Arthroplasty Today 19 (2023) 101085

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

# The Use of Continuous Positive Airway Pressure for Patients With Obstructive Sleep Apnea is Associated With Early Medical and Surgery-Related Complications Following Total Knee Arthroplasty: A National Database Study

Brian P. McCormick, MD *, Sean B. Sequeira, MD, Mark D. Hasenauer, MD, Henry R. Boucher, MD

*Department of Orthopaedic Surgery, MedStar Union Memorial Hospital, Baltimore, MD, USA*

ARTICLE INFO

*Article history:*
Received 9 October 2022
Received in revised form
28 November 2022
Accepted 8 December 2022
Available online xxx

*Keywords:*
Obstructive sleep apnea
Continuous positive airway pressure
Total knee arthroplasty
Postoperative complications

ABSTRACT

*Background:* Obstructive sleep apnea (OSA) has been shown to increase the risk of complications following total knee arthroplasty (TKA) although prior studies were limited by their ability to stratify OSA patients by disease severity. The objective of this study was to determine the effect size of the use of continuous positive airway pressure (CPAP) on early medical and surgery-related complications following TKA among patients with OSA.

*Methods:* Patients with OSA who underwent primary TKA were identified using the PearlDiver Mariner database. Ninety-day incidences of medical complications and 1-year incidences of surgery-related complications as well as hospital utilization were evaluated for OSA patients who had used CPAP prior to TKA compared to those who did not.

*Results:* CPAP patients were at increased 90-day risk of emergency department presentation (odds ratio [OR] 1.61; $P < .0001$), hospital admission (OR 1.33; $P < .001$), ICU admission (OR 1.45, $P < .0001$), pulmonary embolism (OR 1.68, $P < .0001$), deep vein thrombosis (OR 1.31, $P < .0001$), transfusion (OR 1.89, $P < .0001$), pneumonia (OR 1.63, $P < .0001$), cerebrovascular accident (OR 1.92, $P < .0001$), myocardial infarction (OR 1.57, $P = .0015$), sepsis (OR 1.35, $P = .0025$), blood loss anemia (OR 1.67, $P < .0001$), acute kidney injury (OR 1.65, $P < .0001$), and urinary tract infection (OR 1.99, $P < .0001$), as well as increased 1-year risk of undergoing revision surgery (OR 1.14, $P = .0028$), compared to OSA patients not using CPAP.

*Conclusions:* OSA patients on CPAP undergoing TKA have significantly increased complication rates compared to OSA patients not using CPAP.

*Level of Evidence:* III, Retrospective review.



## Introduction

Obstructive sleep apnea (OSA) is a common medical comorbidity characterized by recurrent episodes of upper airway collapse during sleep, affecting up to 5% of women and 7% of men in the United States [1]. Airway collapse during inspiration causes an increase in intrathoracic pressure, which increases afterload and cardiac work, leading to episodes of hypoxia, hypercapnia, and sympathetic activation [2]. This triggers an inflammatory response causing increased free radical production, endothelial injury, and increased blood coagulability. OSA has therefore been associated with an increased risk of idiopathic myocardial infarction (MI), venous thromboembolism, and cerebrovascular accident (CVA) [3–5]. Many patients with OSA can be managed without intervention although patients with moderate to severe OSA may require continuous positive airway pressure (CPAP) at nighttime to maintain an open airway and ensure adequate lung ventilation occurs. CPAP has been shown to ameliorate the consequences of many of these inflammatory processes [6].

The rate of primary total knee arthroplasty (TKA) is on the rise with an expected case volume of 1.26 million per year by 2030 [7].

* Corresponding author. Department of Orthopaedic Surgery, MedStar Union Memorial Hospital, 3333 North Calvert Street, Suite 400, Baltimore, MD 21218, USA. Tel.: +1 301 908 3431.
*E-mail address:* brian.p.mccormick1@gmail.com

https://doi.org/10.1016/j.artd.2022.101085

**Table 1**
OSA diagnosis and CPAP usage ICD-9, ICD-10, and CPT codes.

| | |
|---|---|
| OSA | ICD-9-D-32723, ICD-10-D-G4733 |
| CPAP | CPT-94660, CPT-E0601 |

The population of patients undergoing TKA continues to get younger, [8,9] and OSA typically affects middle-aged patients [10]. Furthermore, the prevalence of obesity among arthroplasty patients is increasing, [11] and obesity is associated with the development of OSA [12,13]. It should therefore be expected that OSA will become increasingly common among patients undergoing TKA. While previous studies have established OSA as a risk factor for perioperative complications following total joint arthroplasty procedures, [14,15] they have failed to stratify this risk profile based on disease severity. The impact of CPAP use on complication rates among OSA patients undergoing TKA has not been previously studied.

Given the prevalence of OSA among arthroplasty patients, it is important to understand how disease severity may impact rates of early medical and surgery-related complications following TKA. The purpose of this study was to evaluate the association between CPAP use and postoperative complication rates following TKA. CPAP use will act as a marker of disease severity in order to better stratify perioperative risk among OSA patients. We hypothesized that patients using CPAP preoperatively would have an increased incidence of early medical and surgery-related complications.

## Methods

This is a retrospective cohort study utilizing the commercially available M151Ortho database via PearlDiver (PearlDiver Inc., Colorado Springs, CO). This database contains deidentified records for 151 million patients in the United States in accordance with the Health Insurance Portability and Accountability Act. Patient records from 2010 through the second quarter of 2019 were queried using International Classification of Diseases (ICD) and Current Procedural Terminology (CPT) codes. This study was deemed exempt from our institution's review board as all queried data were already deidentified in accordance with Health Insurance Portability and Accountability Act.

Patients who underwent primary TKA with at least 90 days of postoperative follow-up were identified using CPT and ICD codes. A test group of OSA patients who were using CPAP within 6 months prior to undergoing TKA was identified using relevant codes listed in Table 1. Patients in the test group were matched 1:1 to a control cohort of OSA patients not utilizing CPAP preoperatively using a propensity scoring methodology based on age, sex, and several medical comorbidities including coronary artery disease, diabetes mellitus, obesity, tobacco use, chronic pulmonary disease, liver disease, peripheral vascular disease, renal disease, cancer, and congestive heart failure. Patients with a first-time documentation of CPAP use following TKA were excluded.

Ninety-day incidences of pulmonary embolism (PE), deep vein thrombosis (DVT), transfusion, pneumonia, CVA, MI, sepsis, blood loss anemia, acute kidney injury, and urinary tract infection were evaluated as medical complications. In order to maintain patient anonymity, the PearlDiver database does not report outcomes with fewer than 10 patients. Medical complications with low incidences such as MI and stroke were therefore not able to be reported as outcome measures in the current study. One-year surgery-related complications were evaluated including periprosthetic joint infection, periprosthetic fracture, component loosening, manipulation under anesthesia, lysis of adhesions, dislocation, and all-cause revision surgery. Ninety-day incidences of emergency department presentation, hospital admission, intensive care unit (ICU) admission, total cost, and length of stay (LOS) were evaluated as healthcare cost and utilization outcomes. Odds ratio (OR) and 95% confidence intervals were calculated for each variable independently using R (University of Auckland, New Zealand). Comparisons for continuous variables such as cost and LOS were performed using student t-tests in R. A *P* value less than .05 was considered statistically significant.

## Results

A total of 31,362 OSA patients who had used CPAP in the preoperative period prior to TKA were matched using propensity

**Table 2**
Patient demographic and comorbidities.

| | OSA + CPAP (n = 31,362) | | Control (n = 31,362) | | Statistical analysis | | |
|---|---|---|---|---|---|---|---|
| | n | % | n | % | OR | 95% CI | *P* |
| Age 45-49 | 1272 | 4.06% | 1241 | 3.96% | 1.0260 | 0.9473-1.1113 | .5279 |
| 50-54 | 3285 | 10.47% | 3147 | 10.03% | 1.0490 | 0.9962-1.1045 | .0693 |
| 55-59 | 5613 | 17.90% | 5436 | 17.33% | 1.0397 | 0.9978-1.0833 | .0636 |
| 60-64 | 7627 | 24.32% | 7357 | 23.46% | **1.8347** | **1.7702-1.9015** | **<.0001** |
| 65-69 | 6821 | 21.75% | 6534 | 20.83% | **1.0561** | **1.0165-1.0973** | **.0051** |
| 70-74 | 5523 | 17.61% | 5289 | 16.86% | **1.0537** | **1.0109-1.0983** | **.0134** |
| 75-79 | 2770 | 8.83% | 2618 | 8.35% | **1.0637** | **1.0059-1.1248** | **.0303** |
| Male | 14,338 | 45.72% | 14,139 | 45.08% | 1.0259 | 0.9942-1.0587 | .1105 |
| Hypertension | 28,484 | 90.82% | 28,545 | 91.02% | 0.9767 | 0.9249-1.0314 | .3966 |
| Tobacco use | 12,957 | 41.31% | 12,897 | 41.12% | 1.0079 | 0.9764-1.0405 | .6265 |
| Alcohol use | 1659 | 5.29% | 1409 | 4.49% | **1.1873** | **1.1040-1.277** | **<.0001** |
| Coagulopathy | 3844 | 12.26% | 4090 | 13.04% | **0.9315** | **0.8886-0.9764** | **.0031** |
| Obesity | 24,172 | 77.07% | 24,291 | 77.45% | 0.9786 | 0.9428-1.0159 | .2569 |
| Diabetes mellitus | 18,445 | 58.81% | 18,600 | 59.31% | 0.9798 | 0.9491-1.0115 | .2082 |
| Chronic kidney disease | 7311 | 23.31% | 7078 | 22.57% | **1.0429** | **1.0048-1.0825** | **.0269** |
| Chronic pulmonary disease | 14,852 | 47.36% | 14,902 | 47.52% | 0.9936 | 0.9630-1.0253 | .6893 |
| Congestive heart failure | 4129 | 13.17% | 3908 | 12.46% | **1.0651** | **1.0164-1.1162** | **.0083** |
| Coronary artery disease | 12,356 | 39.40% | 12,357 | 39.40% | 0.9999 | 0.9683-1.0324 | .9935 |
| Depression | 15,554 | 49.60% | 15,562 | 49.62% | 0.9990 | 0.9682-1.0307 | .9491 |
| Peripheral vascular disease | 8746 | 27.89% | 8587 | 27.38% | 1.0257 | 0.9904-1.0622 | .1557 |

CI, confidence interval.
Bold indicates statistically significant result.

**Table 3**
Ninety-day medical complications following TKA in CPAP and non-CPAP cohorts.

| | OSA + CPAP (n = 31,362) | | Control (n = 31,362) | | Statistical analysis | | |
|---|---|---|---|---|---|---|---|
| | N | % | N | % | OR | 95% CI | *P* |
| PE | 406 | 1.29% | 243 | 0.77% | **1.6796** | **1.4316-1.9705** | **<.0001** |
| DVT | 989 | 3.15% | 761 | 2.43% | **1.3094** | **1.1897-1.4411** | **<.0001** |
| Transfusion | 928 | 2.96% | 498 | **1.59%** | **1.8898** | **1.6929-2.1096** | **<.0001** |
| Pneumonia | 730 | 2.33% | 453 | **1.44%** | **1.6261** | **1.4446-1.8302** | **<.0001** |
| CVA | 178 | 0.57% | 93 | **0.30%** | **1.9192** | **1.4928-2.4674** | **<.0001** |
| MI | 127 | 0.40% | 81 | **0.26%** | **1.5702** | **1.1878-2.0758** | **.0015** |
| Sepsis | 241 | 0.77% | 179 | 0.57% | **1.3491** | **1.1111-1.6379** | **.0025** |
| Blood loss anemia | 555 | 1.77% | 335 | **1.07%** | **1.6685** | **1.4556-1.9126** | **<.0001** |
| AKI | 1187 | 3.78% | 729 | **2.32%** | **1.6530** | **1.5053-1.8151** | **<.0001** |
| UTI | 2361 | 7.53% | 1233 | **3.93%** | **1.9893** | **1.8535-2.1351** | **<.0001** |

AKI, acute kidney injury; CI, confidence interval; UTI, urinary tract infection.
Bold indicates statistically significant result.

scoring to 31,362 OSA patients who had not used CPAP preoperatively with demographic and comorbidity data presented in Table 2. Patients with documented CPAP use preoperatively were associated with significantly higher 90-day incidences of all evaluated medical complications (Table 3), including PE (OR 1.68, $P < .0001$), DVT (OR 1.31, $P < .0001$), transfusion (OR 1.89, $P < .0001$), pneumonia (OR 1.63, $P < .0001$), CVA (OR 1.92, $P < .0001$), MI (OR 1.57, $P = .0015$), sepsis (OR 1.35, $P = .0025$), blood loss anemia (OR 1.67, $P < .0001$), acute kidney injury (OR 1.65, $P < .0001$), and urinary tract infection (OR 1.99, $P < .0001$). Regarding 1-year surgery-related outcomes (Table 4), the CPAP cohort was associated with a significantly higher risk of undergoing revision TKA (OR 1.14, $P = .0028$). There were no differences in rates of periprosthetic joint infection, periprosthetic fracture, component loosening, manipulation under anesthesia, lysis of adhesions, or dislocation between the CPAP and control cohorts. Patients in the CPAP cohort were associated with higher 90-day incidences of emergency department presentation (OR 1.61, $P < .0001$), hospital admission (OR 1.33, $P < .0001$), ICU admission (OR 1.45, $P < .0001$), and increased total cost ($P < .0001$) compared to the control cohort with no significant difference in average LOS (Table 5).

## Discussion

This study revealed that OSA patients using CPAP prior to undergoing TKA were at significantly increased risk of several early postoperative medical complications and revision surgery with increased health-care utilization compared to OSA patients not using CPAP. These findings provide insight into how disease severity in OSA can influence the risk of complications following TKA. CPAP use can act as a marker for more severe diseases, indicating a nearly twofold increased risk of several medical complications and an increased risk of revision surgery compared to OSA patients not using CPAP. These results are consistent with a prior study by Sequeira et al. demonstrating increased risk of medical and surgery-related complications among CPAP users undergoing total hip arthroplasty compared to OSA patients not using CPAP [16].

OSA has been well established as an independent risk factor for complications following primary [14] and revision total joint arthroplasty [15]. A variety of perioperative complications are more prevalent among patients with sleep apnea following TKA including venous thromboembolism, [14,17] delirium, [18] mortality, [14,15] and hematoma or seroma formation [14,15]. Thromboembolic complications are especially prevalent in this patient population secondary to increased circulating levels of coagulation factors, [19] and OSA patients have similarly been found to be at increased risk of CVA [20]. The prothrombotic effect of OSA likely contributed to the increased risk of DVT (OR 1.31), PE (OR 1.68), CVA (OR 1.92), and MI (OR 1.57) among CPAP users observed in the current study. These increased complication rates are consistent with CPAP usage representing more severe diseases among OSA patients. These findings may guide clinicians in stratifying risk of perioperative complications among patients with OSA in order to counsel patients appropriately.

Regarding surgery-related complications, our results demonstrate that OSA patients using CPAP were at increased risk of undergoing all-cause revision surgery (OR 1.14). OSA is known to have a negative effect on bone health as hypoxia disrupts osteoblast maturation and functionality, and previous studies have

**Table 4**
One-year surgery-related complications following TKA in CPAP and non-CPAP cohorts.

| | OSA + CPAP (n = 31,362) | | Control (n = 31,362) | | Statistical analysis | | |
|---|---|---|---|---|---|---|---|
| | N | % | N | % | OR | 95% CI | *P* |
| Revision | 1208 | 3.85% | 1068 | 3.41% | **1.1363** | **1.0449-1.2357** | **.0028** |
| PJI | 607 | 1.94% | 588 | 1.87% | 1.0330 | 0.9212-1.1583 | .579 |
| PpFx | 71 | 0.23% | 79 | 0.25% | 0.8985 | 0.6519-1.2385 | .5133 |
| Loosening | 86 | 0.27% | 64 | 0.20% | 1.3447 | 0.9726-1.8591 | .0731 |
| MUA | 1199 | 3.82% | 1142 | 3.64% | 1.0519 | 0.9685-1.1425 | .2299 |
| LOA | 87 | 0.28% | 77 | 0.25% | 1.1302 | 0.8314-1.5365 | .4346 |
| Dislocation | 108 | 0.34% | 89 | 0.28% | 1.2142 | 0.9167-1.6082 | .1758 |

CI, confidence interval; LOA, lysis of adhesions; MUA, manipulation under anesthesia; PJI, periprosthetic joint infection; PpFx, periprosthetic fracture.
Bold indicates statistically significant result.

**Table 5**
Ninety-day health-care utilization following TKA in CPAP and non-CPAP cohorts.

| | OSA + CPAP (n = 31362) | | Control (n = 31,362) | | Statistical analysis | | |
|---|---|---|---|---|---|---|---|
| | N | % | N | % | OR | 95% CI | *P* |
| ED visit | 6383 | 20.35% | 4300 | 13.71% | **1.6082** | **1.5416-1.6777** | **<.0001** |
| Hospital admission | 11,579 | 36.92% | 9580 | 30.55% | **1.3308** | **1.2873-1.3757** | **<.0001** |
| ICU admission | 502 | 1.60% | 348 | 1.11% | **1.4497** | **1.2633-1.6636** | **<.0001** |
| LOS | 3.10 ± 4.56 | - | 3.07 ± 2.84 | - | | | .3227 |
| Total cost | 6801 ± 22101 | - | 6001 ± 20750 | - | | | **<.0001** |

Bold indicates statistically significant result.

demonstrated a significant association between OSA and the development of osteoporosis [21,22]. This negative effect on bone quality may compromise implant fixation and cause an increased risk of early surgery-related complications. Indeed, a prior database study by Vakharia et al. demonstrated an increased risk of revision surgery, periprosthetic fracture, and mechanical loosening among OSA patients following primary TKA [14]. A more severe disease, as indicated by CPAP usage in the current study, was found to further increase the risk of revision surgery among patients with OSA. Further research is warranted to identify interventions that may improve bone health in this patient population and mitigate the increased risk of early failure.

Patients using CPAP were found to be at increased risk of 90-day emergency department presentation, hospital admission, and ICU admission (Table 5). These results are consistent with prior studies that have shown increased rates of hospital [14] and ICU [23] admission among OSA patients undergoing arthroplasty procedures. Interestingly, patients using CPAP were not found to have increased LOS compared to the control cohort despite having a significantly increased risk of all 90-day medical complications evaluated in the current study. OSA patients using CPAP may benefit from increased surveillance in the inpatient setting to better evaluate and manage any perioperative medical complications.

There are several limitations to the current study. As a retrospective database study, results are dependent upon clinicians accurately diagnosing and coding medical and surgery-related complications. While a limitation of using a large administrative database may be inaccurate coding of diagnoses and procedures, the incidence of inaccuracy is estimated to be less than 1% [24]. CPT codes used to identify patients using CPAP preoperatively do not reflect patient compliance with using CPAP. ICD diagnosis codes do not directly stratify disease severity among OSA patients, so CPAP usage acted as a proxy for a more severe disease. An advantage of this methodology is that CPAP usage may act as a simple marker for a more severe disease by which surgeons may identify OSA patients who are at higher risk of early medical and surgery-related complications. Other strengths of this study include a large sample size necessary to detect small differences in complication rates. Patients included in this study would have received treatments from a wide variety of surgeons and centers, making our results broadly applicable to clinical practice.

## Conclusion

OSA patients using CPAP preoperatively were found to have increased incidences of 90-day medical complications, early revision surgery, and health-care utilization compared to OSA patients not using CPAP. Clinicians may be guided by the results of this study to identify particularly high-risk patients with OSA prior to undergoing TKA. This would allow appropriate counseling of these patients preoperatively and may influence perioperative decision-making. Future research is warranted to identify interventions that may mitigate risk of complications among this patient population.

## Conflict of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.101085.

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