



Original Research

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

Sean B. Sequeira, MD^{*}, Brian P. McCormick, MD, Henry Boucher, MD

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

ARTICLE INFO

Article history:

Received 22 May 2022

Received in revised form

11 August 2022

Accepted 28 August 2022

Available online xxx

Keywords:

Obstructive sleep apnea

Continuous positive airway pressure

Total hip arthroplasty

Postoperative outcomes

ABSTRACT

Background: The objective of this study was to determine the effect size of the use of continuous positive airway pressure (CPAP), as a surrogate in cases of active and more severe diseases, on early medical and surgery-related complications following total hip arthroplasty (THA) within an obstructive sleep apnea (OSA) patient population.

Methods: Patients with OSA who underwent primary THA between 2010 and 2019 were identified using a large national insurance database. Ninety-day incidence of various medical and surgery-related complications and hospital utilization were evaluated for OSA patients who had used CPAP prior to THA and those who did not. Propensity score matching was used to control for patient demographic factors and comorbidities as covariates.

Results: Propensity score matching resulted in 7351 OSA patients who had used CPAP within 6 months of primary THA and 7351 OSA patients who had not. Patients who had used CPAP were at increased 90-day risk of medical complications, as well as 1-year risk of periprosthetic fracture (OR 1.5429; $P = .0356$), osteolysis (OR 2.4488; $P = .0237$), aseptic loosening (OR 2.4057; $P < .001$), and dislocation (OR 1.283; $P = .016$).

Conclusions: Our findings suggest that OSA patients on CPAP are at increased risk of several 90-day medical complications, 1-year surgical complications, and health-care utilization compared to OSA patients not recently using CPAP.

Level of Evidence: III, Retrospective review.

© 2022 The Authors. Published by Elsevier Inc. on behalf of The American Association of Hip and Knee Surgeons. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

Obstructive sleep apnea (OSA) is one of the most common pulmonary medical diagnoses in the United States and worldwide, with estimates suggesting that the prevalence of OSA is as high as 14% in adult men and 5% in adult women in the United States [1–3]. OSA has long been associated with cardiovascular morbidity and mortality [1]. Although OSA can occasionally be managed without intervention, nighttime continuous positive airway pressure (CPAP) is classically a mainstay of treatment by delivering a steady inflow of concentrated oxygen to the patient's lungs.

The rate of primary total hip arthroplasty (THA) is rapidly increasing, with studies projecting growth to 635,000 surgeries by 2030, a greater growth than projections for total knee arthroplasty [4]. Furthermore, younger patients are becoming candidates for THA as implant survivorship continues to be optimized [5]. Since OSA classically manifests in middle-age men and women, more patients undergoing arthroplasty are likely to have a comorbid diagnosis of OSA. OSA has already been identified as a risk factor for perioperative medical complications following total joint arthroplasty (TJA) and revision joint arthroplasty [6,7]. However, the impact of CPAP has not been previously studied as a risk factor for complications following arthroplasty.

Given the prevalence of sleep apnea in the arthroplasty patient population, it is important to understand how the use of CPAP may impact medical and arthroplasty-related complications following TJA. Furthermore, there is no current manner in which to stratify

^{*} Corresponding author. Department of Orthopaedic Surgery, MedStar Union Memorial Hospital, 3333 North Calvert Street, Suite 400, Baltimore, MD 21218, USA. Tel.: +1 804 916 0847.

E-mail address: sean.sequeira@medstar.net

OSA patients' risk of medical and surgery-related complications following TJA. Moreover, the effect size of the use of CPAP for patients with OSA is currently unknown. Therefore, the purpose of this investigation was to evaluate the association between CPAP use and postoperative outcome in patients with a diagnosis of OSA following THA. We hypothesized that patients with preoperative CPAP use would be associated with an increased incidence of early medical and arthroplasty-related complications compared to non-CPAP using OSA patients.

Material and methods

This is a retrospective cohort study performed using the commercially available Mariner database via PearlDiver (PearlDiver Inc., Colorado Springs, CO) patient records database. Mariner is a large, anonymized insurance data set for 121 million patients in the United States. Patient records from 2010 through the second quarter of 2019 were searched using International Classification of Diseases (ICD) and Current Procedural Terminology (CPT) codes. All queried data were deidentified in accordance with the Health Insurance Portability and Accountability Act. Therefore, this study was deemed exempt from our institution's review board process.

Patients who underwent primary THA with at least 90 days of postoperative follow-up in the database were identified using CPT and ICD, ninth revision, (ICD-9) codes. Patients who had a preoperative diagnosis of OSA were identified based on codes listed in [Table S1](#). Patients who were currently using a CPAP machine were identified using CPT and ICD-9/ICD, tenth revision, (ICD-10) procedure codes within 6 months prior to THA.

Preoperative patient variables assessed were age, gender, and preoperative diagnosis of various ICD-9 or ICD-10 codes of uncomplicated diabetes, chronic kidney disease, obesity, ischemic heart disease, tobacco abuse, and congestive heart failure. Patients with preoperative diagnosis of OSA who had used CPAP, as documented by ICD-9/10 procedure codes or CPT codes, 6 months prior to surgery were matched using propensity scoring with patients without a documentation of CPAP use but with a preoperative diagnosis of OSA. Patients who were associated with CPAP use specifically following THA, without CPAP use preoperatively, were excluded from this study.

Ninety-day incidence of readmission, emergency department (ED) visit, reimbursement, and length of stay (LOS) were evaluated as hospital utilization outcomes. One-year incidence of diagnosis of periprosthetic joint infection, periprosthetic fracture, prosthetic dislocation, aseptic loosening, and broken hardware was evaluated as arthroplasty-related complications.

Ninety-day incidence of pulmonary embolism, deep vein thrombosis, myocardial infarction (MI), cerebrovascular accident, need for transfusion, pneumonia, sepsis, acute hemorrhagic anemia, acute renal failure, and urinary tract infection was evaluated as medical complication.

In the aggregate, 7351 total patients who had received CPAP within 6 months from undergoing THA were matched in a propensity scoring methodology in a 1:1 ratio based on age, sex, and various medical comorbidities including coronary artery disease, uncomplicated diabetes mellitus, obesity, tobacco abuse, chronic pulmonary disease, liver disease, peripheral vascular disease, renal disease, cancer, and congestive heart failure. Adjusted odds ratio (ORs) and 95% confidence intervals were calculated for each variable independently using R (University of Auckland, New Zealand). Comparisons of continuous variables, including reimbursement and LOS, were performed using student t-tests in R. A *P* value less than 0.05 was used to ascribe statistical significance.

Results

A total of 7351 patients with OSA who had used CPAP in the late preoperative period prior to THA were matched in propensity scoring to 7351 patients with OSA who had not used CPAP in the late preoperative period prior to THA ([Table S2](#)). The CPAP cohort was associated with a significantly higher 90-day incidence of pulmonary embolism (OR 1.535; *P* = .0178), deep vein thrombosis (OR 1.376; *P* = .0209), transfusion (OR 2.149; *P* < .001), pneumonia (OR 1.609; *P* < .001), cerebrovascular accident (OR 2.259; *P* < .001), MI (OR 1.9185; *P* = .0115), acute hemorrhagic anemia (OR 1.332; *P* = .0204), acute renal failure (OR 2.460; *P* < .001), and urinary tract infection (OR 1.714; *P* < .001) ([Table S3](#)). There was no difference in rates of sepsis between CPAP and non-CPAP cohorts.

The CPAP cohort was associated with a significantly higher 1-year incidence of periprosthetic fracture (OR 1.5429; *P* = .0356), osteolysis (OR 2.4488; *P* = .0237), aseptic loosening (OR 2.4057; *P* < .001), and dislocation (OR 1.283; *P* = .016) ([Table S4](#)). There was no difference between the CPAP and non-CPAP cohort in incidence of revision THA or periprosthetic joint infection 1 year following primary THA.

The CPAP cohort was associated with a significantly higher 90-day incidence of ED visit (OR 1.6116; *P* < .001), readmission (OR 7.0452; *P* < .001), and reimbursement (\$6627.75 ± \$9032.91 vs \$5339.28 ± \$6823.44; *P* < .001) ([Table S5](#)).

Discussion

In this study, we found that patients who use CPAP in the late preoperative period prior to THA are at increased risk of several 90-day medical complications, 1-year surgery-related complications, and increased health-care utilization following THA. Although these findings may be intuitive, they nevertheless provide key insight into how to risk stratify OSA patients in the preoperative period to determine how they might expect to recover in the postoperative period.

Many previous studies have determined that OSA is an independent risk factor for several orthopedic procedures, including primary and revision TJA. A study that evaluated TJA from 2005 to 2014 found that sleep apnea was associated with increased 90-day risk of several medical complications, surgery-related complications, and increased hospital utilization [6]. D'Apuzzo and Browne concluded that OSA was associated with increased risk of in-hospital mortality and wound hematomas/seromas following revision joint arthroplasty [7]. Patients with OSA have been shown to be at elevated risk of needing transfusion and thromboembolic complications, the latter of which is due to increased circulating levels of coagulation factors [8,9]. The elevated levels of prothrombotic agents may also explain the increased risk of cardiovascular complications including MI and stroke. Our findings demonstrate that patients on CPAP are at an increased risk of cardiovascular, thromboembolic, and medical complications compared to OSA patients not on CPAP. We posit that OSA patients on CPAP represent patients with a more severe and more active disease, which may help clinicians and surgeons to risk stratify OSA patients in the preoperative period.

Our findings demonstrate that OSA patients on CPAP are associated with an increased risk of surgery-related complications including dislocation, fracture, osteolysis, and aseptic loosening. Previous studies have explained the relationship between sleep apnea and metabolic bone disease, reporting that poor delivery of oxygen to the blood can impair osteoblast formation and maturation [8]. Indeed, a study by Chen et al. demonstrated that patients with OSA were 2.7 times more likely to develop osteoporosis [10]. Other studies have explained the increased risk of surgery-related

complications in OSA patients by upregulation of complement cascade proteins, endothelial dysfunction, and proinflammatory markers [11,12]. Poor oxygenation may compromise bony maturation and recovery after THA which may lead to complications such as fracture, loosening, and osteolysis.

OSA patients using CPAP were also associated with increased hospital utilization, namely ED visit, readmission, and reimbursement. However, OSA patients using CPAP were not associated with an increased LOS. Previous studies on sleep apnea have concluded that OSA patients tend to experience longer LOS than healthy patients following arthroplasty [6]. These findings are interesting, especially when considering that patients using CPAP prior to THA are at increased risk of several 90-day and 1-year complications, which may suggest that surveillance with more patient-specific granularity may serve these at-risk patients better in the immediate postoperative period.

This study does have its limitations. First, the use of any large-scale administrative insurance database is contingent upon the accurate entry and coding of diagnoses, comorbidities, and procedures within the data. However, recent studies suggest that the incidence of inaccuracy in large databases is lower than 1% [13,14]. Furthermore, ICD-9 and ICD-10 diagnosis codes do not reflect the severity of OSA, and therefore, we cannot comment directly upon the severity of OSA and how it impacts postoperative medical and arthroplasty-related complications. Finally, CPT and ICD-9/10 codes do not comment on the compliance that patients exhibited with their CPAP use, which limits the generalizability of our findings.

This study has important implications for both surgeons and clinicians that manage patients with OSA using CPAP machines and scheduled to undergo arthroplasty. These findings suggest that patients who use CPAP machines are at increased risk of early medical and surgical complications following THA. Although the use of a CPAP machine may likely be a surrogate in cases of a more severe disease, this study helps to characterize the effect size of this at-risk cohort of patients within OSA patients. Although the use of CPAP clearly has important medical benefits, these findings help to highlight that these patients may require additional counseling and optimization in the preoperative and perioperative periods in order to temper their increased likelihood of medical and surgical complications, as demonstrated by our findings.

Conclusion

Our findings suggest that OSA patients on CPAP are at increased risk of several 90-day medical complications, 1-year surgical

complications, and health-care utilization compared to OSA patients not recently using CPAP. These findings provide insight into preoperative and perioperative decision-making when counseling these at-risk patients prior to and during THA.

Conflicts of interest

H. Boucher receives royalties from Innomed and Aesculap/B. Braun and is a paid consultant for Globus Medical, Inc. The other 2 authors declare no potential conflicts of interest.

For full disclosure statements refer to DOI.

References

- [1] Punjabi NM. The epidemiology of adult obstructive sleep apnea. *Proc Am Thorac Soc* 2008;5:136–43.
- [2] Benjafield AV, Ayas NT, Eastwood PR, Heizer MS, Morrell MJ, Nunez CM, et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. *Lancet Respir Med* 2019;7:687–98.
- [3] Franklin KA, Lindberg E. Obstructive sleep apnea is a common disorder in the population—a review on the epidemiology of sleep apnea. *J Thorac Dis* 2015;7:1311–22.
- [4] Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the U.S., 2014 to 2030. *J Bone Joint Surg Am* 2018;100:1455–60.
- [5] Polkowski GG, Callaghan JJ, Mont MA, Clohisy JC. Total hip arthroplasty in the very young patient. *J Am Acad Orthop Surg* 2012;20:487–97.
- [6] Vakharia RM, Cohen-Levy WB, Vakharia AM, Donnally CJ, Law TY, Roche MW. Sleep apnea increases ninety-day complications and cost following primary total joint arthroplasty. *J Arthroplasty* 2019;34:959–964.e1.
- [7] D'Apuzzo MR, Browne JA. Obstructive sleep apnea as a risk factor for postoperative complications after revision joint arthroplasty. *J Arthroplasty* 2012;27(8 Suppl):95–8.
- [8] Stundner O, Chiu YL, Sun X, Ramachandran SK, Gerner P, Vougioukas V, et al. Sleep apnoea adversely affects the outcome in patients who undergo posterior lumbar fusion: a population-based study. *Bone Joint J* 2014;96-B:242–8.
- [9] Liak C, Fitzpatrick M. Coagulability in obstructive sleep apnea. *Can Respir J* 2011;18:338–48.
- [10] Chen YL, Weng SF, Shen YC, Chou CW, Yang CY, Wang JJ, et al. Obstructive sleep apnea and risk of osteoporosis: a population-based cohort study in Taiwan. *J Clin Endocrinol Metab* 2014;99:2441–7.
- [11] Swanson CM, Shea SA, Stone KL, Cauley JA, Rosen CJ, Redline S, et al. Obstructive sleep apnea and metabolic bone disease: insights in to the relationship between bone and sleep. *J Bone Miner Res* 2015;30:199–211.
- [12] Fortis S, Colling KP, Statz CL, Glover JJ, Radosevich DM, Beilman GJ. Obstructive sleep apnea: a risk factor for surgical site infection following colectomy. *Surg Infect (Larchmt)* 2015;16:611–7.
- [13] Khan NF, Harrison SE, Rose PW. Validity of diagnostic coding within the general practice research database: a systematic review. *Br J Gen Pract* 2010;60:e128–36.
- [14] Burns EM, Rigby E, Mamidanna R, Bottle A, Aylin P, Ziprin P, et al. Systematic review of discharge coding accuracy. *J Public Health (Oxf)* 2012;34:138–48.

Table S1
ICD-9 and 10 codes for OSA.

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

Table S2
Patient demographics and comorbidities.

Variable	Total hip arthroplasty		
	OSA + CPAP	OSA - CPAP	P value
Age			
60-64	21.684	20.079	.0167
65-69	18.814	18.474	.5965
70-74	17.494	16.120	.0259
75-79	10.638	10.325	.5357
80-84	1.973	1.863	.6305
Male	57.625	57.162	.5707
Obesity	50.170	54.550	< .001
ETOH	3.891	3.619	.385
Chronic kidney disease	11.985	11.971	.979
Chronic pulmonary disease	33.098	34.213	.1523
Congestive heart failure	10.203	10.135	.8914
Coronary artery disease	28.200	28.404	.7836
Depression	32.159	34.676	.0012
Diabetes mellitus	43.246	45.245	.0146
HTN	79.254	81.281	.0020
PVD	16.678	17.712	.0967
Renal disease	12.665	12.474	.7276
Renal failure	9.401	9.332	.8845
Tobacco use	28.309	29.982	.0255
Geographic location			
Midwest	29.7374507	29.424	.6777
NE	20.1197116	18.596	.0194
South	32.68943	57.149	< .001
West	17.57584	18.610	.1035

PVD, peripheral vascular disease; ETOH, alcohol abuse; HTN, hypertension; NE, Northeast.

Bolded values were statistically significant ($P < .05$).

Table S3

Ninety-day medical complications following THA in CPAP and non-CPAP cohorts.

Complication	OSA + CPAP		OSA - CPAP		Statistical analysis		
	N	%	N	%	OR	95% CI	P
PE	78	1.061	51	0.694	1.535	1.0770-2.1881	.0178
DVT	126	1.714	92	1.252	1.376	1.0496-1.8039	.0209
Transfusion	364	4.952	174	2.367	2.149	1.7884-2.5820	<.001
Pneumonia	158	2.149	99	1.347	1.609	1.2489-2.0730	.0002
Stroke	54	0.735	24	0.326	2.259	1.3953-3.6582	.0009
MI	44	0.599	23	0.313	1.9185	1.1574-3.1801	.0115
Sepsis	89	1.211	79	1.075	1.1281	0.8318-1.530	.438
Acute anemia	155	2.109	117	1.592	1.332	1.0453-1.6968	.0204
ARF	286	3.891	119	1.619	2.460	1.9816-3.0543	<.001
UTI	548	7.455	330	4.489	1.714	1.4891-1.9725	<.001

ARF, acute renal failure; CI, confidence interval; DVT, deep vein thrombosis; PE, pulmonary embolism; UTI, urinary tract infection. Bolded values are statistically significant ($P < .05$).

Table S4

One-year surgery-related complications following THA in CPAP and non-CPAP cohorts.

Complication	OSA + CPAP		OSA-CPAP		Statistical analysis		
	N	%	N	%	OR	95% CI	P
Revision	102	1.388	80	1.088	1.2789	0.9526-1.7169	.1016
PJI	157	2.136	165	2.244	0.9505	0.762-1.1855	.6522
Periprosthetic fracture	60	0.816	39	0.531	1.5429	1.0296-2.3120	.0356
Osteolysis	22	0.299	9	0.122	2.4488	1.1268-5.3218	.0237
Loosening	138	1.877	58	0.789	2.4057	1.7672-3.2749	<.001
Dislocation	218	2.966	171	2.326	1.2833	1.0476-1.5719	.016

CI, confidence interval; PJI, periprosthetic joint infection. Bolded values are statistically significant ($P < .05$).

Table S5

Ninety-day hospital utilization following THA in CPAP and non-CPAP cohorts.

Complication	OSA + CPAP		OSA-CPAP		Statistical analysis		
	N	%	N	%	OR	95% CI	P
ED visit	102	1.388	80	1.088	1.6116	1.4801-1.7547	<.001
Readmission	157	2.136	165	2.244	7.0452	6.267-7.9201	<.001
LOS	2.722 ± 5.0	—	2.713 ± 3.78	—	—	—	.9020
Reimbursement	\$6627.75 ± \$9032.91	—	\$5339.28 ± \$6823.44	—	—	—	<.001

CI, confidence interval; ED, emergency department.

Bolded values are statistically significant ($P < .05$).