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Meta-analysis of the association between obstructive sleep apnoea and postoperative outcome

R. Kaw[1,2]*, F. Chung[3], V. Pasupuleti[4], J. Mehta[3], P. C. Gay[6,7] and A. V. Hernandez[5]

[1] Department of Hospital Medicine and [2] Department of Outcomes Research (Anesthesiology), Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195, USA
[3] Department of Anesthesia, University Health Network, University of Toronto, Ontario, Canada
[4] Department of Molecular Cardiology and [5] Department of Quantitative Health Sciences, Lerner Research Institute, Cleveland Clinic, Cleveland, OH, USA
[6] Department of Neurology and [7] Department of Pulmonary and Critical Care Medicine and Sleep, Mayo Clinic, Rochester, MN, USA

* Corresponding author. E-mail: kawr@ccf.org

Editor's key points

- Patients with obstructive sleep apnoea (OSA) may have a higher incidence of postoperative complications.
- Meta-analysis of OSA and outcome limited by considerable variation between studies in definitions used.
- OSA was associated with increased incidence of desaturation, respiratory failure, cardiac events, and intensive care unit admission.

Background. Obstructive sleep apnoea (OSA) is often undiagnosed before elective surgery and may predispose patients to perioperative complications.

Methods. A literature search of PubMed-Medline, Web of Science, Scopus, EMBASE, Cochrane Database of Systematic Reviews, and Cochrane Central Register of Controlled Trials up to November 2010 was conducted. Our search was restricted to cohort or case–control studies in adults diagnosed with OSA by screening questionnaire, oximetry, or polysomnography. Studies without controls, involving upper airway surgery, and with OSA diagnosed by ICD-9 codes alone were excluded. The primary postoperative outcomes were desaturation, acute respiratory failure (ARF), reintubation, myocardial infarction/ischaemia, arrhythmias, cardiac arrest, intensive care unit (ICU) transfer, and length of stay.

Results. Thirteen studies were included in the final analysis (n=3942). OSA was associated with significantly higher odds of any postoperative cardiac events [45/1195 (3.76%) *vs* 24/1420 (1.69%); odds ratio (OR) 2.07; 95% confidence interval (CI) 1.23–3.50, P=0.007] and ARF [33/1680 (1.96%) *vs* 24/3421 (0.70%); OR 2.43, 95% CI 1.34–4.39, P=0.003]. Effects were not heterogeneous for these outcomes (I^2=0–15%, P>0.3). OSA was also significantly associated with higher odds of desaturation [189/1764 (10.71%) *vs* 105/1881 (5.58%); OR 2.27, 95% CI 1.20–4.26, P=0.01] and ICU transfer [105/2062 (5.09%) *vs* 58/3681 (1.57%), respectively; OR 2.81, 95% CI 1.46–5.43, P=0.002]. Both outcomes showed a significant degree of heterogeneity of the effect among studies (I^2=57–68%, P<0.02). Subgroup analyses had similar conclusions as main analyses.

Conclusions. The incidence of postoperative desaturation, respiratory failure, postoperative cardiac events, and ICU transfers was higher in patients with OSA.

Keywords: complications; sleep apnoea; surgery

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In North America, moderately severe obstructive sleep apnoea (OSA) with an apnoea–hypopnoea index (AHI) >15 is present in 11.4% of men and 4.7% of women, respectively.[1–3] OSA is associated with several co-morbidities such as cardiovascular disease, heart failure, arrhythmias, hypertension, cerebrovascular disease, and metabolic syndrome.[4–7] In patients going for elective surgery, the prevalence of OSA is substantially higher compared with that of the general population.[8 9] Some recent studies report a incidence of >30% in neurosurgical patients and up to 91% in patients undergoing bariatric surgery.[10–12] When screened using the Berlin questionnaire,[8] about 24% patients were noted to be at risk of having OSA, as opposed to 27.5%[13] using STOP (Snoring, Tiredness, Observed apnoeas and high blood pressure) questionnaire. OSA can pose a significant challenge to anaesthetists in the perioperative period due to possible difficult intubation, increased sensitivity to opioids and postoperative upper airway obstruction,[14] the physiological interaction of cross-sectional area, lung volume, and driving pressure changes, body position effects, and fat distribution.[15 16]

Review of the literature shows that the majority of studies have shown a higher overall postoperative complication rate in patients with OSA compared with the general population. Significant variation, however, has been noted in the reporting of these complications between different studies. For example, most studies associate OSA with respiratory complications, but similar association with major complications such as postoperative respiratory failure is not clear. Unanticipated intensive care unit (ICU) transfers after surgery were not reported by some studies, but in others, some ICU transfers were electively scheduled before surgery, and some studies were designed as quality improvement (QI) projects with the explicit goal of minimizing transfers to ICU. There are a number of reasons for this variation, including: whether OSA was diagnosed clinically, by screening or by a gold standard test, whether the comparison was against a group of 'true controls' [OSA excluded by formal polysomnography (PSG)], sample size, whether the study was designed primarily as a QI project to mitigate adverse outcomes, and whether the patients were on treatment with positive airway pressure therapy before surgery and perioperatively. The objective of this meta-analysis is to examine the evidence linking the presence of OSA in patients undergoing elective surgery with perioperative complications.

Methods

Search strategy and study selection

We screened abstracts of published observational studies evaluating the association OSA and postoperative complications in patients undergoing non-cardiac surgery. A literature search was conducted by four authors (R.K., V.P., J.M., and A.V.H.) in PubMed-Medline (1960–October 31, 2010), the Web of Science (1980–October 31, 2010), Scopus (1960–October 31, 2010), the Cochrane Database of Systematic Reviews (2005–October 2010), and the Cochrane Central Register of Controlled Trials (4th quarter 2010). The search used the MESH keywords 'sleep apnea, obstructive' and 'postoperative period' and also the text keywords 'postoperative' and 'complications' or 'outcome', 'perioperative care', 'intraoperative care', 'postoperative care', 'intraoperative monitoring', 'postoperative monitoring', 'perioperative complications', 'intraoperative complications', 'postoperative complications', 'outcome', 'risk', 'morbidity', 'mortality' and 'death' and also 'obstructive sleep apnea', 'obstructive sleep apnea syndrome', 'obstructive sleep apnoea', 'obstructive sleep apnoea syndrome', 'sleep disordered breathing', 'obesity hypoventilation syndrome', 'apnea or apnoea', 'hypopnea or hypopnoea'. The full search strategy used in PubMed is shown in the Appendix.

Our search was restricted to cohort or case–control studies in adult (>18 yr old) patients, with information available on at least one postoperative complication/outcome in patients with and without OSA, published in any language. Patients may have been diagnosed before operation with OSA either by screening questionnaire, oximetry, or PSG. We excluded studies without information on control patients (i.e. those without OSA), studies where patients underwent upper airway surgery, or if the diagnosis of OSA was on the basis of ICD-9 codes alone. Abstracts were reviewed independently by two investigators (R.K. and V.P.), and full-text articles were retrieved for abstracts that fulfilled inclusion/exclusion criteria. A manual review of references from primary or review articles was also performed.

Data extraction

Two investigators (R.K. and V.P.) extracted data, and the results were compiled. Disagreement was resolved by consensus. The following information was collected from each study: year of publication, sample size, size of OSA and control groups, type of surgery, ASA class, age, gender, BMI, history of hypertension, diabetes, coronary artery disease (CAD), heart failure (HF), cerebrovascular accident (CVA), chronic obstructive pulmonary disease, asthma, and the primary outcomes.

Primary outcomes

Our primary postoperative outcomes were any cardiac or respiratory complications. Postoperative respiratory complications were characterized as postoperative desaturation, acute respiratory failure (ARF), and tracheal reintubation. Most studies defined postoperative desaturation as oxygen desaturation ≥4% below baseline or last recorded value for >10 s[17 18] with Sp_{O_2} <90%.[13 19 20] Only three studies provided definitions for ARF; two of these on the basis of need for mechanical ventilation[21 22] and another defined ARF as oxygen saturation <90% or hypercapnia requiring continuous positive airway pressure (CPAP), bilevel positive airway pressure, or reintubation.[23] No standard definition of cardiac complications was used by any study, but these included myocardial infarction, ischaemia, or both, new arrhythmias, tachycardia/bradycardia, hypotension, and cardiac arrest. Other major primary outcomes were ICU transfer and length of stay (LOS).

Study quality assessment

Two investigators (R.K. and V.P.) evaluated the quality of studies. The quality of studies was graded as (i) prospective cohort study, (ii) retrospective cohort study, (iii) case–control study, and (iv) cross-sectional study. We systematically assessed key points of study quality proposed by the MOOSE collaboration[24] including: (i) clear identification of study population, (ii) clear definition of outcome and outcome assessment, (iii) independent assessment of outcome parameters, (iv) no selective loss during follow-up, and (v) important confounders, prognostic factors, or both identified. Each point was rated as Yes/No. If a study did not clearly mention one of these key points, it was considered as No.

Statistical analysis

This study followed the reporting guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[25] The Mantel–Haenzel method was used to combine categorical events, and the inverse variance method to combine continuous events. Fixed effects models were used for all analyses, as they are better when outcomes are scarce. For outcomes with substantial heterogeneity, random models were also used and shown as primary models. The measure of association for categorical events was the odds ratio (OR) for categorical outcomes and the mean difference (MD) for the continuous outcomes. Statistical heterogeneity was evaluated with the Cochran χ^2 and the I^2 statistics.[26] Publication bias was explored with the funnel plot for the outcome with the highest number of studies. When the median and IQR were provided, the mean was estimated by the formula $x=(a+2m+b)/4$ using the values of the median (m), P25 and P75 (a and b, respectively). We used Review Manager (RevMan, version 5.0 for Windows, Oxford, UK; The Cochrane Collaboration, 2008). To explore sources of heterogeneity between the studies, we pre-specified several subgroup analyses. These included studies that defined OSA by PSG criteria, studies that excluded known OSA patients, studies that adjusted for age and BMI, studies initiated as QI projects, and studies that reported prior CPAP use.

Results

Eligible studies

A total of 6247 records were identified and reasons for excluding studies are explained in Figure 1. Only 13 studies[17–21, 23 27–33] were included in the final analysis. The total number of patients was 3942. Some studies only included ICD-9 codes for diagnosis of OSA and unique post-operative complications such as acute respiratory distress syndrome and had to be excluded from the analysis.[22 34] Another was excluded since it only provided the median propensities and not the exact numbers for outcomes.[35] We contacted the authors of these studies,[34 35] but given the specifics of each study, we were unable to obtain the data we needed for our analysis. Most of the studies had a high/moderate quality.

Study characteristics

The studies were heterogeneous (Table 1). Patients had a mean age of 57.4 (14.9) yr, and 1819 (59.6%) were male. Sixteen studies included information on at least one post-operative complication. The number of cardiac events, respiratory failure, and tracheal reintubation was low (0–13.5%), while a higher frequency was noted for desaturation and ICU transfers (0.6–40.9%). Five studies were prospective cohorts and eight retrospective cohorts (Table 2). All studies clearly identified the study populations and defined appropriately the outcomes. Three studies had selective loss of patients during follow-up, and seven studies appropriately adjusted associations for important confounders, prognostic factors, or both. Only four studies mentioned postoperative CPAP use; 14 patients out of 101;[19] six patients out of 31;[18] three patients out of 243;[31] and most patients listed in Hallowell and colleagues.[28] There is wider mention of self-reported home CPAP use before surgery in two studies, 33/101[19] and 106/282.[20] Owing to limited data, self-reported preoperative use of CPAP could only be analysed as a subgroup.

Meta-analysis

Patients with OSA had significantly higher odds of post-operative cardiac events in comparison with those without OSA [45/1195 (3.76%) *vs* 24/1420 (1.69%), respectively; OR 2.07, 95% confidence interval (CI) 1.23–3.50, P=0.007, Fig. 2A]. OSA was also associated with significantly higher odds of respiratory failure [33/1680 (1.96%) *vs* 24/3421 (0.70%); OR 2.43, 95% CI 1.34–4.39, P=0.003, Fig. 2B] and non-significantly higher odds of reintubation [12/1303 (0.92%) *vs* 18/2839 (0.63%); OR 2.05, 95% CI 0.92–4.55, P=0.08, Fig. 2C]. Effects were not heterogeneous among studies for these three outcomes (I^2=0–15%, P>0.3).

The presence of OSA was significantly associated with higher odds of desaturation [189/1764 (10.71%) *vs* 105/1881 (5.58%); OR 2.27, 95% CI 1.20–4.26, P=0.01, Fig. 2D] and ICU transfer [105/2062 (5.09%) *vs* 58/3681 (1.57%), respectively; OR 2.81, 95% CI 1.46–5.43, P=0.002, Fig. 2E]. Both of these outcomes showed a significant degree of heterogeneity of the effect among studies (I^2=57–68%, P<0.02). Finally, the presence of OSA was associated with a higher LOS in two studies[19 21] (MD 1.79 days, 95% CI 0.87–2.72, P=0.0001; I^2=0%). We did not find evidence of publication bias from the evaluation of the funnel plots.

Subgroup analysis

The association between OSA and postoperative outcomes remained unchanged among the subgroup which defined OSA only on the basis of PSG criteria (Supplementary material). The association did not change in the studies that reported the prior use of CPAP among some of their patients and in studies that adjusted for age and BMI. As would be expected, studies that were initiated as QI projects found non-significant associations between OSA and all post-operative outcomes. The subgroup of studies that excluded known OSA patients also showed the same trends as the main analysis. However, due to a limited number of studies, postoperative respiratory failure and tracheal reintubation could not be evaluated.

Discussion

The principal findings are that the incidence of postoperative respiratory desaturation, respiratory failure, postoperative cardiac events, and ICU transfers was higher in patients with OSA when compared with those without OSA. Within the cohort of patients who developed postoperative ARF, the incidence of reintubation during the postoperative course was higher among the OSA patients in studies that specifically reported it but not statistically significant.

As would be anticipated, respiratory difficulties dominate the spectrum of postoperative complications in patients with OSA.

Postoperative ARF

There was a significant variation in the reporting of ARF between studies. The incidence reported did not vary with the number of patients in the study (range: n=31–661),

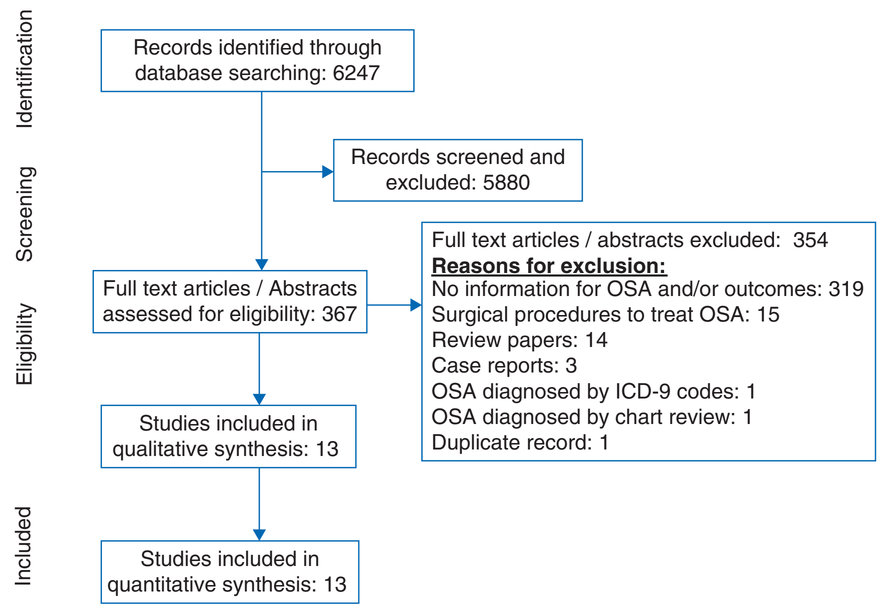

Fig 1 Search strategy for the meta-analysis.

with both extremes reporting a low number of events. In addition, only two studies[21 22] reported ARF using a standard definition, but only one of these could be included in the analysis. One reported respiratory failure as reintubation and/or hypercapnia needing CPAP,[19] and another study[27] dropped all patients with adverse intraoperative events needing prolonged ventilation from the final analysis. More importantly, four out of 13 studies[17 23 27 30] included in our analysis began as clinical practice improvement initiatives to mitigate OSA-related complications in patients considered to be at high risk. Continuous pulse oximetry was used with the aim of improving identification and preventing respiratory complications in these patients, but the type of anaesthesia, sedation, and airway management were not part of the practice improvement. Although many studies did not report the postoperative use of CPAP but the prior use of CPAP in patients with OSA ranged from 20% to 60% and this also could possibly have resulted in lowering the rate of respiratory complications. Although many studies have reported postoperative ARF in patients undergoing surgery, to our knowledge, only one study has reached statistical significance.

Despite the wide range of variability in reporting of ARF, inclusion of four studies whose main aim was to reduce the incidence of adverse postoperative events, inclusion of studies that reported the use of prior CPAP, and exclusion of two large and important studies which used ICD-9 codes, postoperative ARF was more frequent in patients with OSA compared with those without OSA. We consider this as the major finding of our analysis. However, statistical significance was reached by pooling data on this complication that this needs to be confirmed by a large prospective study. This finding was recently shown in ∼50 000 patients with OSA undergoing general and orthopaedic surgery.[34] This study, however, was not included in our analysis, given the large number of OSA patients whose diagnosis was based on inpatient diagnostic code only.

Oxygen desaturation

Oxygen desaturation was defined differently in most studies. It is unlikely that all events were captured in these retrospective studies as therapeutic interventions may have occurred on the presence of desaturation. We do not believe that episodes of transient desaturation represent events of significant hypoxia, but, in patients with OSA, these may predict further worsening of respiratory complications.

Cardiac complications

Despite the relatively low incidence of postoperative cardiac complications in the individual studies, the incidence of cardiac complications in the cohort was statistically significant. Of the nine studies[13 18 20 21 23 27 28 31 33] that reported postoperative cardiac events, three[18 21 31] reported no adverse cardiac events, including one study of cardiac surgery patients.[21] Two patients had cardiac arrest and five patients had MI after operation. The incidence of arrhythmias after surgery in patients varied from 1% to 6%, but most studies did not specify the type of arrhythmia. Patients with OSA have been shown to have a higher prevalence of CAD. Higher AHIs have been reported in patients with a history of MI, CAD, and cardiovascular outcomes.[36–38]

Only one recent study, which could not be used in the analysis, provided details about treatment of intraoperative cardiovascular complications in patients with increased

Table 1 Patient characteristics in studies included in the meta-analysis. *Median (IQR); SD, standard deviation; PC, prospective cohort; RC, retrospective cohort; NA, not available; BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease

Study	Study design	Diagnosis of OSA	Groups	*n*	Age (yr) [mean (range)]	Male [*n* (%)]	BMI [mean (SD)]	HTN [*n* (%)]	DM [*n* (%)]	CAD [*n* (%)]	COPD [*n* (%)]	Asthma [*n* (%)]	Stroke [*n* (%)]	Surgery type
Ahmad and colleagues[18]	PC	PSG	OSA	31	43 (19.0–57.3)	8 (25.8)	50 (9)	10 (32)	8 (26)	1 (3.2)	NA	NA	NA	Abdominal
			Non-OSA	9	42 (11.5–61.1)	0 (0)	48 (6)	1 (11)	1 (11)	0 (0)	NA	NA	NA	
Chung and colleagues[32]	PC	PSG	OSA	147	59 (19.5–81.6)	83 (56.5)	30.4 (6)	72 (49)	40 (27.4)	8 (5.5)	2 (1.4)	5 (10.3)	9 (6.2)	Orthopaedic, general, ENT, ophthalmology, gynaecology, neurosurgical, urology, plastics
			Non-OSA	64	50 (18.8–77.5)	23 (35.9)	27.9 (6)	20 (31.3)	8 (12.3)	3 (4.6)	1 (1.5)	9 (13.9)	1 (1.5)	
Finkel and colleagues[23]	PC	OSA screening questionnaire	OSA	170	52.8 (22.6–84.1)	113 (54.6)	36.9 (33.5–42.0)*	116 (56)	49 (23.7)	22 (10.6)	NA	NA	3 (1.4)	Bariatric, cardiothoracic, general, gynaecology, neurosurgical
		Apnoea Risk Evaluation System (ARES)	Non-OSA	37	56 (17.8–81.6)		26.6 (23.7–29.7)*				NA	NA		ENT, ophthalmology, orthopaedic, urology, vascular, others
Gali and colleagues[30]	PC	OSA questionnaire	OSA	115	59.9 (36.3–82.4)	98 (85.2)	36.0 (7.5)	NA	NA	NA	NA	NA	NA	Orthopaedic, gynaecologic, genitourinary, ENT, plastics
		Sleep Apnoea Clinical Score (SACS)	Non-OSA	25	59.6 (43.3–76.9)	18 (72.0)	29.9 (4.5)	NA	NA	NA	NA	NA	NA	
Gali and colleagues[27]	PC	OSA questionnaire	OSA	221	59.9 (28.5–82.2)	190 (86.0)	35.1 (6.0)	179 (81)	NA	NA	NA	NA	NA	Orthopaedic, thoracic, abdominal, gynaecologic, genitourinary
		Sleep Apnoea Clinical Score (SACS)	Non-OSA	472	58.2 (24.6–88.0)	203 (43.0)	30.4 (6.7)	181 (38)	NA	NA	NA	NA	NA	ENT, neurosurgery, plastics, others
Gupta and colleagues[19]	RC	84% PSG	OSA	101	68.1 (48.4–85.7)	70 (69.3)	33.5 (5.7)	59 (58.4)	NA	27 (26.7)	14 (13.8)	NA	NA	Orthopaedic
		16% nocturnal oximetry	Non-OSA	101	(53.3–95.8)	70 (69.3)	30.2 (8.2)	48 (47.5)	NA	48 (47.5)	11 (10.9)	NA	NA	
Hallowell and colleagues[28]	RC	PSG	OSA	454	NA	NA	NA	NA	NA	NA	NA	NA	NA	Bariatric
			Non-OSA	436	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Hwang and colleagues[17]	RC	Nocturnal oximetry	OSA	98	55.9 (31.5–86.3)	55 (56.1)	36.5 (8.7)	61 (62.2)	20 (20.4)	NA	3 (3.1)	16 (16.3)	3 (3.1)	Orthopaedic, thoracic, abdominal, gynaecologic, genitourinary
			Non-OSA	74	52.7 (18.7–74.4)	30 (40.5)	34.0 (9.0)	37 (45.9)	9 (12.2)	NA	4 (5.4)	13 (17.6)	3 (4.1)	ENT, cardiothoracic, vascular, neurosurgical, others

Continued

Table 1 *Continued*

Study	Study design	Diagnosis of OSA	Groups	*n*	Age (yr) [mean (range)]	Male [*n* (%)]	BMI [mean (SD)]	HTN [*n* (%)]	DM [*n* (%)]	CAD [*n* (%)]	COPD [*n* (%)]	Asthma [*n* (%)]	Stroke [*n* (%)]	Surgery type
Kaw and colleagues[21]	RC	PSG	OSA	37	62.9 (45.4–75.9)	29 (78.4)	31.7 (27.2–36.0)*	NA	8 (21.6)	6 (16.2)	6 (16.2)	NA	Cardiothoracic	
			Non-OSA	185	61.8 (35.5–90.0)	144 (77.8)	31.8 (26.9–36.3)*	NA	37 (20.0)	22 (11.9)	20 (10.8)	NA		
Kaw and colleagues[20]	RC	PSG	OSA	262	56.1 (NA)	119 (44.4)	38.4	180 (66.7)	71 (26..3)	43 (16.0)	33 (12.2)	50 (18.5)	NA	Orthopaedic, thoracic, abdominal, gynaecologic, genitourinary,
			Non-OSA	209	46.7 (NA)	149 (55.6)	33.2	80 (39.6)	24 (11.9)	13 (16.4)	9 (4.5)	41 (20.3)	NA	Vascular, neurosurgical, Others
Luizaga and colleagues[33]	RC	PSG	OSA	69	42 (18.8–60.8)	15 (16.5)	50.6 (8.2)	NA	NA	NA	NA	NA	NA	Bariatric
			Non-OSA	22				NA	NA	NA	NA	NA	NA	
Sabers and colleagues[31]	RC	PSG	OSA	234	57.0 (32.4–97.4)	171 (73.1)	35.5 (7.2)	102 (43.6)	28 (11.9)	26 (11.1)	9 (3.9)	16 (6.8)	NA	Orthopaedic, genitourinary, gynaecologic, abdominal, others
			Non-OSA	234	56.9 (20.5–91.0)	171 (73.1)	33.7 (7.2)	61 (26.1)	12 (5.1)	23 (9.8)	9 (3.9)	1 (0.4)	NA	
Vasu and colleagues[29]	RC	STOP-BANG questionnaire	OSA	56	64.7 (37.7–83.6)	22 (27.8)	NA	37 (66.1)	9 (16.1)	5 (8.9)	2 (3.6)	4 (7.1)	NA	Orthopaedic, gynaecologic, abdominal, genitourinary, vascular
			Non-OSA	79	53 (18.1–90.3)	38 (67.9)	NA	22 (27.8)	5 (6.3)	3 (3.8)	1 (1.3)	5 (6.3)	NA	ENT, cardiothoracic, others

Table 2 Quality of the studies. RC, retrospective cohort; PC, prospective cohort; BMI, body mass index; ODI, oxygen desaturation index; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; OSAS, obstructive sleep apnoea syndrome

Study	Study Design	Study population clearly identified?	Clear definition of outcome and outcome assessment?	Selective loss of patients during follow-up?	Important confounders and/prognostic factors identified?
Gupta and colleagues[19]	RC	Yes	Yes	No	Adjusted for age, sex, operated side, type of operation, surgeon, mode of fixation of the components, year of operation, and type of anaesthesia
Sabers and colleagues[31]	RC	Yes	Yes	No	Adjusted for type of anaesthesia, age, sex, BMI, surgical procedure, and surgical date
Kaw and colleagues[21]	RC	Yes	Yes	No	Adjusted for BMI, weight, gender, race, smoking, emergency, diabetes, COPD/asthma, preoperative haematocrit, and CPB time
Gali and colleageus[30]	PC	Yes	Yes	Yes	No
Hallowell and colleagues[28]	RC	Yes	Yes	No	No
Ahmad and colleagues[18]	PC	Yes	Yes	Yes	No
Chung and colleagues[32]	PC	Yes	Yes	No	No
Hwang and colleagues[17]	RC	Yes	Yes	No	Adjusted for ODI4% group, sex and BMI group
Finkel and colleagues[23]	PC	Yes	Yes	Yes	No
Gali and colleagues[27]	PC	Yes	Yes	No	Adjusted for age, sex, BMI, and recurrent events
Kaw and colleagues[20]	RC	Yes	Yes	No	Adjusted for age, sex, race, BMI, type of anaesthesia, ASA class, and medical co-morbidities
Luizaga and colleagues[33]	RC	Yes	Yes	No	No
Vasu and colleagues[29]	RC	Yes	Yes	No	Adjusted for age, ASA class, risk of OSAS, and BMI[25]

propensity for OSA.[35] The incidence of tachycardia as opposed to postoperative arrhythmias, and related use of i.v. metoprolol, ephedrine, and labetalol was significantly higher in the OSA group, despite the fact that a majority of these patients received regional anaesthesia. Surgical stress, including postoperative pain and endocrine changes, increases the sympathetic activation further. Episodic hypoxaemia during random eye movement sleep lead to brief arousals associated with profound sympathetic activation, which may cause haemodynamic instability and increased mean arterial pressure.[39 40] Postoperative respiratory obstruction is associated with large fluctuations in systolic and diastolic arterial pressure measurement in patients with OSA, but this does not explain intraoperative changes. As a result of chronic adrenergic arousal, patients with sleep apnoea may have down-regulated α-receptors and β-receptors, and thus have an attenuated response to vasopressors.[41]

Transfer to ICU after surgery

Two studies had a major impact on our results.[22 28] One reported the highest rate of ICU transfers (40% *vs* 28%; $P<0.01$) and respiratory complications (33% *vs* 22%; $P=0.01$) in patients with OSA, although the majority of these transfers were planned.[22] This study was however excluded from the analysis since the diagnosis of OSA was taken from the charts and the majority of the transfers to ICU were planned. In contrast, a higher rate of ICU transfer was reported for bariatric surgery patients without OSA (31% *vs* 69%).[28] However, when mandatory, PSG screening before surgery was used between 2004 and 2005 (phase 2); the overall rate of ICU transfer decreased (3.4% *vs* 5.6%). Phase 2 underestimates the effect of OSA on ICU transfer in postoperative patients, and other studies found higher rates of ICU transfer after surgery.[19 21 27] Most of these ICU transfers were unplanned.

There are several limitations to our analysis. Respiratory failure is the main postoperative complication in patients with OSA. However, no standard definition for ARF was used between the studies. Some studies were initiated as QI projects, while others reported prior CPAP use, both of which may have helped reduce postoperative ARF. Our subgroup analyses, however, show that associations between

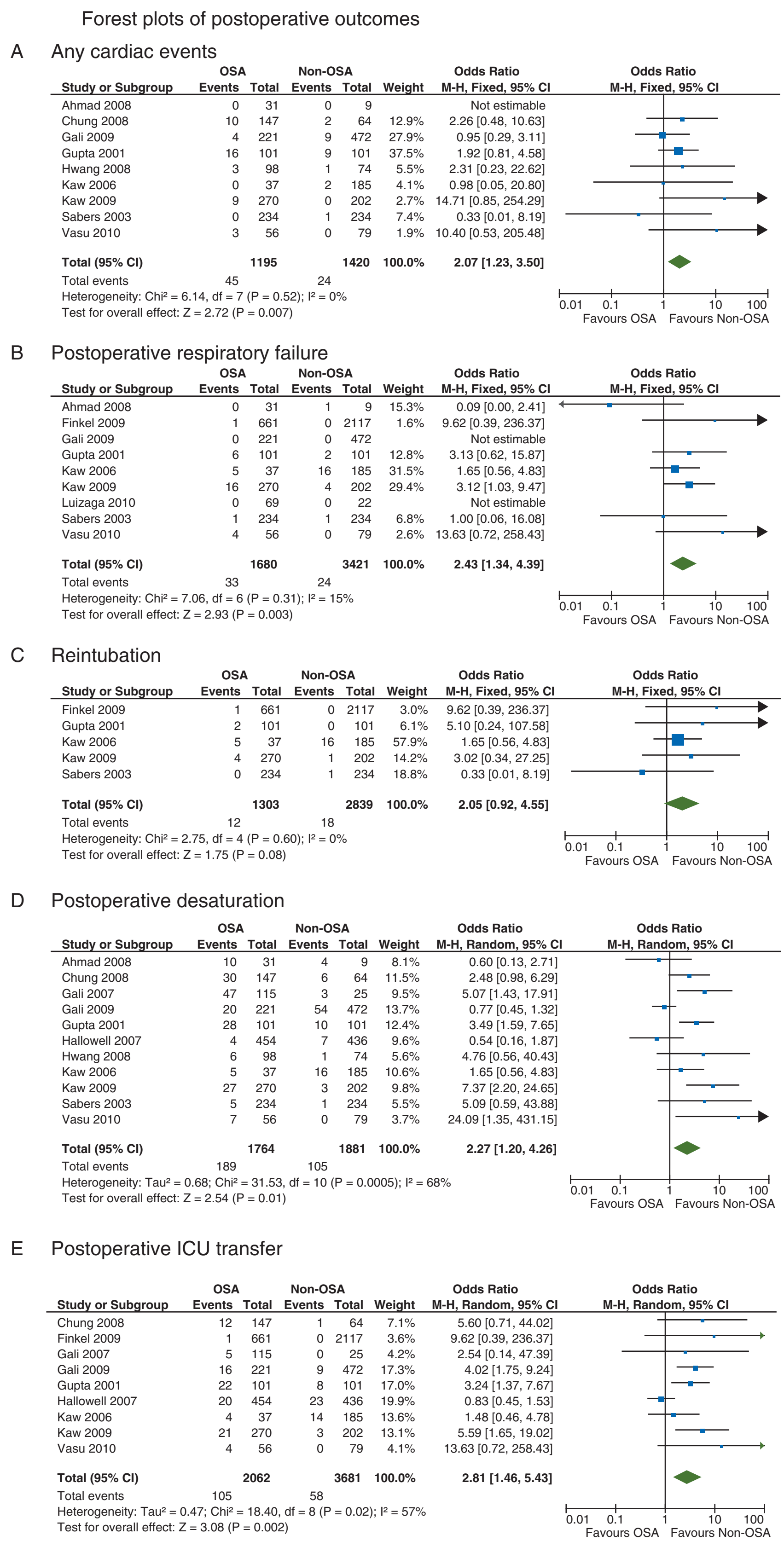

Fig 2 Forest plots of postoperative outcomes.

OSA and ARF remained unchanged, except among studies initiated as QI. Although we reached statistical significance with postoperative cardiac events in patients with OSA, inconsistent reporting between studies and wide range of cardiac and haemodynamic variables reported make the interpretation of this analysis difficult. Two recent studies, one of which had a large sample size, had to be excluded from the analysis for reasons discussed above. And lastly, meta-analysis by design is a univariate analysis and not adjusted for other variables.

In conclusion, patients with OSA undergoing non-cardiac surgery have a higher incidence of postoperative respiratory desaturation, respiratory failure, cardiac events, and ICU transfers than those without OSA.

Authors' contributions

Study concept and design: R.K., F.C., and A.V.H. Acquisition of data: V.P., J.M., R.K., A.V.H., and F.C. Analysis and interpretation of data: A.V.H., R.K., F.C., and P.C.G. Drafting of the manuscript: R.K., A.V.H., V.P., and J.M. Critical revision of the manuscript for intellectual content: A.V.H., R.K., F.C., and P.C.G. Statistical analysis: A.V.H. and R.K. Study supervision: R.K., A.V.H., F.C., and P.C.G.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Declaration of interest

None declared.

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Appendix

PubMed search strategy

{'Obstructive sleep apnoea' (All Fields) or 'sleep apnea, obstructive' (MeSH Terms) or ['sleep' (All Fields) and 'apnea' (All Fields) and 'obstructive' (All Fields)] or 'obstructive sleep apnea' (All Fields) or ['obstructive' (All Fields) and 'sleep' (All Fields) and 'apnea' (All Fields)]} or {'sleep apnoea' (All Fields) or 'sleep apnea syndromes' (MeSH Terms) or ['sleep' (All Fields) and 'apnea' (All Fields) and 'syndromes' (All Fields)] or 'sleep apnea syndromes' (All Fields) or ['sleep' (All Fields) and 'apnea' (All Fields)] or 'sleep apnea' (All Fields)} or {'obstructive sleep apnoea syndrome' (All Fields) or 'sleep apnea, obstructive' (MeSH Terms) or ['sleep' (All Fields) and 'apnea' (All Fields) and 'obstructive' (All Fields)] or 'obstructive sleep apnea' (All Fields) or ['obstructive' (All Fields) and 'sleep' (All Fields) and 'apnea' (All Fields) and 'syndrome' (All Fields)] or 'obstructive sleep apnea syndrome' (All Fields)} and ['anaesthesia' (All Fields) or 'anesthesia' (MeSH Terms) or 'anesthesia' (All Fields)] or perioperative (All Fields), and ['complications' (Subheading) or 'complications' (All Fields)].