Research Article

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Journal of **Comparative Effectiveness Research**

Postoperative outcomes and anesthesia type in total knee arthroplasty in patients with obstructive sleep apnea

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Aim: We investigated the relationship between obstructive sleep apnea (OSA), 30/90-day readmission rates and perioperative complications (postoperative cardiovascular, gastrointestinal, infectious or intraoperative complications) in patients undergoing total knee arthroplasty. **Materials & methods:** We analyzed records of patients who underwent total knee arthroplasty using State Inpatient Databases. Demographics, comorbidities, 30/90-day readmission rates and complications were compared by OSA status. For NY, USA we analyzed outcomes by anesthetic type (regional vs general). **Results:** OSA patients were mostly male, had more comorbidities and had increased 30/90-day readmission rates. There were no differences in complications. In NY, there were no differences in outcomes by anesthetic type. **Conclusion:** OSA was associated with increased 30/90-day readmission rates. Within NY, anesthetic type was not associated with any outcomes.

Plain language summary: By analyzing records of patients who underwent total knee replacement, we investigated the relationship between obstructive sleep apnea (OSA), rates of readmission to the hospital at 30 and 90 days after surgery and perioperative complications (postoperative cardiovascular, gastrointestinal, infectious or intraoperative complication). In the NY, USA population, we analyzed outcomes based on anesthetic type (regional vs general anesthesia). We found that OSA patients were mostly male, had more medical conditions and had increased rates of 30 and 90-day readmission. There were no differences in complications. In NY, there were no differences in outcomes by anesthetic type. In conclusion, OSA was associated with increased rates of readmission to the hospital at 30 and 90 days after surgery. Within NYS, anesthetic type was not associated with any outcomes.

First draft submitted: 2 August 2022; Accepted for publication: 26 September 2022; Published online: 6 October 2022

Keywords: anesthesia • obstructive sleep apnea • outcomes research • regional anesthesia • total knee arthroplasty

Obstructive sleep apnea (OSA) is characterized by episodic upper airway obstruction during sleep resulting in intermittent hypoxemia [1–3]. The prevalence of OSA in the US is suspected to be between 9 and 38% and is more common in men, older individuals and those with a high BMI [4–6]. Untreated OSA can cause additional chronic medical conditions, leading to increased total lifetime healthcare costs and can have a substantial economic impact on society [7]. In the perioperative setting, patients with OSA pose management challenges including increased risk of postoperative hypoxemia and cardiopulmonary complications that can lead to greater resource utilization, longer hospital and intensive care stays and higher readmission rates [8–10]. The American Society of Anesthesiologists (ASA) has established clinical guidelines for management of patients with OSA, first in 2006 and updated in 2014. These recommendations include the perioperative use of positive airway pressure therapy, continuous oxygen saturation monitoring, oxygen therapy and regional anesthesia (RA) whenever possible [11].

Total knee arthroplasty (TKA), one of the most common orthopedic surgical procedures performed in the US, may be performed under regional or general anesthesia (GA), with RA associated with decreased length of stay (LOS) and postoperative complications [9]. OSA prevalence is higher in patients undergoing orthopedic compared

with general surgery procedures, and several studies show an adverse impact of OSA on morbidity and mortality in the orthopedic populations [9,12–15]. Additionally, patients with OSA undergoing TKA report lower satisfaction and patient-rated success scores compared with those without OSA [16]. Furthermore, many patients who present for joint replacement surgery have undiagnosed OSA, which could lead to unexpected complications and patient dissatisfaction [17].

In this study, we sought to investigate the relationship between OSA and postoperative outcomes in patients undergoing elective TKA. We retrospectively analyzed data from the State Inpatient Databases (SID) for NY, FL, MD and KY, USA, for the years 2007–2018. Our main hypothesis was that OSA would increase the rate and the adjusted odds of adverse perioperative outcomes after correction for potential confounders. The primary outcome was 30- and 90-day readmission, quality metrics which represent transitions of care from inpatient to outpatient settings. The secondary outcomes were in-hospital mortality, perioperative complications and LOS.

A further aim was to explore shifts in practice and outcomes that might represent a response to the initial publication of the ASA OSA guidelines in 2006. Here, we hypothesized that adverse postoperative outcomes associated with OSA would decrease over the study period, the use of RA would increase over the study period and adverse postoperative outcomes would be lower in patients who received RA as compared with GA.

Materials & methods

Study database & population

In this retrospective observational study, we analyzed administrative records of patients who underwent elective inpatient TKA from 2007 to 2018 using multi state data from the SID (Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality). States included were FL, MD, KY and WA (all years), NY (2007–2016) and CA (2007–2011). The SID is a discharge level database which contains information on diagnoses, procedures and patient demographics for nearly all inpatient hospitalizations within a particular state. The database contains present-on-admission (POA) indicators which distinguish pre-existing comorbidities from complications developed in the inpatient stay. In certain states and years, a variable linking records to an individual patient enables longitudinal analyses of patient readmissions.

Inclusion criteria for the full sample were adults aged 18+ years with a TKA on the inpatient record. TKA surgeries were identified using International Classification of Diseases Clinical Modification, 9th Revision (ICD-9-CM) code 81.54 and International Classification of Diseases Procedure Codes, 10th Revision (ICD-10-PCS) codes 0SRD0J9, 0SRC0J9, 0SRC0JA and 0SRD0JA [18]. Records were excluded if they had missing data for primary payer or sex, or if the TKA was identified as non elective. Readmission data were feasible except for in the state of KY (all years), MD before 2012 and WA before 2009.

NY, USA data contains a variable for anesthesia type, which can take on only one value per inpatient record [18,19]. Because a patient could receive multiple types of anesthesia during a hospital admission, records that had more than one procedure (i.e., any procedure other than the TKA) listed were excluded, to ensure the anesthesia type recorded was for the TKA procedure only. The variable is coded hierarchically (in descending order): general, regional, local, other and no anesthesia. For the secondary analysis of NY data, only records reporting the use of GA or RA for the TKA procedure were compared.

All study activities were approved by the Institutional Review Board at Weill Cornell Medical College. STROBE guidelines for the reporting of observational studies were followed [20].

Primary variable of interest

Patients were categorized based on the presence or absence of a POA diagnosis of OSA. OSA was identified by ICD-9-CM 327.23 and ICD-10-CM G4733.

Primary outcome

The primary outcomes were binary indicators of 30- and 90-day readmission, separately. If a readmission analysis was not possible for a record, the binary indicator was set to missing. Secondary outcomes included in-hospital mortality, LOS (in days) and the presence of a cardiovascular, infectious, gastrointestinal or intraoperative complication (separately and as a composite binary measure). A list of all ICD-9 codes comprising the complication measures can be found in Supplementary Table 1, and a corresponding list of ICD-10 codes can be found in Supplementary Table 2.

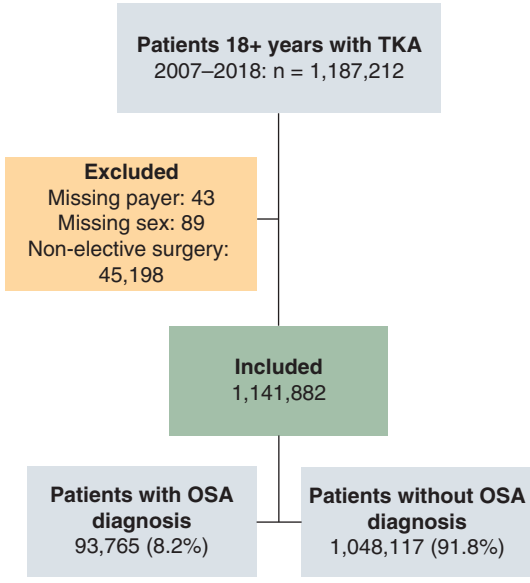

Figure 1. Sample attrition for all included states.
OSA: Obstructive sleep apnea; TKA: Total knee arthroplasty.

Statistical analysis

We compared patient demographics and comorbidities by OSA status in the full population and in the population of NY only. In the NY population, we additionally compared patients with OSA by anesthesia type (RA or GA).

For all binary outcomes, generalized linear mixed models were fitted on the full sample, clustering on the individual hospital. For the outcome of LOS, a Cox proportional hazards model was fitted. In the NY data, we repeated the main analyses in a population of OSA patients only. We also conducted a multivariable logistic regression model with the outcome of receiving GA (compared with RA).

A sensitivity analysis was conducted of the full sample in which the primary outcomes of 30- and 90-day readmission were repeated with an additional interaction term of OSA status and continuous positive airway pressure (CPAP) use. These models were compared with the corresponding models without the interaction term using likelihood ratio tests. If the likelihood ratio tests showed that the interaction models had a better fit, linear combination of coefficients were calculated with significant categories of the interaction term(s) and the respective categories.

Variables

In all multivariable models, the following covariates were included: a binary indicator of OSA status, primary insurance payer (unordered categories: Medicare, Medicaid, private insurance, other insurance, self-pay/no charge/uninsured), race/ethnicity (unordered categories: White, Black, Hispanic, other, missing), state-based quartile of median income for the patient's ZIP code, sex, age, 29 binary Elixhauser comorbidities, year of procedure, quartile of hospital TKA procedure volume (based upon the entire sample), year of procedure and state of hospital [21]. Additional measures of logged total hospital charges from the index admission and logged LOS stay were included in models of 30- and 90-day readmission. In all models a binary indicator for invasive or non invasive in-hospital CPAP use was included.

Results

Demographics

After applying exclusion criteria, the study population consisted of 1,141,882 patients, with 93,765 (8.2%) of patients with a POA diagnosis of OSA (Figure 1). While the TKA population at-large was two-thirds female, those with a POA diagnosis of OSA were only 50% female (Table 1). Within the study population, the prevalence of OSA increased from 2% in 2007 to 8% in 2018, with the highest prevalence in 2016 (13.1%) (Table 1). Patients with OSA were more likely to be male and had higher rates of multiple comorbidities including congestive heart failure, valvular disease, pulmonary circulation disorders, vascular disorders, hypertension, neurological disorders, pulmonary disease, diabetes, hypothyroidism, renal disease, liver disease, peptic ulcer disease, rheumatoid arthritis, coagulopathies, obesity, electrolyte disorders, anemia, alcohol and drug abuse and depression than patients without

Table 1. Demographic and medical characteristics of patients undergoing total knee arthroplasty according to obstructive sleep apnea status.

Characteristic	No OSA (%)	OSA (%)	Overall (%)	p-value
Total	1,048,117 (91.8)	93,765 (8.2)	1,141,882 (100)	
Age (years)				<0.0001
Mean (standard deviation)	66.88 (9.99)	64.83 (8.89)	66.71 (9.92)	
Gender				<0.0001
Male	380,537 (36.3)	47,071 (50.2)	427,608 (37.4)	
Female	667,580 (63.7)	466,94 (49.8)	714,274 (62.6)	
Year				<0.0001
2007	82,565 (7.9)	1874 (2)	84,439 (7.4)	
2008	85,201 (8.1)	3692 (3.9)	88,893 (7.8)	
2009	86,892 (8.3)	5399 (5.8)	92,291 (8.1)	
2010	91,512 (8.7)	6898 (7.4)	98,410 (8.6)	
2011	89,878 (8.6)	7637 (8.1)	97,515 (8.5)	
2012	90,230 (8.6)	8456 (9)	98,686 (8.6)	
2013	93,811 (9)	9291 (9.9)	103,102 (9)	
2014	96,463 (9.2)	10,178 (10.9)	106,641 (9.3)	
2015	99,705 (9.5)	11,380 (12.1)	111,085 (9.7)	
2016	103,470 (9.9)	12,329 (13.1)	115,799 (10.1)	
2017	72,787 (6.9)	9104 (9.7)	81,891 (7.2)	
2018	55,603 (5.3)	7527 (8)	63,130 (5.5)	
State				<0.0001
FL	392,924 (37.5)	30,911 (33)	423,835 (37.1)	
KY	100,959 (9.6)	12,004 (12.8)	112,963 (9.9)	
MD	120,542 (11.5)	12,715 (13.6)	133,257 (11.7)	
NY	278,760 (26.6)	22,033 (23.5)	300,793 (26.3)	
WA	154,932 (14.8)	16,102 (17.2)	171,034 (15)	
Median household income state quartile for patient zip code (by quartile)				<0.0001
First quartile	222,172 (21.2)	19,324 (20.6)	241,496 (21.1)	
Second quartile	268,409 (25.6)	23,964 (25.6)	292,373 (25.6)	
Third quartile	278,619 (26.6)	25,073 (26.7)	303,692 (26.6)	
Fourth quartile	260,344 (24.8)	23,902 (25.5)	284,246 (24.9)	
Missing	18,573 (1.8)	1502 (1.6)	20,075 (1.8)	
Race				<0.0001
White	819,886 (78.2)	76,980 (82.1)	896,866 (78.5)	
Black	86,473 (8.3)	8800 (9.4)	95,273 (8.3)	
Hispanic	55,489 (5.3)	3715 (4)	59,204 (5.2)	
Other	43,752 (4.2)	2840 (3)	46,592 (4.1)	
Missing	42,517 (4.1)	1430 (1.5)	43,947 (3.8)	
Hospital volume				<0.0001
First quartile	16,770 (1.6)	696 (0.7)	17,466 (1.5)	
Second quartile	94,490 (9)	5737 (6.1)	100,227 (8.8)	
Third quartile	243,162 (23.2)	18,650 (19.9)	261,812 (22.9)	
Fourth quartile	693,695 (66.2)	68,682 (73.2)	762,377 (66.8)	
Primary payer				<0.0001
Medicare	612,412 (58.4)	49,817 (53.1)	662,229 (58)	
Medicaid	37,062 (3.5)	3064 (3.3)	40,126 (3.5)	
Private insurance	352,569 (33.6)	36,145 (38.5)	388,714 (34)	
Other	40,213 (3.8)	4316 (4.6)	44,529 (3.9)	
Self-pay/no charge	5,861 (0.6)	423 (0.5)	6284 (0.6)	

p-value refer to comparisons between OSA statuses. Percent may not sum to 100 due to rounding.
OSA: Obstructive sleep apnea; TKA: Total knee arthroplasty.

Table 1. Demographic and medical characteristics of patients undergoing total knee arthroplasty according to obstructive sleep apnea status (cont.).

Elixhauser comorbidities				
Congestive heart failure	24,202 (2.3)	5644 (6)	29,846 (2.6)	<0.0001
Valvular disease	36,799 (3.5)	4213 (4.5)	41,012 (3.6)	<0.0001
Pulmonary circulation disorders	6479 (0.6)	1838 (2)	8317 (0.7)	<0.0001
Peripheral vascular disorders	20,950 (2)	2832 (3)	23,782 (2.1)	<0.0001
Hypertension, uncomplicated	626,264 (59.8)	64,844 (69.2)	691,108 (60.5)	<0.0001
Hypertension, complicated	49,559 (4.7)	8820 (9.4)	58,379 (5.1)	<0.0001
Paralysis	863 (0.1)	80 (0.1)	943 (0.1)	0.7607
Other neurological disorders	18,365 (1.8)	2218 (2.4)	20,583 (1.8)	<0.0001
Chronic pulmonary disease	147,519 (14.1)	24,939 (26.6)	172,458 (15.1)	<0.0001
Diabetes, uncomplicated	180,649 (17.2)	26,061 (27.8)	206,710 (18.1)	<0.0001
Diabetes, complicated	22,269 (2.1)	5577 (5.9)	27,846 (2.4)	<0.0001
Hypothyroidism	162,900 (15.5)	17,094 (18.2)	179,994 (15.8)	<0.0001
Renal failure	45,994 (4.4)	7939 (8.5)	53,933 (4.7)	<0.0001
Liver disease	10,562 (1)	1733 (1.8)	12,295 (1.1)	<0.0001
Peptic ulcer disease excluding bleeding	4429 (0.4)	451 (0.5)	4,880 (0.4)	0.0086
AIDS/HIV	419 (0)	32 (0)	451 (0)	0.3879
Lymphoma	2,176 (0.2)	219 (0.2)	2,395 (0.2)	0.0961
Metastatic cancer	718 (0.1)	55 (0.1)	773 (0.1)	0.2667
Solid tumor without metastasis	4754 (0.5)	431 (0.5)	5.185 (0.5)	0.7906
Rheumatoid arthritis/collagen vascular diseases	46,581 (4.4)	4600 (4.9)	51,181 (4.5)	<0.0001
Coagulopathy	12,955 (1.2)	1742 (1.9)	14,697 (1.3)	<0.0001
Obesity	232,534 (22.2)	50,046 (53.4)	282,580 (24.7)	<0.0001
Weight loss	1234 (0.1)	115 (0.1)	1,349 (0.1)	0.6748
Fluid and electrolyte disorders	27,728 (2.6)	3101 (3.3)	30,829 (2.7)	<0.0001
Blood loss anemia	3169 (0.3)	267 (0.3)	3436 (0.3)	0.3459
Deficiency anemia	11,328 (1.1)	1452 (1.5)	12,780 (1.1)	<0.0001
Alcohol abuse	9706 (0.9)	1175 (1.3)	10,881 (1)	<0.0001
Drug abuse	6932 (0.7)	1002 (1.1)	7934 (0.7)	<0.0001
Psychoses	2332 (0.2)	308 (0.3)	2640 (0.2)	<0.0001
Depression	128,923 (12.3)	20,231 (21.6)	149,154 (13.1)	<0.0001

p-value refer to comparisons between OSA statuses. Percent may not sum to 100 due to rounding.
OSA: Obstructive sleep apnea; TKA: Total knee arthroplasty.

OSA (Table 1). Of note, 138 patients were diagnosed with OSA during their hospital admission. This is considered not POA (nPOA) diagnosis and these patients were excluded from all analysis.

Primary & secondary outcomes

Regarding the primary outcomes, patients with OSA had increased 30-day (0.5 vs 0.4%, adjusted odds ratio [aOR]: 1.13 [1.00, 1.26]) and 90-day (2.3 vs 1.8%, aOR: 1.11 [1.05, 1.17]) readmission rates, with similar LOS (median interquartile range [IQR]: 2, 3 days for both, adjusted relative risk [aRR]: 0.96 [0.96, 0.97]) (Table 2). In terms of secondary outcomes, in-hospital mortality was the same between the two groups (0.1% for both groups, aOR: 0.23 [0.18, 0.31]). In adjusted analyses, patients with OSA were not more likely than patients without OSA to experience cardiovascular, infectious, gastrointestinal or intraoperative complications (Table 2).

Analysis by anesthetic type in NY OSA population

After applying exclusion criteria, the subgroup population of patients from the New York SID contained 95,869 patients (Figure 2). In this group, 6854 patients (7.1%) carried the diagnosis of OSA, 46.5% of whom received RA as the primary anesthetic compared with 48.5% in the non-OSA population (Figure 2).

Table 2. Frequency and risk adjusted odds of outcome measures for patients undergoing total knee arthroplasty according to obstructive sleep apnea status.

Outcome	n (%)	aOR (95% CI)
30-day readmission		
No OSA	3,307 (0.4)	1.00 (reference)
OSA	361 (0.5)	1.13 (1.00,1.26)†
90-day readmission		
No OSA	14,900 (1.8)	1.00 (reference)
OSA	1,676 (2.3)	1.11(1.05,1.17)‡
In-hospital mortality		
No OSA	569 (0.1)	1.00 (reference)
OSA	74 (0.1)	0.23 (0.18,0.31)‡
Cardiovascular complication		
No OSA	13,761 (1.3)	1.00 (reference)
OSA	1707 (1.8)	1.02 (0.97,1.09)
Infectious complication		
No OSA	9431 (0.9)	1.00 (reference)
OSA	1074 (1.1)	0.95 (0.89,1.03)
Intraoperative complication		
No OSA	2940 (0.3)	1.00 (reference)
OSA	279 (0.3)	0.99 (0.86,1.13)
Gastrointestinal complication		
No OSA	2578 (0.2)	1.00 (reference)
OSA	340 (0.4)	1.11 (0.97,1.26)
LOS (days)		
No OSA	3 (2; 3) §	1.00 (reference)
OSA	3 (2; 3) §	0.96 (0.96,0.97)‡, ¶

Percent may not sum to 100 due to rounding and missing values.
†$p < 0.05$.
‡$p < 0.001$.
§Median (IQR).
¶Adjusted risk ratio.
aOR: Adjusted odds ratio; IQR: Interquartile range; OSA: Obstructive sleep apnea; TKA: Total knee arthroplasty.

We found no differences in the rates of any complication (cardiovascular, infectious, gastrointestinal or intraoperative), LOS, 30-day or 90-day readmission in patients who received GA compared with those who received RA as the primary anesthetic (Table 3). Over the study period, the odds of patients with OSA receiving GA initially trended downwards in the first 2 years, with 2009 being the only statistically significant decrease (reference year: 2007). Since 2009, the overall trend has been toward increased use of GA with a peak in the final year (2016) of the study (Table 4).

Discussion

We retrospectively analyzed the effect of OSA diagnosis on postoperative outcomes in a multistate cohort of patients undergoing TKA over a 12-year period (2007–2018). After adjustment for comorbid conditions, we observed an increased rate of 30- and 90-day readmissions in patients diagnosed with OSA (our primary outcome). OSA has consistently been identified as a risk factor for hospital readmission and is not limited to the orthopedic surgery population [22,23]. In TKA patients, readmissions pose a problem as this disrupts recovery, leads to decreased satisfaction, and is an indicator of inferior quality of care. Additionally, readmissions lead to higher costs for both patients and hospital systems and can result in penalties and decreased reimbursements [13,22,24]. By identifying OSA as a risk factor for readmission, providers can focus on optimizing these patients in the perioperative setting. Different strategies should be considered for this patient population to reduce readmissions including longer immediate postoperative admissions or closer postoperative follow-up [24,25]. Some beneficial measures may include promoting

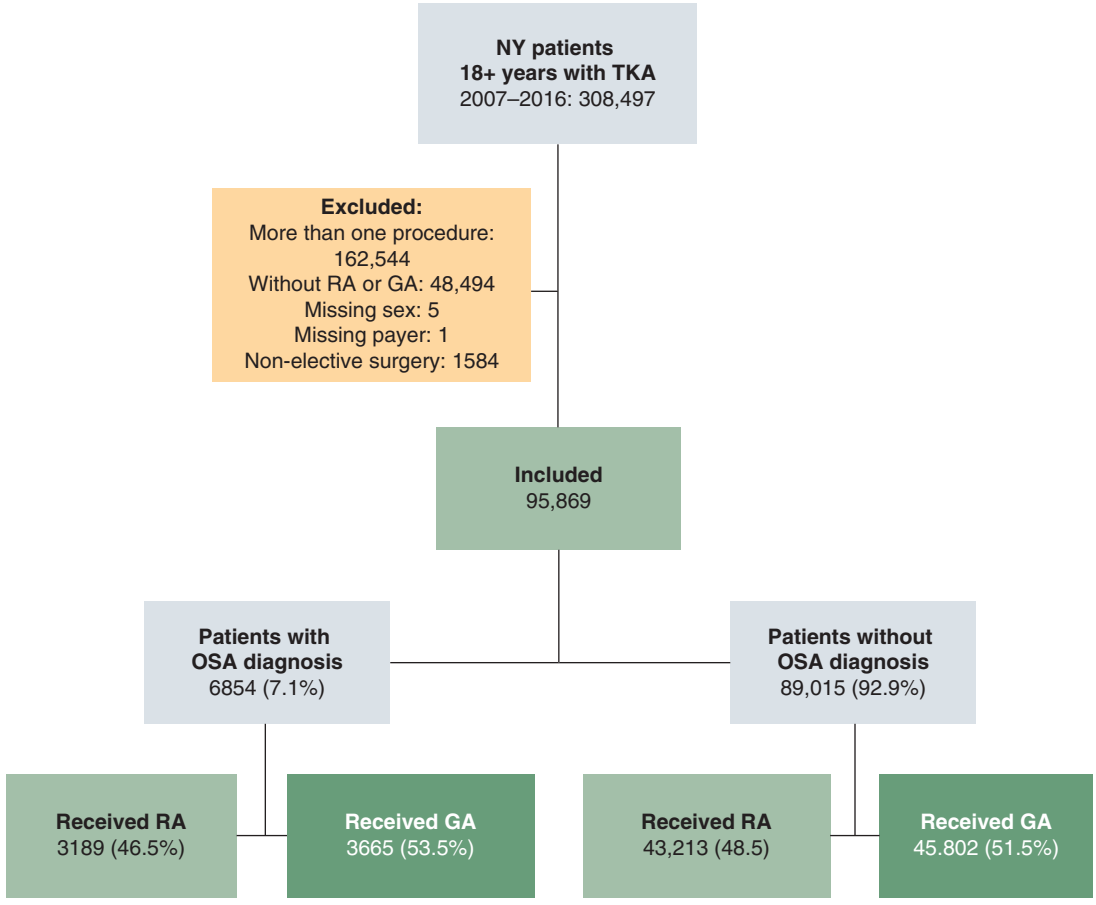

Figure 2. Sample attrition for NY, USA.
GA: General anesthesia; NY: New York; OSA: Obstructive sleep apnea; RA: Regional anesthesia; TKA: Total knee arthroplasty.

incentive spirometry use, ensuring CPAP use after surgery, early mobility and cautious use of opioids both while in the hospital and after discharge [26–28].

Cardiovascular complications have also been associated with both OSA diagnosis and readmissions post-total joint arthroplasty (TJA) [29–33]. However, this is not consistently seen in all the literature and we did not observe a significant association between OSA and cardiovascular complications in our population [14]. Also in our population, there was no association between OSA diagnosis and infectious, gastrointestinal or intraoperative complications, nor were there any associations between OSA diagnosis and risk of longer LOS.

Within the study population, we noted a yearly increase in the prevalence of OSA until 2016 (13.1%), with a subsequent decrease in 2017 (9.7%) and 2018 (8%). Increased prevalence in OSA is being seen globally, especially as the world population becomes older with higher rates of obesity [4,5]. It is not surprising that this trend persists in the surgical population as well, especially in patients undergoing TKA, a procedure more commonly performed in older and heavier patients [4,5].

Contrary to our stated hypothesis, in the subgroup of NY patients with OSA, we found no relationship between the primary anesthetic type and complications (cardiovascular, infectious, gastrointestinal or intraoperative), LOS or 30- and 90-day readmission rates. Similarly, our hypothesis that the use of GA would decrease over time was not supported, as we observed no change in the use of GA over the study period. We found this surprising given the ASA's recommendations for RA use in both the OSA and orthopedic population [34,35]. This is perhaps due to the lack of strong evidence suggesting that RA provides benefit on major perioperative outcomes, when compared with GA [36].

Our findings should not be viewed without acknowledging certain limitations inherent to the SID. First, we were unable to investigate the association of POA diagnosis of OSA with perioperative pulmonary complications

Table 3. Frequency and risk adjusted odds of outcome measures for patients undergoing total knee arthroplasty in NY, USA with a diagnosis of obstructive sleep apnea, according to anesthesia type (overall and stratified by sex).

Outcome	Overall		Male		Female	
	n (%)	aOR (95% CI)	n (%)	aOR (95% CI)	n (%)	aOR (95% CI)
30-day readmission						
RA	<30 (<0.4)	1.00 (reference)	19 (0.4)	1.00 (reference)	<11 (<0.3)	1.00 (reference)
GA	<22 (<0.3)	0.86 (0.32–2.31)	11 (0.3)	0.67 (0.20–2.20)	<11 (<0.3)	0.50 (0.04–5.88)
90-day readmission						
RA	151 (1.9)	1.00 (reference)	92 (2.2)	1.00 (reference)	59 (1.5)	1.00 (reference)
GA	111 (1.7)	0.80 (0.52–1.24)	55 (1.7)	0.52 (0.28–0.95) †	56 (1.6)	1.41 (0.75–2.65)
Cardiovascular complication						
RA	183 (2.2)	1.00 (reference)	94 (2.1)	1.00 (reference)	89 (2.3)	1.00 (reference)
GA	162 (2.3)	1.16 (0.71–1.88)	74 (2.2)	1.18 (0.60–2.32)	88 (2.4)	1.14 (0.55–2.36)
Infectious complication						
RA	82 (1.0)	1.00 (reference)	32 (0.7)	1.00 (reference)	50 (1.3)	1.00 (reference)
GA	73 (1.0)	1.07 (0.50–2.28)	20 (0.6)	0.51 (0.11–2.31)	53 (1.4)	1.18 (0.40–3.46)
Intraoperative complication						
RA	<11 (<0.2)	1.00 (reference)	<11 (<0.2)	1.00 (reference)	0 (0.0)	1.00 (reference)
GA	<11 (<0.2)	¶	0 (0.0)	¶	<11 (<0.3)	¶
Gastrointestinal complication						
RA	<22 (0.3)	1.00 (reference)	<11 (<0.2)	1.00 (reference)	<11 (<0.3)	1.00 (reference)
GA	<27 (0.3)	2.64 (0.82–8.49)	16 (0.5)	¶	<11 (<0.3)	¶
LOS (days)						
RA	3 (3–4)‡	1.00 (reference)	3 (3–4)‡	1.00 (reference)	3 (3–4)‡	1.00 (reference)
GA	3 (3–4)‡	1.04 (0.99–1.10)§	3 (3–4)‡	1.06 (0.99–1.14)§	3 (3–4)‡	1.03 (0.96–1.11)§

Percent may not sum to 100 due to rounding and missing values.
†$p < 0.05$.
‡Median (IQR).
§Adjusted risk ratio.
¶Model unable to be fit due to non convergence.
aOR: Adjusted odds ratio; GA: General anesthesia; IQR: Interquartile range; OSA: Obstructive sleep apnea; RA: Regional anesthesia; TKA: Total knee arthroplasty.

Table 4. Proportion and risk adjusted odds of general anesthesia use (compared with regional anesthesia) for total knee arthroplasty in patients with obstructive sleep apnea diagnosis in NY, USA from 2007 to 2016.

Year	n (%)	aOR (95% CI)
2007	93 (55.4)	1.00 (reference)
2008	109 (47.4)	0.69 (0.46,1.06)
2009	161 (46.9)	0.65 (0.44,0.97)†
2010	286 (49.4)	0.71 (0.50,1.03)
2011	332 (53.0)	0.82 (0.57,1.17)
2012	414 (55.7)	0.90 (0.63,1.29)
2013	375 (49.3)	0.78 (0.55,1.12)
2014	493 (51.1)	0.75 (0.53,1.07)
2015	668 (56.6)	0.90 (0.63,1.27)
2016	734 (58.4)	1.03 (0.73,1.46)

†$p < 0.05$.
aOR: Adjusted odds ratio; OSA: Obstructive sleep apnea.

due to the use of CPAP being coded as a complication in the SID database. This is unfortunate as pulmonary complications have been previously reported to be high in this population [14,29–33]. Second, patients who received both GA and RA for the TKA would be coded simply as GA, which could bias the differences seen between the anesthesia type cohorts. Additionally, all RA techniques are coded as RA and thus there was no way to stratify further by regional technique (neuraxial vs peripheral nerve block vs both) [18,19]. Finally, the use of the SID (as

with any administrative database) requires accurate coding in the electronic medical records from which the data is obtained. As a result, it is possible that there are errors in the coding of OSA diagnoses or other comorbidities that could bias the results of the present study.

Conclusion

In conclusion, in a large population-based cohort, we found an increase in the prevalence of OSA in patients undergoing TKA and an association of OSA diagnosis with 30- and 90-day readmission rates. There were no differences with the use of general versus regional anesthetic on any of the postoperative outcomes studied and no observed changes in the percentage of GA used over the study time period. While there are known benefits of RA that may make it the preferable anesthetic choice for the OSA population, our study suggests that the use of GA may not provide significant disadvantage in terms of major postoperative complications.

Summary points

- Patients with obstructive sleep apnea (OSA) pose perioperative management challenges that can lead to greater resource utilization, longer hospital stays and higher readmission rates.
- In this retrospective observational study, we analyzed administrative records of patients who underwent elective inpatient total knee arthroplasty from 2007 to 2018 using multistate data from the State Inpatient Databases.
- The primary outcomes were 30- and 90-day readmission rates. Secondary outcomes included in-hospital mortality, length of stay and the presence of a cardiovascular, infectious, gastrointestinal or intraoperative complications.
- In our cohort, patients with OSA had increased 30- and 90-day readmission rates, with similar length of stay.
- In our cohort, patients with OSA were not more likely to experience cardiovascular, infectious, gastrointestinal or intraoperative complications, compared with patients without OSA.
- In the NY, USA population, we found no differences with the use of general versus regional anesthetic on any of the outcomes studied.
- While there are known benefits of regional anesthesia that may make it the preferable anesthetic choice for the OSA population, our study suggests that the use of general anesthesia may not provide significant disadvantage in terms of major postoperative complications.

Supplementary data

To view the supplementary data that accompany this paper please visit the journal website at: www.futuremedicine.com/doi/suppl/10.2217/cer-2022-0139

Author contributions

All authors participated sufficiently in the work to take responsibility for the content, based on the conditions listed on the author disclosure form.

Financial & competing interests disclosure

RS White is the recipient of FAER grant ID no. MRTG-08-15-2021-White. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

No writing assistance was utilized in the production of this manuscript.

Ethical conduct of research

All study activities were approved by the Institutional Review Board at Weill Cornell Medical College. STROBE guidelines for the reporting of observational studies were followed.

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