Association between sleep apnea and perioperative outcomes among patients undergoing shoulder arthroscopy

Association entre l'apnée du sommeil et les complications périopératoires chez les patients subissant une arthroscopie de l'épaule

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Abstract

Purpose Sleep apnea is a recognized risk factor for adverse perioperative outcomes in total joint arthroplasty. Nevertheless, little is known about its impact on shoulder arthroscopy, which is a commonly performed ambulatory procedure. Our primary objective was to determine whether sleep apnea was associated with increases in complications and healthcare utilization in this setting.

Methods We analyzed administrative data collected from 583 U.S. hospitals between 2010–2015 and identified a cohort of 128,932 patients who underwent shoulder arthroscopy. Using a cross-sectional study design, we examined the relationship between sleep apnea and perioperative outcomes including mortality, stroke,

myocardial infarction, and pulmonary complications. We also examined a variety of health utilization outcomes.

Results Among patients who underwent shoulder arthroscopy, approximately 6% (7,761 of 128,932) had the diagnosis of sleep apnea. The overall complication rate in these patients was 1.39% (95% confidence interval [CI], 1.33 to 1.45). In a crude analysis, sleep apnea was associated with increases in the majority of systemic complications. In adjusted analyses, sleep apnea was associated with a 4.95 (95% CI, 1.81 to 13.5) times greater odds of acute myocardial infarction and a 4.92 (95% CI, 2.72 to 8.9) times greater odds of pulmonary complications. Sleep apnea was also associated with increased odds of requiring postoperative ventilation, hospital admission, and intensive care unit admission.

Conclusion Sleep apnea is associated with an increased risk of complications and resource utilization in patients undergoing shoulder arthroscopy.

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Résumé

Objectif L'apnée du sommeil est un facteur de risque connu d'événements périopératoires indésirables au cours des arthroplasties. Néanmoins, nous ne savons peu de choses sur son impact chez les patients subissant une arthroscopie de l'épaule qui est une procédure fréquemment pratiquée en ambulatoire. Notre objectif principal était de déterminer si le diagnostic d'apnées du sommeil étaient associées à une augmentation des complications et du recours aux soins de santé dans ce contexte.

Méthodes Nous avons analysé les données administratives provenant de 583 hôpitaux aux États-Unis entre 2010 et 2015 et nous avons identifié une cohorte de

128 932 patients ayant subi une arthroscopie de l'épaule. Nous avons examiné avec un plan d'étude transversale la relation entre l'apnée du sommeil et les événements périopératoires, notamment la mortalité, les AVC, les infarctus du myocarde et les complications pulmonaires. Nous avons également examiné différents critères d'utilisation des ressources de santé.

Résultats Parmi les patients ayant subi une arthroscopie de l'épaule, approximativement 6 % (7 761 sur 128 932) avaient reçu un diagnostic d'apnées du sommeil. Le taux global de complications chez ces patients était de 1,39 % (intervalle de confiance [IC] à 95 % : 1,33 à 1,45). Dans une analyse sommaire, l'apnée du sommeil a été associée à une augmentation de la majorité des complications systémiques. Dans les analyses ajustées, l'apnée du sommeil a été associée à une probabilité d'infarctus aigu du myocarde multipliée par 4,95 (IC à 95 % : 1,81 à 13,5) et de complications pulmonaires multipliée par 4,92 (IC à 95 % : 2,72 à 8,9). L'apnée du sommeil a aussi été associée à une augmentation de la probabilité de ventilation postopératoire, d'hospitalisation, et d'admission en unité de soins critiques.

Conclusion L'apnée du sommeil est associée à une augmentation du risque de complications et d'utilisation des ressources chez les patients subissant une arthroscopie de l'épaule.

Obstructive sleep apnea (OSA) is a recognized risk factor for adverse perioperative outcomes in orthopedic surgery, shown most notably in total joint arthroplasty.¹⁻⁴ Some suggest this, in part, may be due to a worsening of symptoms caused by anesthetic medications that impair arousal, further decrease pharyngeal tone, and diminish ventilatory drive.^{5,6} Additionally, OSA is often associated with coexisting diseases (e.g., hypertension, diabetes, right heart failure) that, if left untreated, can lead to devastating complications, especially in the perioperative setting.⁶ Although the association between OSA and increased morbidity in joint replacement surgery is known, currently there is little information regarding the incidence and impact of OSA on patients undergoing shoulder arthroscopy, a commonly performed ambulatory procedure.

Although 1-4% of the general population is thought to have OSA, there is growing evidence to suggest that the prevalence of this disease state is higher in surgical patients and even as high as 8.7% in patients undergoing total joint arthroplasty.^{1,2,4,7} An increasing percentage of orthopedic surgeries are performed in ambulatory surgery centres.⁸ Whether or not OSA patients are suitable candidates for

operative procedures in this type of setting is controversial given their presumed increased risk of adverse events.^{1-4,9}

The 2006 American Society of Anesthesiology practice guidelines for the perioperative management of OSA patients states that the “literature is insufficient to offer guidance regarding which patients with OSA can be safely managed on an outpatient...basis”.¹⁰ Since then, several validated screening tools have been developed to identify patients with OSA, particularly those that are likely to develop postoperative complications, with the aim of assisting practitioners in making educated decisions about the appropriateness of ambulatory surgery in this population.¹¹ Substantial infrastructure and resources are needed to screen, treat, and provide anesthetic care for various disease burdens. Therefore, efforts to granularly understand risks, both absolute and relative, in different surgical populations are warranted and should help inform policies aimed at optimizing safety and quality.

Shoulder arthroscopy is a very common orthopedic procedure, and in 2006, over 500,000 shoulder arthroscopies were performed in the United States.^{8,12,13} The number of these cases performed as an outpatient procedure has increased as a result of advancements in surgical technique that allow pathology previously repaired by an open incision to be corrected by arthroscopy.^{8,14} Several studies have attempted to identify risk factors for morbidity after shoulder arthroscopy.^{14,15} Nevertheless, to date, there is a paucity of information examining the impact of OSA on perioperative outcomes and resource utilization in these patients. Therefore, we examined the extent to which OSA is associated with decrements in perioperative outcomes using data from a large population-based patient cohort. We also determined whether OSA was associated with increases in healthcare utilization. We hypothesized that OSA would increase both complications and the resources needed to care for patients with this diagnosis.

Methods

In a large sample of patients who underwent shoulder arthroscopy, we examined the relationship between OSA and perioperative outcomes. Data for this study were obtained from Premier Research ServicesTM (Charlotte, NC, USA), which is the largest acute care Health Insurance Portability and Accountability Act (HIPAA)-compliant administrative database, accounting for 20% of inpatient discharges. Premier Health Database provides information from over 700 U.S. hospitals with comprehensive billing, cost, device, medication, and procedure information.¹⁶ Premier Health Database is a validated and leading source

for claims and administrative data that has been used extensively for scientific evaluation.^{1,16,19}

Information used in this study was de-identified and publicly available by purchase; thus, it was deemed exempt from institutional board review by the Dartmouth College Committee for the Protection of Human Subjects (10/16/17 – Study 00030615).

Study population

We identified all patient records from 1 January 2010 to 31 December 2015 that had one or more International Classification of Diseases-9th Revision-Clinical Modification (ICD-9-CM) procedure codes or a current procedural terminology code for shoulder arthroscopy (Appendix 1). From this subset, we identified patient records with at least one ICD-9-CM code for sleep apnea (Appendix 1). These years were chosen because they were the most recently available (at the time of initial analysis).

Perioperative outcomes

Complications

Perioperative complications were identified by using ICD-9-CM diagnosis codes defined as systemic complications including cerebrovascular events, pulmonary compromise, acute myocardial infarction (MI), cardiac complications (non-MI), pneumonia, infection, acute renal failure, gastrointestinal complications, and any other complication. Definitions of “cardiac complications (non-MI)” and “pulmonary compromise” are noted in table format in Appendix 3A/3B. We calculated 30-day all-cause mortality rates captured only for the hospital where the surgery occurred.

Resource utilization

We created several measures of healthcare use. Using ICD-9-CM and billing data, we determined whether or not patients required two life-prolonging procedures: blood transfusions and mechanical ventilation. We identified patients who had a hospital readmission within 30 days and those who required admission to either the hospital or intensive care unit on the day of surgery.

Covariates

We extracted several additional measures to be used as covariates in our statistical analyses. Sociodemographic characteristics included age, sex, and race/ethnicity (non-Hispanic White, non-Hispanic Black, and Hispanic *vs* other), and type of insurance coverage (Medicare,

Medicaid, commercial, and uninsured *vs* other). We also determined the admission type (elective *vs* urgent-emergent). Analyzed health system characteristics included the number of hospital beds (< 299, 300–499, > 500), academic teaching status, and urban *vs* rural location. We identified three distinct anesthesia types based on administrative and billing data consisting of general anesthesia, combined general anesthesia-peripheral nerve block, and peripheral nerve block alone.

For risk adjustment, we used a comorbidity index. Pre-existing medical conditions were identified and the overall comorbidity burden was assessed using the Deyo-Charlson method.^{17,18} The Charlson comorbidity index was designed as a tool to look at medical records to create an overall comorbidity index, but was not designed to use ICD-9 codes. Deyo developed an algorithm based on the Charlson method that used ICD-9 codes to assess the overall comorbidity burden.^{17,18}

Statistical analyses

For our analyses, we examined the relationship between OSA status and each perioperative outcome. We compared sociodemographic characteristics, pre-existing comorbidities, and perioperative outcomes between patients with and without OSA using simple descriptive analyses. We used a Chi-square test to compare proportions and a two-sample *t*-test to compare means for continuous measures.

All perioperative outcomes were dichotomous end points. Complication outcomes included all-cause mortality, cerebrovascular events, pulmonary compromise, cardiac complications, pneumonia, infection, acute renal failure, gastrointestinal complications, and any other complication, whereas healthcare use end points included 30-day hospital readmission, hospital admission, intensive care unit admission, and life-prolonging treatment (blood transfusions and mechanical ventilation). We used generalized linear models with a logit link function to examine the relationship between OSA and perioperative dichotomous end points while adjusting for differences. Coefficients were exponentiated to express associations in the form of odds ratios. Covariates for our models were selected a priori based on our previous work.¹⁹ Final models were adjusted for age, sex, race/ethnicity, comorbidity, healthcare insurance, admission type, hospital size, hospital location, and hospital teaching status. Patients were clustered within hospital; therefore, standard errors for all statistical models were based on robust estimation clustered on hospital. To correct for multiple hypothesis testing across the various perioperative

outcomes, *P* values from our statistical models were corrected for the false discovery rate.²⁰

To determine if anesthesia type affected our results in any meaningful way, we performed a sensitivity analysis (Appendix 2). For the sensitivity analysis, we compared results with and without including anesthesia type (general anesthesia [GA], GA plus block, block only, and missing anesthesia type) in our adjustment model. All analyses were conducted using STATA version 12.1 (StataCorp, College St, TX, USA).

Results

We identified 128,932 patients that underwent shoulder arthroscopy at 583 hospitals between 1 January 2010 and 31 December 2015 in the Premier Healthcare Database. Among these, approximately 6% (7,761 of 128,932) of patients had the diagnosis of sleep apnea. Of the 113,130 patients with complete data on anesthesia type, 73.2% (82,811) received general anesthesia alone, 11.5% (13,009) had general anesthesia with a peripheral nerve block, and 3.1% (3,507) received a block alone (Table 1). Continuous regional anesthesia techniques were used in 0.9% (1,018) of patients.

Most of the surgeries were performed in urban hospitals; in both groups, the majority of procedures were performed under general anesthesia in non-teaching hospitals with < 300 beds (Table 1).

Characteristics of patients with sleep apnea

Patients with OSA were more likely to be of older age, white (non-Hispanic), and male (Table 1). The pre-existing comorbidity data are shown in Table 2 and reveal a higher comorbid burden in patients with OSA, especially regarding uncomplicated diabetes and chronic obstructive pulmonary disease. Table 3 reveals the crude rates of systemic complications overall and by OSA status. The overall complication rate for any complication was 1.39% (95% CI, 1.33 to 1.45); 30-day mortality was 1.2 per 10,000 (95% CI, 0.7 to 2.0). Of the systemic complications, the most commonly observed was cardiac (non-MI), which occurred in 1.15% (1,487 of 128,932) of all patients and included conditions such as atrial fibrillation. An increase in complication rates was identified for the OSA group across all categories with the exception of stroke and gastrointestinal complications. Table 3 also highlights the increased resource utilization by OSA patients including rates of hospital admission. Although the need for postoperative intensive care unit (ICU) care was rare in this ambulatory surgical population, an inpatient admission occurred in 1.16% (1,502 of 128,932) of patients.

Association between sleep apnea and perioperative outcomes

Adjusting for sociodemographic characteristics, comorbidities, and hospital differences, OSA was associated with a 2.23 (95% CI, 1.90 to 2.59) times greater odds of experiencing any complication (Figure). Table 4 and the Figure demonstrate that OSA was also associated with a 4.92 (95% CI, 2.72 to 8.9) times greater odds of experiencing pulmonary complications. In terms of resource utilization, OSA was associated with substantially greater odds of receiving blood transfusions, ICU transfers, and the need for a hospital admission (Figure).

Sensitivity analysis

We repeated all analyses by including anesthesia type (general anesthesia, general anesthesia and block, block only, and missing) in our main adjustment model with no appreciable differences in the relationship between OSA and the various outcome variables (Appendix 2).

Discussion

We found a strong association between the presence of sleep apnea and poorer outcomes as well as increases in resource utilization following shoulder arthroscopy in the United States. This negative quality relationship appears independent from anesthesia technique.

Changes in healthcare are driving physicians and policy leaders to re-evaluate the implications of patient outcomes and periprocedural costs when assessing patients for surgical appropriateness. Complications following routine ambulatory surgery can have large negative financial and patient satisfaction implications.^{21,22} Our research is the first attempt to utilize a large-scale population-based data registry to demonstrate a difference in perioperative outcomes in patients with a diagnosis of OSA who underwent shoulder arthroscopy.

At face value, our findings are not unexpected given the higher comorbidity burden noted in the cohort of OSA patients compared with those without the diagnosis. This is consistent with previous studies that linked an increasing Charlson Comorbidity Index score with a higher risk of complications after shoulder arthroplasty.²³ Some speculate that the higher comorbidity burden carried by patients with OSA may overstate the effect of sleep apnea on adverse outcomes. Although these disease states may exist separately but concomitantly (i.e., OSA and heart disease), untreated OSA may also be the direct cause of these associated comorbidities (i.e., OSA and right heart failure), and these relationships should not be dismissed.

Table 1 Patient and healthcare system-related characteristics by sleep apnea status

Characteristic	Overall <i>n</i> = 128,932	No sleep apnea <i>n</i> = 121,171	Sleep apnea <i>n</i> = 7,761	<i>P</i> value [†]
Age in yr, mean (SD)	48.7 (15.9)	48.2 (16.1)	55.8 (11.1)	< 0.001
Female sex, %	39.4	39.7	32.3	< 0.001
Race/ethnicity, %				< 0.001
Non-Hispanic White	77.5	77.4	79.1	
Non-Hispanic Black	7.6	7.5	8.7	
Hispanic	0.7	0.71	0.26	
Other	14.2	14.4	11.9	
Missing	0.05	0.06	0.0	
Admission type, %				< 0.001
Urgent/emergent	1.9	1.9	1.93	
Elective	76.9	76.8	80.1	
Missing	21.1	21.3	18.0	
Health insurance, %				< 0.001
Commercial	19.3	18.5	31.3	
Medicaid	6.5	6.5	5.2	
Medicare	67.6	68.4	57.3	
Uninsured	1.3	1.3	0.6	
Other	6.8	5.2	5.6	
Hospital beds, %				< 0.001
≤ 299	48.0	48.1	46.2	
300-499	31.5	31.2	36.6	
≥ 500	20.5	20.8	17.2	
Hospital location, %				0.02
Urban	87.0	86.9	87.9	
Rural	13.0	13.1	12.1	
Teaching hospital, %				0.02
No	62.8	62.7	64.0	
Yes	37.2	37.3	36.0	
Anesthesia type				< 0.001
General	73.2	73.0	75.8	
General and block	11.5	11.5	11.0	
Block only	3.1	3.1	2.3	
Missing	12.3	12.4	10.9	
Deyo Index Ω	0.17 (0.6)	0.16 (0.6)	0.46 (1.0)	< 0.001

[†] *P* value compares sleep apnea and no sleep apnea groups. Chi-square test used to compare proportions; *t*-test used to compare continuous variables

Ω The index is a weighted score reflecting the comorbidity burden of a patient

SD = standard deviation

Although the overall risk of cerebrovascular accident (one per 10,000) is low in this ambulatory population, this is the first large series to quantify this risk—a complication that is particularly worrisome in patients who are placed in the beach-chair position for surgery.

A strength of using a large administrative database is the ability to capture rare, infrequent complications that can only be identified after analyzing a considerable number of patients. Despite these advantages, there are inherent limitations in using administrative health data for

Table 2 Pre-existing health conditions by sleep apnea status

	<i>n</i> (%)			<i>P</i> value [†]
	Overall (<i>n</i> = 128,932)	No sleep apnea (<i>n</i> = 121,171)	Sleep apnea (<i>n</i> = 7,761)	
Myocardial infarction	2,145 (1.7)	1,805 (1.5)	340 (4.4)	< 0.001
Peripheral vascular disease	655 (0.51)	545 (0.45)	110 (1.42)	< 0.001
Cerebrovascular disease	421 (0.33)	354 (0.29)	67 (0.86)	0.10
COPD	13,263 (10.3)	11,543 (9.5)	1,722 (22.2)	< 0.001
Dementia	15 (0.01)	13 (0.01)	2 (0.03)	0.23
Rheumatic disease	1,314 (1.2)	3,018 (1.1)	208 (2.7)	< 0.001
Mild liver disease	14 (0.11)	115 (0.09)	25 (0.32)	< 0.001
Severe liver disease	14 (0.01)	10 (0.01)	4 (0.05)	< 0.001
Uncomplicated diabetes	15,527 (12.0)	13,156 (10.9)	2,371 (30.6)	< 0.001
Complicated diabetes	469 (0.36)	351 (0.29)	118 (1.52)	< 0.001
Renal disease	936 (0.73)	746 (0.62)	190 (2.5)	< 0.001
AIDS	35 (0.03)	33 (0.03)	2 (0.03)	0.94
Paraplegia	61 (0.05)	52 (0.04)	9 (0.12)	0.004
Cancer	324 (0.25)	289 (0.24)	35 (0.45)	< 0.001

[†] *P* value compares sleep apnea and non-sleep apnea categories. Chi-square test used to compare proportions

AIDS = acquired immune deficiency syndrome; COPD = chronic obstructive pulmonary disease

Table 3 Perioperative outcomes by sleep apnea status

	<i>n</i> (%) or mean (SD)			<i>P</i> value [†]
	Overall	No sleep apnea	Sleep apnea	
<i>Complications</i>				
Cerebrovascular event	7 (0.01)	4 (0.00)	3 (0.04)	< 0.001
Pulmonary compromise	78 (0.06)	53 (0.04)	25 (0.32)	< 0.001
Cardiac (non-infarction)	1,487 (1.15)	1,221 (1.01)	266 (3.43)	< 0.001
Pneumonia	77 (0.06)	61 (0.05)	16 (0.21)	< 0.001
Infections	185 (0.14)	164 (0.14)	21 (0.27)	< 0.001
Acute renal failure	46 (0.04)	34 (0.03)	12 (0.15)	< 0.001
Gastrointestinal complication	21 (0.02)	20 (0.02)	5 (0.06)	0.81
Acute myocardial infarction	18 (0.01)	13 (0.01)	18 (0.15)	< 0.001
Any complication	1,797 (1.39)	1,483 (1.22)	214 (4.10)	< 0.001
<i>Resource utilization</i>				
Mechanical ventilation	89 (0.07)	62 (0.05)	27 (0.35)	< 0.001
Blood product transfusion	115 (0.09)	103 (0.09)	12 (0.15)	0.05
ICU admission	71 (0.06)	50 (0.04)	21 (0.27)	< 0.001
Hospital admission ^{††}	1,502 (1.16)	1,258 (1.04)	244 (3.14)	< 0.001
Readmission Ω (30-day)	149 (0.20)	106 (0.20)	16 (0.21)	0.92
<i>Mortality Ω</i>				
30-Day mortality	16 (0.01)	15 (0.01)	1 (0.01)	0.97

[†] *P* value compares sleep apnea vs no sleep apnea groups, Chi-square test used to compare proportions; two-sample *t*-test used to compare means

^{††} Admitted the day of surgery

Ω Refers to hospital in which the surgery was performed only

Figure Forest plot illustrating odds ratios for the association between sleep apnea and perioperative outcomes. The horizontal bar illustrates the confidence interval. Values are adjusted for age, sex, race, comorbidities, admission type, hospital bed size, hospital location, and teaching status. Standard errors based on robust estimation clustered on hospital. *P* values adjusted multiple hypotheses by correcting for false discovery rate. †Refers to Premier affiliated hospitals only; prolonged length of stay defined as four days or more. †† Defined as one night or longer length of stay. CI = confidence interval

Table 4 Odds ratios for the association between sleep apnea and perioperative outcomes

	Odds ratio (95% CI)	<i>P</i> value*
<i>Systemic complications</i>		
Cerebrovascular event	7.70 (1.09 to 54.32)	0.071
Pulmonary compromise	4.92 (2.72 to 8.94)	< 0.001
Cardiac complications (non-infarction)	2.25 (1.91 to 2.66)	< 0.001
Acute myocardial infarction	4.95 (1.81 to 13.52)	0.005
Pneumonia	2.99 (1.67 to 5.39)	< 0.001
All infections	1.53 (0.94 to 2.49)	0.14
Acute renal failure	2.90 (1.43 to 5.93)	0.006
Gastrointestinal complication	0.76 (0.09 to 6.42)	0.98
<i>Resource utilization</i>		
Mechanical ventilation	5.93 (3.40 to 10.34)	< 0.001
Blood transfusion (any)	0.99 (0.44 to 2.21)	0.98
Readmission† (30 day)	1.05 (0.55 to 2.00)	0.98
Hospital admission ≈	2.15 (1.68 to 2.78)	< 0.001
Intensive care unit stay	4.66 (2.59 to 8.40)	< 0.001
Mortality† (30-day)	0.93 (0.09 to 9.36)	0.98

Adjusted for age, sex, race, comorbidities, admission type, hospital bed size, hospital location, and teaching status; standard errors based on robust estimation clustered on hospital

† Refers to Premier affiliated hospitals only; prolonged length of stay defined as ≥ 4 days

**P* value compares sleep apnea vs no sleep apnea groups; adjusted for multiple hypotheses by correcting for false discovery rate

≈ Defined as one day or longer length of stay

CI = confidence interval

research including the reliance on subjective diagnosis and treatment coding and the general lack of objective health measures (e.g., body mass index). Because this study is observational in nature, it is also subject to unmeasured factors and confounding. Nevertheless, we think our robust

adjustment model, the magnitude of the effect sizes, and the use of the validated Charlson-Deyo comorbidity score increase the confidence in our findings. Although a recent study by McIsaac merits caution in using diagnostic coding for OSA status because of the distinct limitations of

administrative data in identifying patients with OSA in terms of the sensitivity and specificity, these conclusions were limited by a small sample size at a single academic health institution and may lack generalizability compared with Premier.²⁴ Alternative research has suggested that the specificity of using administrative data to code for sleep apnea is much higher than the sensitivity.²⁵ This would mean that there is the potential for more of those with OSA to be placed in the control group (false negatives). Such an error would attenuate our measured effect size, making our results an underestimate of the risk of OSA. Additionally, our finding that OSA was associated with more disease burden provides additional biologic evidence the coding is appropriate.

Additionally, ICD-9 coding does not account for severity of disease or treatment status—both factors that can have an impact on outcomes. From a clinical perspective, understanding their effects independently would be useful to help determine which patients are suitable for ambulatory surgery. This also assumes that those treated for OSA are actually compliant with treatment, and this is difficult to discern retrospectively.

As a final limitation, our 30-day readmission and mortality rates capture only those patients who received treatment at the institution where their initial procedure was performed and do not take into account the potential for those in our cohort to have been treated at other facilities.

Because the anesthesia technique has previously been demonstrated to impact perioperative outcomes following total shoulder arthroplasty, we conducted a secondary sensitivity analysis by including anesthesia type in our adjustment model (Appendix 2).^{19,26} We were reassured to see that the relationship between OSA and our various outcomes was not substantially changed.

Despite these inherent limitations, our large sample size across numerous different types of hospitals should make the outcomes applicable to a large audience compared with a single-institution study.

We hope our findings assist physicians and policy leaders in their continuous quality improvement activities. On a population health level, OSA for shoulder arthroscopy is associated with worse perioperative outcomes and increases in resource utilization. Future prospective studies are warranted to examine whether specific interventions can reverse these negative relationships.

Conflicts of interest The authors declare no competing interests.

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Appendix 1 ICD-9-CM codes and CPT codes to identify cohort

Identify cohort	ICD-9-CM codes/CPT codes
Shoulder arthroscopy	80.21 (CPT code) 29805, 29806, 29807, 29819, 29820, 29821, 29822, 29823, 29824, 29825, 29826, 29827, 29828
Sleep apnea	786.03, 780.51, 780.53, 780.57, 327.20, 327.21, 327.23, 327.27, 327.29

CPT = current procedural terminology; ICD-9-CM = International Classification of Diseases-9th Revision-Clinical Modification

Appendix 2 Odds ratios for the association between sleep apnea and perioperative complications adjusted^Ω for anesthesia type

	Odds ratio (95% CI)	P value*
<i>Systemic complications</i>		
Cerebrovascular event	6.95 (1.00 to 48.16)	0.09
Pulmonary compromise	4.79 (2.71 to 8.50)	< 0.001
Cardiac complications (non-infarction)	2.24 (1.89 to 2.65)	< 0.001
Acute myocardial infarction	4.97 (1.84, 13.48)	0.005
Pneumonia	3.02 (1.69 to 5.43)	< 0.001
All infections	1.50 (0.92 to 2.44)	0.14
Acute renal failure	2.88 (1.42 to 5.85)	0.006
Gastrointestinal complication	0.76 (0.09 to 6.33)	0.94
<i>Resource utilization</i>		
Mechanical ventilation	5.69 (3.25 to 9.95)	< 0.001
Blood transfusion (any)	0.95 (0.42 to 2.17)	0.94
Readmission [†] (30 day)	1.06 (0.56 to 2.01)	0.94
Hospital admission [≈]	2.06 (1.68 to 2.54)	< 0.001
Intensive care unit stay	4.53 (2.56 to 8.02)	< 0.001
Mortality [†] (30 day)	0.91 (0.08 to 9.35)	0.94

^Ω Adjusted for age, sex, race, comorbidities, admission type, hospital bed size, hospital location, teaching status, anesthesia type (general, general and block, block only, and missing anesthesia type); standard errors based on robust estimation clustered on hospital

^{††} Refers to Premier affiliated hospitals only; prolonged length of stay defined as 4 days or more

* *P* value compares sleep apnea vs no sleep apnea groups, adjusted for multiple hypotheses by correcting for false discovery rate

[≈] Defined as one day or longer length of stay

CI = confidence interval

Appendix 3A Most common ICD-9 codes used for pulmonary compromise outcome

ICD-9 Code	Description	Percent %
514	CONGESTION/HYPOSTASIS, PULMONARY	11.24
518.4	EDEMA, ACUTE LUNG NOS	17.98
518.5	INSFCY, PULMONARY, PSTTRAUM/ SURG	19.10
518.81	FAILURE, ACUTE RESPIRATORY	44.94
518.82	INSUFFICIENCY, PULMONARY NEC	6.74

Appendix 3B Most common ICD-9 codes used for cardiac (non-myocardial infarction) outcome

ICD-9 Code	Description	Percent %
426.0	BLOCK, AV, COMPLETE	0.65
427.31	FIBRILLATION, ATRIAL	92.10
427.32	FLUTTER, ATRIAL	4.05
427.41	FIBRILLATION, VENTRICULAR	0.26
427.42	FLUTTER, VENTRICULAR	0.13
997.1	COMPLICATIONS, CARDIAC	2.81

ICD-9 = International Classification of Diseases-9th Revision-Clinical Modification

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