patients who underwent upper airway surgeries.[25–31] Only a few studies have evaluated postoperative complications in patients who underwent other types of surgery.[22,32–36] Our study complements this growing body of literature by demonstrating that OSA patients undergoing different types of surgery have an increased rate of postoperative complications, mainly oxygen desaturation. In a retrospective study of 101 patients with OSA who were undergoing hip replacement or knee replacement, Gupta *et al.*[22] demonstrated that patients with OSA have an increased incidence of total postoperative complications and major complications. The patients with OSA in that study also had a higher percentage of total and unplanned intensive care unit (ICU) transfers and a longer hospital stay.[22] In another retrospective study of 37 patients with OSA undergoing cardiac surgery, Kaw *et al.*[32] found that there was an increased incidence of postoperative encephalopathy and infection rates (mostly mediastinitis). Hwang *et al.*[35] showed that surgical patients with the clinical features of OSA and oxygen desaturation index ≥ 5 on home nocturnal oximetry before surgery had a significantly higher rate of postoperative complications. In another study conducted by Chung *et al.*,[34] the patients who had apnea-hypopnea index >5 on preoperative polysomnography had a higher incidence of postoperative complications. These studies all support that OSA in surgical patients is associated with an increased incidence of postoperative complications.

In this study, hypoxemia (oxygen desaturation) was the most common postoperative complication in patients with OSA. Three other studies have also demonstrated a similar result.[22,34,35] However, a recent study of 31 OSA and 9 non-OSA morbidly obese patients did not find a difference in the number of hypoxemic episodes during the first 24 hr after surgery.[36] This similarity of observed events may have been due to the high percentage of patients in both groups receiving oxygen therapy during the first 24 hr after surgery.[36] Recently, we found that the apnea-hypopnea index (AHI) and the oxygen-desaturation index are greater among OSA patients on the third postoperative night compared with either the first postoperative night or preoperatively.[37]

In Gupta's retrospective study on 101 matched pairs of patients undergoing hip or knee replacement, major complications (cardiac events and complications needing ICU transfer or urgent respiratory support) were significantly higher in patients with OSA.[22] Our study did not show an increase in serious cardiopulmonary complications in OSA patients *vs* matched non-OSA patients. The cardiac arrests in two OSA patients, one during tracheal intubation and the

other after extubation, were related to problems with airway management. This further supports the notion that airway management in OSA patients can be difficult. The cardiac arrest that occurred in one non-OSA patient was related to myocardial infarction.

Our results suggest that patients with OSA require more perioperative care than their non-OSA counterparts. Patients with OSA required prolonged oxygen therapy and additional monitoring and were admitted to ICU more frequently. Gupta's study also demonstrated that more OSA patients required ICU care, both planned and unplanned.[22] The unplanned ICU transfers occurred mainly in patients whose OSA was undiagnosed at the time of surgery. In our study, it is likely that patients were diagnosed before surgery, although we cannot exclude the possibility that OSA was diagnosed as a result of a perioperative event. The departmental policy that existed during the study period did not require OSA patients to be monitored more intensively or to be admitted to ICU. However, the anesthesiologist may have been aware of OSA when considering the need for ICU. This might account for the higher number of patients requiring ICU transfer in the OSA group and no increase in the unplanned ICU admission rate.

The recent ASA practice guideline for the perioperative management of patients with OSA recommends that the CPAP or nasal intermittent positive pressure ventilation (NIPPV) should be administered postoperatively to the OSA patients on home CPAP.[38] As a matter of routine in most hospitals, a patient with OSA on home CPAP would be ordered to receive CPAP after surgery. However, our data suggests this guideline is not routinely observed, as only 63% of OSA patients on home CPAP received CPAP postoperatively. This observation suggests the need for education programs to ensure greater consistency of care for patients with OSA.

The patients with OSA who were not receiving home CPAP included two different patient populations, i.e., patients who did not require CPAP because of mild OSA and patients who were non-compliant with their CPAP devices. In our study, 27% of OSA patients not using home CPAP required CPAP postoperatively. These patients had the highest incidence of postoperative complications (Table 8). This finding is likely due to CPAP having been initiated in response to an adverse event, which may also have led to the chart abstracters coding for the disease. However, we must again reiterate that this is a retrospective study, and it is difficult to identify the exact reasons for the high incidence of postoperative complications in this group of patients.

In conclusion, these results suggest that one aspect of the preoperative assessment should focus on the evaluation and diagnosis of OSA. Patients who are non-compliant with their treatment of CPAP are at an increased risk of postoperative oxygen desaturation. These results await further prospective assessment.

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Competing interests None declared.

Appendix

See Table 9.

Table 9 Definitions of postoperative adverse events

Adverse event	Definition
Total postoperative complications (case)	Number of patients with one or more postoperative adverse events
Respiratory complication	Any postoperative respiratory event
Serious postoperative adverse events	Adverse events which are potentially life threatening and requiring ICU monitoring
Oxygen desaturation	$SaO_2 < 95\%$ for >1 min and needing oxygen therapy
Severe desaturation	$SaO_2 < 90\%$ for more than 1 min and/or cyanosis and/or $PaO_2 < 60$ mmHg
Hypercapnea	$RR < 8\ min^{-1}$ and or $PaCO_2 > 50$ and/or $EtCO_2 > 55$
Respiratory failure	Need for mechanical ventilation
Pulmonary edema	Difficulty breathing, coughing up frothy sputum and bilateral fluffy infiltrates on chest *x-ray*
Bronchospasm	Expiratory wheezing
Laryngospasm	Stridor with upper airway obstruction

Table 9 continued

Adverse event	Definition
Upper airway obstruction	Stridor with upper airway obstruction due to causes other than laryngospasm
Difficult intubation	A grade 3 or 4 view on laryngoscopy and requiring >2 attempts at tracheal intubation
Myocardial infarction	The evolving changes in the ST-T segment and/or new Q wave on an electrocardiogram; symptoms of ischemia plus abnormal serum levels of Troponin T or symptoms of myocardial ischemia plus new left bundle branch block
Cardiac arrest	The abrupt cessation of normal circulation of the blood due to failure of the heart to contract effectively during systole
Myocardial ischemia	New or more severe chest pain diagnosed as ischemia and requiring treatment
Congestive heart failure	New pulmonary edema on a chest radiograph or a diagnosis of congestive heart failure
Dysrhythmia	Rhythm different than preoperative or premature ventricular beats >5 min^{-1} for >5 min
Tachycardia	HR > 120 beats · min^{-1} > 15 min
Bradycardia	HR < 50 beats · min^{-1} > 15 min
Hypertension	Systolic blood pressure > 200 mmHg for >5 min
Hypotension	Systolic blood pressure < 80 mHg for >5 min
Ischemia	>1 mm ST depression and/or inversion of the T wave
Transient ischemic attack (TIA)	Abrupt onset of a focal neurological deficit lasting <24 hr and resulting from cerebrovascular ischemia
Confusion	New disorientation in Time/Place/Person >30 min after awakening
Agitation	Extreme restlessness which cannot be resolved by verbal assurance
Motor deficit	Unexpected inability to lift the upper or lower extremity for more than one hour (excluding spinal or epidural anesthesia)
Sensory deficit	Unexpected inability to feel pinprick in either the upper or lower extremity for >30 min
Prolonged oxygen therapy	The patients still requires oxygen therapy after discharge from PACU
Addition monitoring	Including oximetry, invasive arterial blood pressure monitoring, central venous pressure monitoring, and/or arterial blood gas monitoring
Additional need for treatment	Requiring prolonged oxygen therapy, addition monitoring and ICU transfer
Unanticipated admission	Patient who is admitted to the hospital/ICU instead of being transferred shifted to home/ward. The reasons for unanticipated admission, including medical, surgical, anesthesia-related, and social reasons were recorded
Re-admission after 7 days and within 30 days	Patients requiring readmission to hospital after 7 days and within 30 days of day surgery. Medical, surgical, and anesthesia reasons are documented

HR heart rate, *PACU* postanesthesia care unit, *ICU* intensive care unit, *RR* respiratory rate

References

1. *Kryger MH*. Diagnosis and management of sleep apnea syndrome. Clin Cornerstone 2000; 2: 39–47.
2. *Young T*, *Hutton R*, *Finn L*, *Badr S*, *Palta M*. The gender bias in sleep apnea diagnosis. Are women missed because they have different symptoms? Arch Intern Med 1996; 156: 2445–51.
3. *Bresnitz EA*, *Goldberg R*, *Kosinski RM*. Epidemiology of obstructive sleep apnea. Epidemiol Rev 1994; 16: 210–27.
4. *Simonds AK*. Sleep studies of respiratory function and home respiratory support. BMJ 1994; 309: 35–40.
5. *Hung J*, *Whitford EG*, *Parsons RW*, *Hillman DR*. Association of sleep apnoea with myocardial infarction in men. Lancet 1990; 336: 261–4.
6. *Doherty LS*, *Kiely JL*, *Swan V*, *McNicholas WT*. Long-term effects of nasal continuous positive airway pressure therapy on cardiovascular outcomes in sleep apnea syndrome. Chest 2005; 127: 2076–84.
7. *Leung RS*, *Bradley TD*. Sleep apnea and cardiovascular disease. Am J Respir Crit Care Med 2001; 164: 2147–65.
8. *Moruzzi P*, *Sarzi-Braga S*, *Rossi M*, *Contini M*. Sleep apnoea in ischaemic heart disease: differences between acute and chronic coronary syndromes. Heart 1999; 82: 343–7.
9. *Schafer H*, *Koehler U*, *Ploch T*, *Peter JH*. Sleep-related myocardial ischemia and sleep structure in patients with obstructive sleep apnea and coronary heart disease. Chest 1997; 111: 387–93.
10. *Young T*, *Finn L*, *Peppard PE*, *et al.* Sleep disordered breathing and mortality: eighteen-year follow-up of the Wisconsin sleep cohort. Sleep 2008; 31: 1071–8.
11. *Kanagala R*, *Murali NS*, *Friedman PA*, *et al.* Obstructive sleep apnea and the recurrence of atrial fibrillation. Circulation 2003; 107: 2589–94.
12. *Frey WC*, *Pilcher J*. Obstructive sleep-related breathing disorders in patients evaluated for bariatric surgery. Obes Surg 2003; 13: 676–83.
13. *Chung F*, *Ward B*, *Ho J*, *Yuan H*, *Kayumov L*, *Shapiro C*. Preoperative identification of sleep apnea risk in elective surgical patients, using the Berlin questionnaire. J Clin Anesth 2007; 19: 130–4.

14. *Isono S*, *Kochi T*, *Ide T*, *Sugimori K*, *Mizuguchi T*, *Nishino T*. Differential effects of vecuronium on diaphragm and geniohyoid muscle in anaesthetized dogs. Br J Anaesth 1992; 68: 239–43.
15. *Keamy MF III*, *Cadieux RJ*, *Kofke WA*, *Kales A*. The occurrence of obstructive sleep apnea in a recovery room patient. Anesthesiology 1987; 66: 232–4.
16. *Lamarche Y*, *Martin R*, *Reiher J*, *Blaise G*. The sleep apnoea syndrome and epidural morphine. Can Anaesth Soc J 1986; 33: 231–3.
17. *Samuels SI*, *Rabinov W*. Difficulty reversing drug-induced coma in a patient with sleep apnea. Anesth Analg 1986; 65: 1222–4.
18. *Cullen DJ*. Obstructive sleep apnea and postoperative analgesia—a potentially dangerous combination. J Clin Anesth 2001; 13: 83–5.
19. *Catley DM*, *Thornton C*, *Jordan C*, *Lehane JR*, *Royston D*, *Jones JG*. Pronounced, episodic oxygen desaturation in the postoperative period: its association with ventilatory pattern and analgesic regimen. Anesthesiology 1985; 63: 20–8.
20. *Reeder MK*, *Goldman MD*, *Loh L*, *Muir AD*, *Casey KR*, *Lehane JR*. Late postoperative nocturnal dips in oxygen saturation in patients undergoing major abdominal vascular surgery. Predictive value of pre-operative overnight pulse oximetry. Anaesthesia 1992; 47: 110–5.
21. *Rosenberg J*, *Wildschiodtz G*, *Pedersen MH*, *von Jessen F*, *Kehlet H*. Late postoperative nocturnal episodic hypoxaemia and associated sleep pattern. Br J Anaesth 1994; 72: 145–50.
22. *Gupta RM*, *Parvizi J*, *Hanssen AD*, *Gay PC*. Postoperative complications in patients with obstructive sleep apnea syndrome undergoing hip or knee replacement: a case-control study. Mayo Clinic Proc 2001; 76: 897–905.
23. *Fleiss JL, Levin B, Paik MC*. Regression models for matched samples. Statistical methods for rates and proportions. 3rd ed. Wiley; 2004.
24. *Alexander MT, Kufera JA*. Butting heads on matched cohort analysis using SAS® software. www.nesug.org/proceedings/nesug07/sa/sa01.pdf. Accessed August 2009.
25. *Hathaway B*, *Johnson JT*. Safety of uvulopalatopharyngoplasty as outpatient surgery. Otolaryngol Head Neck Surg 2006; 134: 542–4.
26. *Esclamado RM*, *Glenn MG*, *McCulloch TM*, *Cummings CW*. Perioperative complications and risk factors in the surgical treatment of obstructive sleep apnea syndrome. Laryngoscope 1989; 99: 1125–9.
27. *Kim JA*, *Lee JJ*, *Jung HH*. Predictive factors of immediate postoperative complications after uvulopalatopharyngoplasty. Laryngoscope 2005; 115: 1837–40.
28. *Pang KP*. Identifying patients who need close monitoring during and after upper airway surgery for obstructive sleep apnoea. J Laryngol Otol 2006; 120: 655–60.
29. *Terris DJ*, *Fincher EF*, *Hanasono MM*, *Fee WE Jr*, *Adachi K*. Conservation of resources: indications for intensive care monitoring after upper airway surgery on patients with obstructive sleep apnea. Laryngoscope 1998; 108: 784–8.
30. *Kezirian EJ*, *Weaver EM*, *Yueh B*, *et al.* Incidence of serious complications after uvulopalatopharyngoplasty. Laryngoscope 2004; 114: 450–3.
31. *Mickelson SA*, *Hakim I*. Is postoperative intensive care monitoring necessary after uvulopalatopharyngoplasty? Otolaryngol Head Neck Surg 1998; 119: 352–6.
32. *Kaw R*, *Golish J*, *Ghamande S*, *Burgess R*, *Foldvary N*, *Walker E*. Incremental risk of obstructive sleep apnea on cardiac surgical outcomes. J Cardiovasc Surg (Torino) 2006; 47: 683–9.
33. *Sabers C*, *Plevak DJ*, *Schroeder DR*, *Warner DO*. The diagnosis of obstructive sleep apnea as a risk factor for unanticipated admissions in outpatient surgery. Anesth Analg 2003; 96: 1328–35.
34. *Chung F*, *Yegneswaran B*, *Liao P*, *et al.* Validation of the Berlin questionnaire and American Society of Anesthesiologists checklist as screening tools for obstructive sleep apnea in surgical patients. Anesthesiology 2008; 108: 822–30.
35. *Hwang D*, *Shakir N*, *Limann B*, *et al.* Association of sleep-disordered breathing with postoperative complications. Chest 2008; 133: 1128–34.
36. *Ahmad S*, *Nagle A*, *McCarthy RJ*, *Fitzgerald PC*, *Sullivan JT*, *Prystowsky J*. Postoperative hypoxemia in morbidly obese patients with and without obstructive sleep apnea undergoing laparoscopic bariatric surgery. Anesth Analg 2008; 107: 138–43.
37. *Liao P*, *Sun F*, *Amirshahi B*, *et al*. A significant exacerbation of sleep breathing disorders in OSA patients undergoing surgery with general anesthesia. Sleep 2009; 32: 0684.
38. *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: 1081–93.