



# Perioperative complications in patients with sleep apnea following primary total shoulder arthroplasty: An analysis of 33,366 patients

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## ABSTRACT

**Introduction:** The study evaluated whether sleep apnea (SA) patients undergoing total shoulder arthroplasty (TSA) are at greater odds of: 1) medical complications; 2) implant-related complications; 3) readmission rates; and 4) costs.

**Methods:** Complications and readmissions were assessed using logistic regression analysis. Welch's *t*-test was used to compare CCI and cost between cohorts.

**Results:** 33,366 patients equally distributed in both cohorts. SA increased the odds of medical [Odds-ratio (OR)]: 2.52,  $p < 0.001$ ) and implant-related complications (OR: 1.43,  $p < 0.001$ ). Readmission rates were similar to controls (OR: 0.99,  $p = 0.878$ ), whereas costs were higher ( $p < 0.001$ ).

**Conclusion:** SA increases complications and costs following TSA.

## 1. Introduction

It is well known that patients with SA are more susceptible to medical-related complications compared to patients without SA.<sup>1–3</sup> Several studies have reported the impact of SA leading to cardiopulmonary complications, neurocognitive effects, depressed quality of life, increased risk of motor vehicle accidents, headaches, and other complications. In addition to medical complications, patients with SA have been shown to have worse outcomes following orthopedic surgery. Recent epidemiologic studies have shown the prevalence of SA to have increased nearly 15-fold in the past 17-years from 420,000 patients to 6.37 million patients, with risk factors for SA being: obesity, BMI greater than 30 kg/m<sup>2</sup>, large adenoids, smoking, female sex, in addition to others.<sup>4–6</sup>

SA has been shown to be an independent risk factor increasing the risk of infections, revision procedures, and ultimately the cost of care in patients following spine and total joint arthroplasty, however the literature on the impact of SA following TSA is limited.<sup>7–9</sup> Griffin et al. analyzed the impact of SA following TSA and hemiarthroplasty, but a limitation to their study was not differentiating the outcomes between the two procedures.<sup>10</sup> With the rising incidence and prevalence of patients undergoing TSA and SA, respectively, there is a paucity in the

literature evaluating the impact of following primary TSA within the Medicare population.

Therefore, the purpose of this study was to determine whether SA increases the odds of: 1) 90-day medical complications; 2) 2-year implant related complications; 3) 90-day readmission rates; and 4) total 90-day episode of care costs compared to patients without SA, by analyzing an administrative database.

## 2. Materials and methods

### 2.1. Database

Data for the study was ascertained from the PearlDiver (PearlDiver Technologies, Fort Wayne, Indiana) patient records database. PearlDiver is a commercially available database containing the records of over 100 million patients from various insurance databases, which has been utilized extensively for orthopedic-related research.<sup>11–13</sup> For the present study, records from the Medicare Standard Analytical Files from 2005 to 2014, were queried. Since the records are deidentified, the study was exempt from our institution's International Review Board (IRB) approval.

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**Table 1**

Patient demographics of age, gender, body mass index (BMI), and charlson-comorbidity index (CCI) of Patients with and without sleep apnea undergoing primary total shoulder arthroplasty within the medicare database. CCI = charlson-comorbidity index.

Demographics	Size (%)
<b>AGE</b>	
< 64	2947 (17.66)
65-69	6160 (36.92)
70-74	4104 (24.60)
75-79	2351 (14.09)
80-84	799 (4.79)
85 <	136 (0.82)
Unknown	186 (1.11)
<b>GENDER</b>	
Female	8347 (50.03)
Male	8150 (48.85)
Unknown	186 (1.11)
<b>BMI</b>	
< 25 kg/m <sup>2</sup>	302 (1.81)
25–30 kg/m <sup>2</sup>	867 (5.19)
30–39 kg/m <sup>2</sup>	8841 (52.99)
40–70 kg/m <sup>2</sup>	6674 (40.01)
CCI	4 ± 3

**2.2. Study group**

Patients who underwent primary TSA were identified using International Classification of Disease, ninth revision (ICD-9) procedural code 81.80. Using Boolean command operations, the inclusion criteria for the study group consisted of patients undergoing primary TSA with a 90-day history of SA prior to the index procedure. Patients with a diagnosis of SA were queried using ICD-9 diagnosis codes 327.20 to 327.29 and 780.57. No exclusion criteria were used. Patients without a history of SA undergoing primary TSA served as controls. Patients in the study group and control group were randomly matched in a one-to-one method according to age, gender, BMI and CCI. CCI was used as a marker to ensure that both cohorts were properly matched and no statistical difference existed between the cohorts, as used in previous studies.<sup>11–13</sup> After the matching process, two mutually exclusive cohorts were formed.

This yielded 33,366 patients equally distributed in the study and control groups. CCI for both cohorts was 4 ± 3 with a *p*-value of 1.00 indicating the two cohorts were properly matched (Table 1). The incidence of patients with SA undergoing TSA increased across the study period (*R*<sup>2</sup> = 0.66; *p* = 0.03) with 2615 patients with SA undergoing primary TSA in 2005 compared to 3200 patients in 2014.

**2.3. Outcomes assessed**

Ninety-day medical, 2-year implant related complications, 90-day readmission rates, and total global 90-day episode of care costs were analyzed and compared between both cohorts. Medical and implant related complications assessed included: acute kidney failure (AKF) (ICD-9: 584.9), acute post-hemorrhagic anemia (APA) (ICD-9: 285.1), acute pancreatitis (ICD-9: 577.0), cerebrovascular accidents (CVA) (ICD-9: 434.90 to 434.91), continuous mechanical ventilation > 96 h (ICD-9: 967.2), deep vein thrombosis (DVT) (ICD-9: 453.4), dyspnea (ICD-9: 786.05), myocardial infarction (MI) (ICD-9: 410), paralytic ileus (ICD-9: 560.1), pneumonia (ICD-9: 480–486), pulmonary embolism (PE) (ICD-9: 415.1), seroma (ICD-9: 786.05), transfusions (ICD-9: 99. X), and urinary tract infections (UTI) (ICD-9: 599.0).

Two-year implant related complications analyzed and compared included: articular bearing surface wear (ICD-9: 996.46), broken prosthetic joint implant (ICD-9: 996.44), dislocation of prosthetic joint (ICD-9: 996.42), mechanical loosening of prosthetic joint (ICD-9:

996.41), periprosthetic fractures (ICD-9: 996.44), periprosthetic osteolysis (ICD-9: 996.45), and prosthetic joint infection (PJI) (ICD-9: 996.66).

Reimbursements were used as a marker for costs as they are a more accurate representation as to what providers are paid by the insurance companies.<sup>14,15</sup> Ninety days was chosen as to be compliant with the bundled payment care initiative (BPCI) put forth by the Center for Medicare and Medicaid Services.<sup>14,15</sup>

**2.4. Data analysis**

Statistical analysis was performed using the programming language R (<http://www.r-project.org/> R, University of Auckland, New Zealand). Logistic-regression analysis was used to calculate odds-ratios (OR) along with their respective 95% confidence intervals (95%CI) and *p*-values. Welch's *t*-test was used to test for significance in CCI and cost between the cohorts. Due to the number of medical and implant related comparisons made in the study, a Bonferroni-adjusted correction was performed to minimize the probably of a type I error. As a result, an alpha value less than 0.002 was considered statistically significant for medical and implant related complications. This value was attained by dividing 0.05 by the total number (*n* = 21) of medical and implant related complications compared within the study.

**3. Results**

**3.1. 90-Day complications**

Patients with SA undergoing TSA had greater incidence and odds of medical related complications (25.97% vs 12.27; OR: 2.52, 95%CI: 2.38–2.67, *p* < 0.001) compared to controls. Patients with SA were at greater odds of developing medical complications such as paralytic ileus (OR: 2.75, 95%CI: 1.78–4.25, *p* < 0.001), dyspnea (OR: 2.74, 95%CI: 2.40–3.13, *p* < 0.001), APA (OR: 2.65, 95%CI: 2.24–3.12, *p* < 0.001), PE (OR: 2.53, 95%CI: 1.95–3.29, *p* < 0.001), thrombocytopenia (OR: 2.26, 95%CI: 1.66–3.08, *p* < 0.001), DVT (OR: 2.02, 95%CI: 1.56–2.62, *p* < 0.001) in addition to other complications compared to patients without SA following primary TSA (Table 2).

**3.2. 2-Year implant related complications**

Sleep apnea patients were found to have greater incidence and odds

**Table 2**

Comparison of 90-Day Medical Complications Amongst Patients With and Without Sleep Apnea Undergoing Primary Total Shoulder Arthroplasty Within the Medicare Population. 95%CI = 95% Confidence Interval; APA = Acute Posthemorrhagic Anemia; PE = Pulmonary Embolism; DVT = Deep Vein Thrombosis; AKF = Acute Kidney Failure; CIMV = Continuous Invasive Mechanical Ventilation; UTI = Urinary Tract Infection; MI = Myocardial Infarction CVA = Cerebrovascular Accident; § = *p* < 0.001.

Complication	Sleep Apnea (%)	Control (%)	Odds-Ratio	95%CI	<i>p</i> -value
Paralytic Ileus	.461	.168	2.75	1.78–4.25	§
Dyspnea	4.93	1.82	2.74	2.40–3.13	§
APA	3.17	1.20	2.65	2.24–3.12	§
PE	1.20	.473	2.53	1.95–3.29	§
Thrombocytopenia	.797	.353	2.26	1.66–3.08	§
DVT	1.04	.515	2.02	1.56–2.62	§
AKF	2.27	1.14	2.01	1.69–2.39	§
CIMV < 96 h	.347	.174	2.00	1.28–3.13	0.002
UTI	6.19	3.28	1.94	1.75–2.16	§
Transfusions	2.23	1.25	1.80	1.51–2.13	§
Pneumonia	2.41	1.35	1.79	1.52–2.11	§
MI	.467	.269	1.78	1.23–2.56	0.002
CVA	.485	.287	1.69	1.18–2.41	0.004
Total	25.97	12.27	2.52	2.38–2.67	< 0.001

**Table 3**

Comparison of 2-Year Short Term Implant Related Complications Amongst Patients with and Without Sleep Apnea Undergoing Primary Total Shoulder Arthroplasty Within the Medicare Population. SA = Sleep Apnea; 95%CI = 95% Confidence Interval; § =  $p < 0.001$ .

Complication	SA (%)	Control (%)	Odds-Ratio	95%CI	p-value
Periprosthetic Osteolysis	.323	.113	2.84	1.68–4.80	§
Articular Bearing Surface Wear	.425	.233	1.82	1.23–2.69	0.003
Mechanical Loosening	2.19	1.46	1.51	1.28–1.78	§
Broken Prosthetic Joint	.881	.647	1.36	1.06–1.75	0.014
Periprosthetic Fracture	.611	.449	1.36	1.01–1.83	0.042
Prosthetic Joint Infection	2.48	1.87	1.33	1.15–1.54	§
Dislocation of Prosthetic Joint	2.82	2.21	1.28	1.11–1.47	§
Total	9.73	6.98	1.43	1.33–1.55	< 0.001

of implant-related complications (9.73% vs 6.98%; OR: 1.43, 95%CI: 1.33–1.55,  $p < 0.001$ ) compared to controls. Implant related complications which were higher in patients with SA included periprosthetic osteolysis (OR: 2.84, 95%CI: 1.68–4.80,  $p < 0.001$ ), articular bearing surface wear (OR: 1.82, 95%CI: 1.23–2.69,  $p = 0.003$ ), mechanical loosening (OR: 1.51, 95%CI: 1.28–1.78,  $p < 0.001$ ), broken prosthetic joint (OR: 1.36, 95%CI: 1.06–1.75,  $p = 0.014$ ) in addition to other implant-related complications (Table 3).

### 3.3. 90-Day readmission rates and episode-of-care reimbursements

Patients with SA undergoing primary TSA had similar 90-day readmission rates compared to controls (OR: 0.99, 95%CI: 0.91–1.08,  $p = 0.878$ ). The most common causes for readmission in SA patients included transfusion of packed cells (1.10%), venous catheterization (0.68%), other total shoulder replacement (0.59%), revision of joint replacement of upper extremity (0.49%), and non-invasive mechanical ventilation (0.37%). 90-day total episode-of-care reimbursements were significantly higher in patients with SA undergoing primary TSA (\$14,325.13 vs \$13,604.41,  $p < 0.001$ ).

## 4. Discussion

As the demand for TSA increases due to its increasing popularity, positive outcomes, and cost-effectiveness; identifying modifiable risk factors is of great importance.<sup>16,17</sup> The objective of this study was to compare postoperative complications in patients with and without SA undergoing primary TSA within the Medicare population, by utilizing an administrative database. The results of the study demonstrate that SA is an independent risk factor for 90-day medical complications, 2-year implant-related complications, and increasing the episode-of-care costs amongst patients undergoing primary TSA, while 90-day readmission rates were similar to that of the general population.

While the study has its advantages of being adequately powered, there are limitations to the study, which are mostly inherent through the use of using an administrative database. The study was dependent on the use of ICD-9 coding to assess outcomes, which were not intended to be used for research purposes.<sup>18</sup> Additionally, the study was reliant on accurate coding and it is currently estimated there are approximately 1.3% of coding errors within the Medicare database.<sup>19</sup> Furthermore, the authors of the study only analyzed a single insurer's database, and may not be a true cross-sectional representation of the impact of SA on TSA.<sup>20</sup> In addition, the database did not provide information regarding the severity of SA as depicted by the apnea-hypopnea index (AHI) scores, which could serve as the basis of future prospective studies on determining medical and implant-related complications of SA patients undergoing TSA.<sup>21</sup> Despite these limitations, the study is the first to evaluate the impact of SA, of this sample size, in patients undergoing primary TSA.

The results of the study are consistent with the findings in the literature.<sup>22–24</sup> Previous studies have demonstrated SA to meet the requirements of Virchow's triad (i.e. venous stasis, endothelial

dysfunction, and hypercoagulability) by interfering with vascular hemodynamics and leading to a reduction in venous return and causing venous stasis.<sup>25</sup> Hypoxia is a cardinal feature for SA and the cyclical patterns of hypoxia and re-oxygenation have led to endothelial dysfunction.<sup>26</sup> In a prospective study of 54 male patients (36 with SA; 18 controls), Shamsuzzaman et al. compared fibrinogen levels in SA patients to controls with varying AHI levels and found statistically increased levels of fibrinogen levels when comparing mild ( $p = 0.02$ ) and severe SA ( $p = 0.003$ ) to controls.<sup>22</sup> These hemodynamic changes could potentially explain the increased frequency of thromboembolic complications in SA patients undergoing primary TSA. In addition to thromboembolic complications, the results of the study demonstrate that patients with SA were found to have greater odds of cardiopulmonary complications such as myocardial infarction (MI) and pneumonia.

In a prospective study of 782 patients Ludka et al. evaluated the prevalence of SA in patients following MI and found 65.7% of patients with an acute-MI.<sup>23</sup> In a population based study of 34,000 patients from January 1, 2000 to December 31, 2010, Su et al. found after multivariate adjustment that patients with SA had a 1.20-fold increase in the incidence of MI compared to control patients.<sup>24</sup> Increased aspiration risk and impaired immunity have been implicated as reasons for increased risk of developing pneumonia in patients with SA.<sup>24</sup> Studies have shown that patients with SA have impaired sensation of the upper airway and exhibit impaired swallowing reflex which may lead to aspiration of pathogen-containing pharyngeal secretions, saliva, or oral contents into the respiratory tract.<sup>27</sup> Furthermore, SA may involve hypercapnia, which has been linked to impaired neutrophil function, making patients further susceptible to developing pneumonia.<sup>27</sup> These changes could help explain the increased frequency of cardiopulmonary complications noted in patients with SA.

Patients with SA following primary TSA were also found to incur greater total episode-of-care costs compared to controls. The increased frequency of medical and implanted related complications associated with SA could be the main driver for the increased cost of care in these patients. Patients in the study were found to have greater odds of thromboembolic complications, requiring blood transfusions, pneumonia, and prosthetic joint infection. Studies have demonstrated the economic burden of these complications can range from \$7552 - \$16,132.68, per episode of care.<sup>28–30</sup> It is for this reason the American Academy of Sleep Medicine (AASM) advocates towards the use of CPAP, which has been shown to minimize complications observed within the study, mortality, and ultimately drive down the cost of care in patients.<sup>31–33</sup>

In a multi-center randomized clinical trial study of 224 elderly patients greater than the age of > 70 years old, Martínez-García et al. studied the effects of CPAP use in patients with SA (CPAP = 115 patients; no CPAP = 109 patients). The study found that three months of continuous CPAP utilization resulted in greater improvement in all quality-of life domains ( $p < 0.001$ ), sleep-related symptoms ( $p < 0.001$ ), anxiety ( $p = 0.016$ ), depression ( $p < 0.001$ ), and cognition ( $p = 0.047$ ) compared to controls.<sup>33</sup> (26022945) In a similar multi-

center randomized clinical trial study, Campos-Rodriguez et al. evaluated the effects of three months of continuous CPAP use in 307 women (CPAP = 151 patients; no CPAP = 156 patients) with SA, and found women utilizing CPAP use had less daytime sleepiness ( $p < 0.001$ ), improved mood state ( $p = 0.012$ ), reduced anxiety ( $p = 0.014$ ), and reduced depression ( $p = 0.016$ ) compared to controls.<sup>34</sup>

## 5. Conclusion

The study demonstrates the increasing prevalence of patients with SA undergoing total shoulder arthroplasty and the potential risks these patients may develop following the procedures. Adequate preoperative optimization may potentially mitigate many of these postoperative complications. Appropriate postoperative awareness may also benefit the patient such as minimizing the use of narcotics, positioning the patient upright, continuous use of oxygen and pulse oximetry. Most importantly, Orthopedic surgeons should counsel patients on continuous use of their CPAP machine which has been shown to prevent many of the complications found in the study.

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This research did not receive any grant funding.

## Ethical review committee statement

The study was exempt from our institution's International Review Board (IRB) approval.

## Conflicts of interest outside submitted work

None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jor.2019.04.003>.

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