The Effects of Continuous Positive Airway Pressure on Postoperative Outcomes in Obstructive Sleep Apnea Patients Undergoing Surgery: A Systematic Review and Meta-Analysis

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The Effects of Continuous Positive Airway Pressure on Postoperative Outcomes in Obstructive Sleep Apnea Patients Undergoing Surgery: A Systematic Review and Meta-Analysis

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BACKGROUND: Obstructive sleep apnea (OSA) is a commonly encountered comorbid condition in patients undergoing surgery and is associated with a greater risk of postoperative adverse events. Our objective in this review was to investigate the effectiveness of continuous positive airway pressure (CPAP) in reducing the risk of postoperative adverse events in patients with OSA undergoing surgery, the perioperative Apnea-Hypopnea Index (AHI), and the hospital length of stay (LOS).

METHODS: We performed a systematic search of the literature databases. We reviewed the studies that included the following: (1) adult surgical patients (>18 years old) with information available on OSA; (2) patients using either preoperative and/or postoperative CPAP or no-CPAP; (3) available reports on postoperative adverse events, preoperative and postoperative AHI, and LOS; and (4) all published studies in English including case series.

RESULTS: Six studies that included 904 patients were eligible for the meta-analysis. The meta-analysis for postoperative adverse events was performed in 904 patients (CPAP: n = 471 vs no-CPAP: n = 433; adverse events: 134 vs 133; P = 0.19). There was no significant difference in the postoperative adverse events between the 2 groups. The preoperative baseline AHI without CPAP was reduced significantly with postoperative use of CPAP (preoperative AHI versus postoperative AHI, 37 ± 19 vs 12 ± 16 events per hour, P < 0.001). LOS showed a trend toward significance in the CPAP group versus the no-CPAP group (4.0 ± 4 vs 4.4 ± 8 days, P = 0.05).

CONCLUSIONS: Our review suggests that there was no significant difference in the postoperative adverse events between CPAP and no-CPAP treatment. Patients using CPAP had significantly lower postoperative AHI and a trend toward shorter LOS. There may be potential benefits in the use of CPAP during the perioperative period. (Anesth Analg 2015;120:1013–23)

Obstructive sleep apnea (OSA) is a common sleep-breathing disorder, and its prevalence is increasing throughout the world. In the general population, the prevalence ranges from 9% to 25%.† Its prevalence, however, is greater in the surgical population.‡ In bariatric surgical patients, the prevalence of OSA may be >70%.§ Furthermore, the majority of surgical patients with OSA may not have been diagnosed or treated before their surgery.** OSA may have serious implications for anesthetic management because of its association with several comorbid conditions, such as cardiovascular disease, heart failure, arrhythmias, hypertension, stroke, and metabolic syndrome.† The independent association of OSA has been associated with an increased incidence of perioperative adverse events.

Among the different treatment modalities available, continuous positive airway pressure (CPAP) is the most effective and the most widely used. It is highly effective in controlling symptoms of OSA in the general population, such as reducing nocturnal events and providing subjective benefits of improvement in daytime sleepiness, cognitive function, and well-being.‡,§,|| CPAP has also been shown to decrease arterial blood pressure in OSA patients with hypertension and to improve glucose control in diabetic patients with severe OSA.‡,|| Liao et al.|| have recently reported that newly diagnosed OSA patients can be effectively treated with auto-titrated continuous positive airway pressure (APAP) in the perioperative period. OSA patients without APAP treatment had more hypoxemia and greater Apnea-Hypopnea Index (AHI) scores postoperatively versus OSA patients receiving APAP treatment.‡,§ Surgical patients identified to have OSA in the preoperative clinic who were adherent to CPAP therapy were shown to have long-term health benefits, including better sleep quality and less daytime sleepiness.|| Timely diagnosis of OSA before surgery and
treatment also led to a reduction of medication usage for the associated medical diseases.21

In contrast, the authors of another randomized controlled trial (RCT) reported that APAP was not effective in shortening the length of stay (LOS) when applied postoperatively to patients deemed as high risk of having OSA.22 Because of a small sample size, this study was not powered to demonstrate an effect on LOS.22 At present, the efficacy of preoperative and/or postoperative CPAP or APAP is not known, and their effectiveness in decreasing postoperative adverse events, reducing AHI, and shortening LOS in surgical patients with OSA needs to be determined. In this review, we investigated the effectiveness of CPAP in reducing the risk of postoperative adverse events in patients with OSA undergoing surgery and its effect on perioperative AHI and LOS.

METHODS

Search Strategy and Study Selection

We screened published articles evaluating the association of surgical patients with OSA treated with CPAP and postoperative outcomes. The literature search was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines, and the search strategy was implemented with the help of an expert librarian familiar with the literature search. We searched the literature databases PubMed-MEDLINE (1946 to October 31, 2013), MEDLINE in-process, and other nonindexed citations (to November 4, 2013), Embase (1947 to November 4, 2013), Cochrane central register of controlled trials (to October 31, 2013), Cochrane database of systematic reviews (to October 31, 2013), and Health Technology Assessment (Fourth Quarter 2013).

The search used the Medical Subject Heading keywords “sleep apnea,” “obstructive,” “continuous positive airway pressure,” and “perioperative complications.” Also, the following text keywords were used for the literature search: “obstructive sleep apnea syndrome,” “obstructive sleep apnoea,” “obstructive sleep apnoea syndrome,” “sleep disordered breathing,” “obesity hypoventilation syndrome,” “apnea or apnoea,” “hypopnea or hypopnoea” and also “positive airway pressure,” “auto-titrating positive airway pressure,” “bi-level positive airway pressure” and also “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.”

The criteria to include studies in our review were as follows: (1) adult surgical patients (>18 years old) with information available on OSA; (2) patients in the study were using either preoperative and/or postoperative CPAP or no-CAP; (3) reports on postoperative adverse events, preoperative and postoperative AHI, and LOS were available; and (4) all published studies were in English, including case series. The diagnosis of OSA before surgery was established either by polysomnography, STOPBang questionnaire (STOP = Snoring/Tired, sleepiness, or fatigue/Observed apnea/ Patient blood pressure >140/90 mm Hg),23,24 Flemons Sleep Apnea Clinical Score,25 or International Classification of Diseases, 9th Revision, codes. Exclusion criteria were as follows: (1) case reports, (2) studies with no information on control patients (i.e., OSA surgical patients without CPAP treatment), and (3) studies in which patients had upper airway surgery.

Studies were selected independently by 2 reviewers who screened the titles and abstracts to determine whether the studies met the eligibility criteria. A citation search by manual review of references from primary or review articles also was performed.

Data Extraction

Data extraction was performed independently by 2 reviewers. Any disagreements were resolved by consensus or by consulting the second author. The following information was collected from each study: author, year of publication, type of study, sample size of CPAP group and no-CPAP group, type of surgery, age, gender, body mass index, comorbid conditions, time when CPAP was delivered, postoperative adverse events, preoperative and postoperative AHI, and LOS.

Postoperative Events

The postoperative events were defined as events occurring in the postoperative period producing clinical disease or dysfunction that adversely affected the clinical course. Common postoperative respiratory adverse events included postoperative hypoxemia, reintubation, pneumonia, and atelectasis. Cardiac adverse events included arrhythmias, tachycardia, bradycardia, dysrhythmias, ischemia, cardiac arrest, and hypotension or hypertension. The other common postoperative event was transfer to the intensive care unit (ICU). To evaluate these adverse events, a combined adverse event was created to indicate having at least one of the aforementioned adverse events.

Study Quality Assessment

The study quality was evaluated using the Cochrane risk of bias tool including the following: (1) random sequence generation, (2) allocation concealment, (3) blinding, (4) incomplete outcome data, (5) selective reporting, and (6) other bias. Each point was rated as yes, no, or unclear.

Statistical Analysis

Our main objective was to compare the occurrence of perioperative adverse events between patients with and without CPAP treatment. The efficacy of CPAP was evaluated as risk reduction (RR) along with the corresponding 95% confidence intervals (CIs). The RR for the individual studies was estimated and then pooled across studies using random-effect modeling. The results were graphically expressed as forest plots, where the size of each box is proportional to the weight of the corresponding study. Number needed to treat to benefit (NNTB) also was estimated, that is, the number of patients who had to be treated with CPAP to avoid postoperative adverse events. Statistical analysis was conducted using Review manager (RevMan, version 5.2 Copenhagen).

The analysis of pooled preoperative AHI versus postoperative AHI was based on dataset pooling the original data from 2 studies. Because of the lower postoperative compliance with CPAP, the results of AHI were analyzed as per protocol as opposed to intention-to-treat. The pooled LOS was estimated with weighted mean and pooled SD. Both
Perioperative CPAP in Obstructive Sleep Apnea Patients to Decrease Complications

AHI and LOS were inferred with mean difference and 95% CI. The Mantel-Haenszel method was used to combine the categorical events, and the meta-analysis was performed using fixed-effect model if no heterogeneity was present. Statistical heterogeneity between the studies was evaluated with the Cochrane $\chi^2$ and $P$ statistic test. The role of the publication bias was estimated using a graphical method (funnel plot) and a weighted regression.

RESULTS

Study Selection

The search strategy is listed in Figure 1 and data extraction depicted in Figure 2. Our initial electronic search identified 1970 articles. After the initial screening, 1868 articles were excluded because they did not satisfy the predetermined eligibility criteria. Of the remaining 102 articles, 96 articles were excluded for the following reasons: nonpertinent papers excluded by abstract and/or full-text review ($n = 83$), studies of non-OSA patients ($n = 6$), and no data available for either study groups and/or control group ($n = 7$). Finally, meta-analysis was performed on 6 studies, including 904 patients (CPAP treatment: $n = 471$; no-CPAP treatment: $n = 433$) (Figs. 1 and 2).

Study Characteristics

Of the 6 studies in the meta-analysis, 3 were observational studies, 2 were RCTs, and 1 was a case series. Table 1 shows the methodologic quality of the 6 studies. The studies were of high or moderate quality, and heterogeneity was low ($\chi^2 = 5.45$, $df = 5$, $P = 0.36$, $F$ statistic = 8%). Figure 3 shows an inverted symmetrical funnel plot, suggesting the absence of publication bias.

The study populations were clearly identified, and the adverse events were defined appropriately in the selected studies. The descriptive data of the population included in the selected trials are summarized in Table 2. The use of CPAP was not consistent in both the preoperative and postoperative period (Table 3). CPAP was used both preoperatively and postoperatively in 4 of the 6 studies. In the study by Jensen et al., CPAP was used only in the preoperative period, whereas in the study by O’Gorman et al., CPAP was used solely in the postoperative period. Of the 471 patients in the CPAP group, 43 patients did not receive home CPAP in the preoperative period and of the 428 patients who used preoperative home CPAP, only 211 continued to receive CPAP in the postoperative period during the hospital stay.

Details of postoperative adverse events are listed in Table 4. Most studies provided data on ICU admission and LOS, whereas 3 studies indicated postoperative hypoxemia and oxygen desaturation. The analysis for postoperative adverse events was performed in 904 patients (CPAP: $n = 471$; no-CPAP: $n = 433$). There was no statistically significant difference in the adverse events between the 2 groups (CPAP, events = 134 versus no-CPAP, events = 133, $P = 0.19$). RR was 12% with a risk ratio of 0.88 (95% CI, 0.73–1.06; $P = 0.19$), corresponding to an NNTB of 45 (Fig. 4). The variation in risk ratio attributable to heterogeneity was negligible ($I^2$ statistic = 8%) with a low risk of bias.

Only 2 studies, by Liao et al. and Rennotte et al., reported on preoperative and postoperative AHI in patients using CPAP treatment (Table 5). One hundred patients received CPAP before surgery, and 51 patients continued CPAP in the postoperative period. The preoperative baseline

Figure 1. Flow chart of study selection process. OSA = obstructive sleep apnea; CPAP = continuous positive airway pressure.
AHI without CPAP was reduced significantly with postoperative CPAP use (preoperative AHI versus postoperative AHI, 37 ± 19 vs 12 ± 16 events per hour; mean difference, 27.52; 95% CI, 22.09–32.96; P < 0.001). Only Liao et al.20 compared perioperative AHI between CPAP versus no-CPAP group.

Five of 6 studies reported LOS.20,22,40–42 Four studies were used in the meta-analysis because they provided information on LOS by reporting mean ± SD or median (range), which could be converted to mean ± SD.21,22 The study by O’Gorman et al.22 was excluded from the analysis because LOS was provided in median (interquartile range). In the case-series study by Rennotte et al.,42 1 patient died on the 14th postoperative day, and 1 experienced postoperative adverse events with a corresponding NNTB of 45.

Despite advancement in anesthesia and surgical care, adverse postoperative events remain a significant problem in OSA patients undergoing surgery. OSA has been associated with an increased risk of postoperative oxygen desaturation, respiratory failure, atrial fibrillation, cardiac events, ICU transfers, and longer hospital stay.11–15 Furthermore, the risk may increase with undiagnosed and untreated OSA patients. Sedatives, narcotics, and anesthetics have been shown to increase pharyngeal collapse, decrease ventilatory response, and impair the arousal response, leading to worsening of sleep-disordered breathing in the perioperative period and postoperative complications. CPAP remains the most effective therapy for OSA, acting as a pneumatic splint to maintain upper airway patency as well as improving lung volumes and reducing atelectasis, thereby significantly reducing apneas and hypopneas and the associated hypoxic and hypercapnic events. CPAP therapy can also decrease upper airway edema and inflammation leading to increased upper airway volume and stability. The application of CPAP also improves gas exchange, minimizes atelectasis formation, and increases functional residual capacity and oxygenation with reduction in the work of breathing.

CPAP has been shown to alleviate the symptoms of OSA, including amelioration of excessive daytime sleepiness, restoration of quality of life, improvement in vigilance, concentration and memory, lessening of fatigue, reduction of health care resource usage, and a decrease in traffic accidents.17,44–47 One study has shown reduced daytime sleepiness and decreased usage of medications for associated medical diseases by identifying patients having OSA in the preoperative clinic and providing long-term CPAP treatment.21 Moreover, long-term CPAP use has been associated with reduction in cardiovascular morbidity and mortality in

<table>
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<th>Blinding</th>
<th>Incomplete outcome data assessed</th>
<th>Free of selective outcome reporting</th>
<th>Free of other biases</th>
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DISCUSSION

This systematic review/meta-analysis is the first to examine the effectiveness of CPAP therapy on postoperative adverse events, postoperative AHI, and LOS in OSA patients undergoing surgery. There was no significant difference in postoperative adverse events between CPAP (events = 134) and no-CPAP groups (event = 133) (P = 0.19). Patients with OSA who used CPAP either preoperatively and/or postoperatively compared with no-CPAP had a risk ratio of 0.88 (0.73–1.06) and 12% risk reduction of postoperative adverse events with a corresponding NNTB of 45.

The preoperative baseline AHI without CPAP was reduced significantly with postoperative CPAP use (preoperative AHI versus postoperative AHI, 37 ± 19 vs 12 ± 16 events per hour, P < 0.001). LOS showed a trend toward significance for the CPAP group versus no-CPAP group (4.0 ± 4.0 vs 4.4 ± 8.2 days; P = 0.05).

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CPAP has been shown to alleviate the symptoms of OSA, including amelioration of excessive daytime sleepiness, restoration of quality of life, improvement in vigilance, concentration and memory, lessening of fatigue, reduction of health care resource usage, and a decrease in traffic accidents.17,44–47 One study has shown reduced daytime sleepiness and decreased usage of medications for associated medical diseases by identifying patients having OSA in the preoperative clinic and providing long-term CPAP treatment.21 Moreover, long-term CPAP use has been associated with reduction in cardiovascular morbidity and mortality in
both men and women with severe OSA. CPAP in sleep apnea patients improves existing comorbidities, including hypertension, cardiac function, diabetes mellitus, and other physiologic functions. It is possible that CPAP may improve preoperative optimization of such comorbidities. As perioperative physicians, anesthesiologists are positioned uniquely to diagnose and treat OSA, thereby providing an opportunity to improve the long-term health outcomes, including better sleep quality and less daytime sleepiness.

The efficacy of CPAP in patients without a diagnosis of OSA has been well established for abdominal and cardiac surgery in the postoperative setting. Squadrone et al. demonstrated that the use of CPAP led to a reduction in the incidence of endotracheal intubation, pneumonia, infection, and sepsis in patients who develop hypoxemia after elective major abdominal surgery. Zarbock et al. also noted significant reduction in the rate of pulmonary complications with the prophylactic use of nasal CPAP in patients undergoing elective cardiac surgery. Kindgen-Milles et al. found that CPAP significantly reduced pulmonary morbidity and LOS after thoracoabdominal aortic surgery. A meta-analysis of 9 RCTs in patients undergoing abdominal surgery reported a reduction in the rate of postoperative pulmonary complications with the perioperative use of CPAP.

The efficacy of CPAP in OSA patients undergoing surgery recently was demonstrated by Mutter et al. This cohort study demonstrated that CPAP significantly decreased the risk of cardiovascular complications, primarily cardiac arrest and shock. The cardiovascular complications were significantly different between undiagnosed OSA (odds ratio, 2.20 [95% CI, 1.16–4.17]) and diagnosed OSA patients (odds ratio, 0.75 [95% CI, 0.43–1.28]). Patients with a preoperative diagnosis of OSA and prescription for CPAP were less than half as likely to experience cardiovascular complications as those diagnosed after surgery.

At present, the efficacy of CPAP on the risk of perioperative cardiorespiratory events, AHI, and LOS in OSA patients is not known. The effectiveness of CPAP in 16 OSA patients was first reported in a case series by Rennotte et al. Two OSA patients without CPAP experienced postoperative adverse events and 1 patient died, whereas 14 patients treated with CPAP had an uneventful postoperative course. Gupta et al. identified that OSA patients without CPAP had greater postoperative adverse events compared with OSA patients treated with CPAP (44% vs 27%). Liao et al. reported that many of the OSA patients not using home CPAP developed an adverse event such as hypoxemia or upper airway obstruction resulting in initiation of postoperative CPAP. One recent RCT has shown the feasibility of perioperative APAP in OSA patients.

Perioperative APAP significantly reduced postoperative AHI and improved oxygen saturation in patients with moderate and severe OSA. Perhaps perioperative reduction in AHI may lead to a decrease in postoperative adverse events. Even though CPAP is supposed to be effective in reducing hypoxemic episodes, we were unable to demonstrate a significant difference in postoperative adverse events between the CPAP and no-CPAP groups in our meta-analysis. Normally, it is difficult to demonstrate any intervention in its ability to impact significant cardiovascular events. Also, this might have been attributable to the large differences between studies in the event rates where the authors of the various studies did not examine the same events or had different criteria. Undoubtedly, larger studies will be needed to effectively address this question.

The benefits of CPAP may be less than expected in our meta-analysis because of the low compliance in the preoperative and postoperative period. Guralnick et al. found that surgical patients with suspected OSA had low compliance with anesthesiologists’ requests to undergo sleep studies, and those who were diagnosed with OSA and received APAP therapy showed suboptimal compliance (only 33% of patients used the CPAP >4 hours). Liao et al. also found that the perioperative compliance rate of CPAP was only 45%. In this review, we found that 428 patients used home

Figure 3. Funnel plot for the association of postoperative adverse events and Apnea-Hypopnea index in obstructive sleep apnea patients with continuous positive airway pressure versus no continuous positive airway pressure treatment. RR = risk ratio.
<table>
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<tr>
<th>First author, reference no.</th>
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<td>PSG</td>
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<td>68±7</td>
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<td>Prospective cohort study</td>
<td>PSG</td>
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<td>ICD-9</td>
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Values expressed as mean ± SD and median (range).

OSA = obstructive sleep apnea; BMI = body mass index; PSG = polysomnography; CPAP = continuous positive airway pressure; HTN = hypertension; CAD = coronary artery disease; CABG = coronary artery bypass grafting; COPD = chronic obstructive pulmonary disease; BiPAP = bilevel positive airway pressure; NA = not available; ICD-9 = International Classification of Disease, 9th Revision, codes; GERD = gastroesophageal reflux disease; ENT = ear nose throat; APAP = auto-titrated continuous positive airway pressure.
CPAP, but only 211 patients (approximately 50%) continued CPAP postoperatively in the hospital.

The possible reasons for the low CPAP compliance in the postoperative period are postoperative discomfort and nausea/vomiting accounting for 70% of CPAP noncompliance. With better control of postoperative pain and nausea/vomiting, it may improve the compliance with CPAP among OSA patients. Also, health care professionals and patients might not have recognized the interaction of postoperative respiration depression by opioids and sleep-disordered breathing and the importance of continuation of postoperative CPAP. In addition, OSA patients who were noncompliant with their home CPAP might not have benefited from the treatment, thus decreasing the effectiveness of CPAP. Therefore, it is plausible that improved CPAP compliance may further decrease postoperative adverse events, thus favoring the use of CPAP in OSA surgical patients. Further work needs to be performed in this area to streamline the process of perioperative treatment. Education of health care professionals and patients regarding the importance of perioperative CPAP is imperative to prevent postoperative adverse events during this vulnerable period that may be attributable to untreated OSA. Also, the severity of OSA may have an impact on the incidence of adverse postoperative events. It is possible that OSA patients not receiving home CPAP therapy might have had milder forms of OSA. These patients with mild OSA may have lower risks of adverse events versus patients with moderate-to-severe OSA, thus favoring the analysis toward OSA patients without CPAP.

Only 2 studies reported on the effect of CPAP on perioperative AHI. These patients used CPAP before surgery and continued in the postoperative period. In this review, we found that perioperative AHI was reduced significantly by an average of 25 events per hour postoperatively. Many clinicians may expect that CPAP (or APAP) may completely resolve sleep-disordered breathing. Our data summarizing the only 2 studies demonstrate that in fact some residual sleep-disordered breathing persists with mean AHI 12 ± 16 events per hour despite using CPAP.

The hospital LOS was 0.4 days shorter in the CPAP group compared with the no-CPAP group. Gupta et al. showed a prolonged LOS in the no-CPAP group compared with CPAP group (no-CPAP versus CPAP: 7.2 ± 3.1 vs 6.0 ± 2.1 days, *P* < 0.03). In contrast, O’Gorman et al. reported that APAP was not effective in shortening the LOS when applied postoperatively to patients deemed as high risk of having OSA. Because of its small sample size, however, this study was not statistically powered to demonstrate an effect on LOS with treatment. In another study in ambulatory surgical patients, CPAP was not effective for decreasing the median hospital LOS in OSA patients compared with non-OSA patients (7 vs 6 hours, *P* = 0.058). These contrasting results from different studies might have been attributable to varying criteria for hospital discharge from different institutions, changing practice standards over time, and possible cohort bias.

The literature currently lacks an adequate number of published RCTs to provide quality information regarding the use of preoperative and/or postoperative CPAP in OSA patients. Our literature search was limited to the English language, and we may have missed articles in other languages. Our strict inclusion criteria did not allow studies with positive results to be included in the systematic review and meta-analysis, even though their results were in favor of CPAP in OSA patients. Most of these studies had missing data in either the study group or control group, which precluded them from being included in our meta-analysis.

Preexisting medical conditions may contribute to the development of postoperative adverse events and may influence the results. In our analysis, one of the studies did not specify the comorbid conditions. One limitation of the included studies is the lack of uniformity while reporting postoperative adverse events. Jensen et al. reported on anastomotic leaks, pulmonary complications, LOS, and death, whereas other studies reported on hypoxemia and ICU admissions. The trials also differed in how CPAP was applied, including the type of interfaces, devices, and the duration of use. With advances in anesthesia and surgery, postoperative cardiopulmonary adverse events are rare. The small number of patients in this meta-analysis who developed serious cardiopulmonary events is a limitation. Also, for LOS data, some patients in the study by Gupta et al. were receiving home CPAP, and we may not have seen the true effect of preoperative and/or postoperative CPAP. In the study by Rennotte et al., the LOS showed wide CIs as well.

### Table 3. Data on CPAP Use in the Included Studies (n = 471)

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<tbody>
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<td>Gupta41</td>
<td>Yes</td>
<td>Yes</td>
<td>Home CPAP + continuous postoperative CPAP 24–48 h and then night time only.</td>
</tr>
<tr>
<td>Jensen42</td>
<td>Yes</td>
<td>No</td>
<td>&lt;50% of the home CPAP patients continued CPAP on first postoperative night.</td>
</tr>
<tr>
<td>Liao43</td>
<td>Yes</td>
<td>Yes</td>
<td>Home CPAP/BiPAP approximately 10–16 cm H2O.</td>
</tr>
<tr>
<td>O’Gorman44</td>
<td>No</td>
<td>Yes</td>
<td>62% of the home CPAP patients continued postoperatively.</td>
</tr>
</tbody>
</table>

CPAP = continuous positive airway pressure; BiPAP = bilevel positive airway pressure; APAP = auto-titrated continuous positive airway pressure; PACU = postanesthesia care unit.

*P* = 0.058. These contrasting results from different studies might have been attributable to varying criteria for hospital discharge from different institutions, changing practice standards over time, and possible cohort bias.
The impact of reduction in AHI, shortened LOS, and the efficacy of CPAP in postoperative adverse events needs further investigation. It is difficult to conduct RCTs with a placebo arm in which patients with known OSA receiving home CPAP therapy are randomized to placebo perioperatively, which effectively deprives them from their standard home CPAP therapy for OSA. From a pragmatic standpoint, an RCT would be more feasible, although still challenging, in patients who are newly diagnosed with OSA and are waiting for their treatment. In fact, O’Gorman et al. had to discontinue their RCT after enrolling 86 patients labeled as high suspicion for OSA based on a screening questionnaire because of increased physician and patient awareness of postoperative complications associated with OSA and an unwillingness for patients identified at high risk for OSA to be randomized to standard care. Their sample size calculation was originally estimated at 208 patients. This might be the reason for the limited number of RCTs in the literature, because long-term CPAP use has been associated with a reduction in cardiovascular morbidity and mortality in both men and women with severe OSA. We may expect more observational studies on this topic. It is therefore important to have a summary of the existing data from systematic reviews and meta-analyses of the literature.

Moreover, we believe that it is important not to overinterpret our results. Given the improvement in surgical and anesthesia techniques, devastating postoperative outcomes have become relatively rare events. As such, it will be

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<table>
<thead>
<tr>
<th>First author, reference no.</th>
<th>n</th>
<th>Intervention</th>
<th>Complications</th>
<th>Groups</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rennotte</td>
<td>16</td>
<td>CPAP versus no-CPAP</td>
<td>Pulmonary infiltrates 4</td>
<td>CPAP (n = 14)</td>
<td>No-CPAP (n = 2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bronchitis 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hypertension, oliguria 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bronchospasm, renal failure, arrhythmia 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Death 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total 6 (42%)</td>
<td>2 (100%)</td>
<td></td>
</tr>
<tr>
<td>Gupta</td>
<td>101</td>
<td>CPAP versus no-CPAP</td>
<td>Any complications 9</td>
<td>CPAP (n = 33)</td>
<td>No-CPAP (n = 68)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Serious complications 3</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ICU 1</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unplanned ICU 1</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total 9 (27%)</td>
<td>30 (44%)</td>
<td></td>
</tr>
<tr>
<td>Jensen</td>
<td>284</td>
<td>CPAP versus no-CPAP</td>
<td>Pneumonia 1</td>
<td>CPAP (n = 144)</td>
<td>No-CPAP (n = 140)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reintubation 0</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Anastomotic leak 0</td>
<td>NS</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Death 0</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total 1 (0.6%)</td>
<td>3 (2%)</td>
<td></td>
</tr>
<tr>
<td>Liao</td>
<td>240</td>
<td>CPAP versus no-CPAP</td>
<td>Respiration complications 45</td>
<td>CPAP (n = 150)</td>
<td>No-CPAP (n = 90)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total desaturation 39</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mild desaturation (91–92%) 19</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Severe desaturation (90%) 20</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ICU admissions 60</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unplanned ICU admissions 2</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Additional monitoring 18</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prolonged oxygen therapy 29</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total 61 (40%)</td>
<td>42 (46%)</td>
<td></td>
</tr>
<tr>
<td>Liao</td>
<td>177</td>
<td>APAP versus no APAP</td>
<td>Hypoxemia (SPO₂ &lt;90%) 42</td>
<td>APAP (n = 87)</td>
<td>Control (n = 90)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bradycardia 0</td>
<td>0.939</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CNS complications 0</td>
<td>0.367</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ICU admission 0</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total 47 (56%)</td>
<td>47 (52%)</td>
<td></td>
</tr>
<tr>
<td>O’Gorman</td>
<td>86</td>
<td>APAP versus no APAP</td>
<td>ICU transfer 1</td>
<td>APAP (n = 43)</td>
<td>Control (n = 43)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adjustment of oxygen 10</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Delirium 0</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Atelectasis 2</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Any complications 10</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total 10 (23%)</td>
<td>9 (20%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Grand total in each group</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total postoperative adverse events (cases)</td>
<td>1020 (28%)</td>
<td></td>
</tr>
</tbody>
</table>

OSA = obstructive sleep apnea; CPAP = continuous positive airway pressure; NA = not available; ICU = intensive care unit; NS = not significant; CNS = central nervous system; APAP = auto-titrated continuous positive airway pressure.
It is difficult to design an adequately powered RCT to assess the effectiveness of preoperative and/or postoperative CPAP on devastating cardiopulmonary outcomes. Our data also show that postoperative CPAP compliance is 50%. Despite the poor compliance, we found a 12% risk reduction in the CPAP group. It is plausible that larger studies with improved preoperative and postoperative CPAP compliance may further decrease postoperative adverse events, thus favoring CPAP use in OSA surgical patients. Nevertheless, the recent findings that diagnosed OSA patients with a CPAP prescription have fewer cardiac complications is important and may have implications for the optimal perioperative care of these patients.

Importantly, this review summarizes the existing limited literature, and our hope is that it fosters further clinical research in this field by anesthesiologists and sleep medicine specialists. CPAP is an important intervention that is likely underused by anesthesiologists in the perioperative period. Further research also is needed to rigorously examine the possible beneficial impact of CPAP on the airway, lungs, circulatory, and nervous system. The only 2 RCTs were not designed to address the various potential perioperative benefits of CPAP. Further research is needed to address this important aspect of perioperative CPAP use in patients with OSA.

This paper serves several purposes: raising the awareness of preoperative and postoperative use of CPAP, educating the health professional about the findings in the literature, and serving as an impetus for further research in several areas.

We hope this review and meta-analysis will stimulate the readership and provide a focused assessment of the current limited state of knowledge so that future investigators and clinicians can formulate clinically relevant questions such as: (1) Which OSA phenotype undergoing which type of surgery would benefit the most from preoperative/postoperative CPAP treatment? (2) What is the optimal time and duration of CPAP therapy in the preoperative period? (3) What is the possible beneficial impact of CPAP on the airway, lungs, circulatory, and nervous system? (4) What are the best types of CPAP devices for perioperative use? (5) What are the reasons for the lack of compliance with CPAP and to determine how to improve perioperative CPAP compliance (6) What is the cost-effectiveness of preoperative diagnosis of OSA and perioperative implementation of CPAP therapy?

![Figure 4](image-url) Forest plot of the association of postoperative adverse events in obstructive sleep apnea patients with continuous positive airway pressure (CPAP) versus no-CPAP treatment. CI = confidence interval; Chi^2 = χ^2 test; df = degrees of freedom.

![Table 5](image-url)

<table>
<thead>
<tr>
<th>First author, reference no.</th>
<th>N</th>
<th>Mean ± SD</th>
<th>Median (range)</th>
<th>N</th>
<th>Mean ± SD</th>
<th>Median (range)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liao^20</td>
<td>87</td>
<td>34 ± 17</td>
<td>30 (15–104)</td>
<td>40</td>
<td>10 ± 17</td>
<td>3 (0.0–83)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rennotte^40</td>
<td>13</td>
<td>55 ± 22</td>
<td>59 (23–89)</td>
<td>11</td>
<td>18 ± 13</td>
<td>16 (4–49)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>37 ± 19</td>
<td>32 (15–104)</td>
<td>51</td>
<td>12 ± 16</td>
<td>5 (0–83)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data presented as median (range) or mean ± SD. AHI = Apnea-Hypopnea Index.

![Figure 5](image-url) Forest plot of the association of length of hospital stay in obstructive sleep apnea patients with continuous positive airway pressure (CPAP) versus no-CPAP treatment. CI = confidence interval; Chi^2 = χ^2 test; df = degrees of freedom.
In conclusion, this systematic review suggests that CPAP therapy significantly reduces postoperative AHI and there was a trend toward shorter LOS in OSA patients. There was no significant difference in adverse events between the CPAP versus no-CPAP group. Further research is needed in the area of preoperative and postoperative CPAP use.

DISCLOSURES
Name: Mahesh Nagappa, MD, DNB, MNAMS.
Contribution: This author helped conduct the study, analyze the data, and write the manuscript.
Attestation: Mahesh Nagappa approved the final manuscript.
Name: Babak Mokhlesi, MD, MSc.
Contribution: This author helped conduct the study, analyze the data, and write the manuscript.
Attestation: Babak Mokhlesi approved the final manuscript.
Name: Jean Wong, MD, FRCP.
Contribution: This author helped analyze the data and write the manuscript.
Attestation: Jean Wong approved the final manuscript.
Name: David T. Wong, MD.
Contribution: This author helped analyze the data and write the manuscript.
Attestation: David T. Wong approved the final manuscript.
Name: Roop Kaw, MD.
Contribution: This author helped analyze the data and write the manuscript.
Attestation: Roop Kaw approved the final manuscript.
Name: Frances Chung, MD, FRCP.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: Frances Chung approved the final manuscript.
This manuscript was handled by: Peter S. A. Glass, MBChB.

REFERENCES
Perioperative CPAP in Obstructive Sleep Apnea Patients to Decrease Complications


