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The Impact of Obstructive Sleep Apnea on Clinical, Perioperative, and Cost Outcomes in Patients Who Underwent Posterior Cervical Decompression and Fusion: A Single-Center Retrospective Analysis From 2008 to 2016

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ABSTRACT

Background: Obstructive sleep apnea (OSA) is a pervasive problem that can result in diminished neurocognitive performance, increased risk of all-cause mortality, and significant cardiovascular disease. While previous studies have examined risk factors that influence outcomes following cervical fusion procedures, to our knowledge, no study has examined the cost or outcome profiles for posterior cervical decompression and fusion (PCDF) procedures in patients with OSA.

Methods: All cases at a single institution between 2008 and 2016 involving a PCDF were included. The primary outcome was prolonged extubation, defined as an extubation that took place outside of the operating room. Secondary outcomes included admission to the intensive care unit (ICU), complications, extended hospitalization, nonhome discharge, readmission within 30 and 90 days, emergency room visit within 30 and 90 days, and higher total costs.

Results: We reviewed 1191 PCDF cases, of which 93 patients (7.81%) had a history of OSA. At the univariate level, patients with OSA had higher rates of ICU admissions (33.3% vs 16.8%, $P < 0.0001$), total complications (29.0% vs 19.0%, $P = 0.0202$), and respiratory complications (12.9% vs 6.6%, $P = 0.0217$). Multivariate regression analyses revealed no difference in the odds of a prolonged extubation ($P = 0.4773$) and showed that history of OSA was not predictive of higher costs. However, a significant difference was observed in the odds of having an ICU admission ($P = 0.0046$).

Conclusion: While patients with sleep apnea may be more likely to be admitted to the ICU postoperatively, OSA status a lone is not a risk factor for poor primary and secondary clinical outcomes following posterior cervical fusion procedures.

Clinical Relevance: Various deformities of the cervical spine can exert extraluminal forces that partially collapse or obstruct the airway, thereby predisposing patients to OSA; however, no study has examined the cost or outcome profiles for PCDF procedures in patients with OSA. Therefore, this investigation highlights the ways in which OSA influences the risks, outcomes, and costs following PCDF using medical data from an institutional registry.

Level of Evidence: 3.

Cervical Spine

Keywords: cervical spine surgery, obstructive sleep apnea, posterior cervical decompression and fusion

INTRODUCTION

Obstructive sleep apnea (OSA) is a chronic condition that results from repeated episodes of narrowing or partial collapse of the upper airway during sleep. OSA is a pervasive problem in the adult population with an increasing prevalence estimated to be around 9% to 24%.[1,2] Over time, OSA results in diminished neurocognitive performance, increased daytime sleepiness, increased risk of all-cause mortality, and medical problems such as cardiovascular disease, systemic hypertension, stroke, and altered glucose metabolism.[3] OSA has also been shown to have a profound impact on patient function and quality-of-life scores.[4–6] As such, OSA represents an important medical comorbidity that requires special consideration in the perioperative setting.

There are many factors that may predispose patients to OSA. These include age, male sex, obesity, and craniofacial abnormalities such as short mandibular size, adenoid hypertrophy, and extended head posturing.[3,7] While the bony and cartilaginous structures in the naso- and oropharynx have traditionally been credited with maintaining patency in the upper airway, the cervical spine is increasingly being recognized as a critical structure that influences patency as well.[7–9] Given their proximity to the airway, the cervical vertebrae normally contribute passive support to the posterior wall of the upper airway. However, various deformities and pathologies of the cervical spine can also exert extraluminal forces that may partially collapse or obstruct the airway, thereby predisposing patients to OSA.[10–17]

In recent years, procedures that decompress and fuse the spine have been increasingly used to treat a variety of spine diseases.[18–21] Typically, these fusion procedures are approached either anteriorly (anterior cervical decompression and fusion), posteriorly (posterior cervical decompression and fusion [PCDF]), or both (frontback). Despite our increasing understanding of the biomechanical forces that the cervical spine may exert upon the upper airway, there is a dearth of literature assessing the unique influence that OSA has on outcomes for fusion procedures for various spinal abnormalities. Furthermore, while previous studies have examined risk factors that influence the complications and outcomes of cervical fusion procedures, no study, to our knowledge, has examined the cost or outcome profiles for PCDF procedures in patients with OSA. Given the importance of this medical comorbidity, it has the potential to influence discussions of research, policy, and delivery of care to this challenging patient population.

In light of this deficit in the literature, we sought to conduct a rigorous retrospective analysis of how OSA influences the risks, outcomes, and costs following PCDF using medical data from our institution. Given the additional challenges of airway management in this patient population, the central hypothesis was that patients with OSA would experience greater risk of prolonged extubation, more frequent cardiovascular and pulmonary complications, and higher costs of treatment than patients without OSA. This topic deserves careful consideration because of the increasing prevalence of OSA in our adult population,[1] the vulnerability of patients with cervical deformities that predispose to OSA,[7] and the profound effect that OSA has on function and quality of life.[5]

METHODS

Data Source, Inclusion Criteria, and Patient Stratification

Medical records within our institution were retrospectively reviewed for all cases involving a PCDF procedure performed for cervical stenosis between 2008 and 2016. These cases were identified utilizing the current procedural terminology (CPT) codes 22600, 63045, 63001, 63015, 22110, and 22210. Those who underwent anterior cervical surgery within the same hospitalization were excluded with the CPT codes 22554, 22551, and 63075.

Covariates

Demographic data were collected for each patient's age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) status classification, admission type, and Elixhauser Comorbidity Index (ECI) score.[22,23] In addition, several pertinent intraoperative and perioperative variables were also obtained for each patient. Respiratory complications included pneumonia, pulmonary edema, pulmonary embolism, pulmonary insufficiency, and respiratory failure. We also examined in detail the morbidity by organ system, including airway, bleeding, renal failure, myocardial infarction, cardiac arrest, stroke, deep venous thrombosis, pneumonia, pulmonary embolism, wound dehiscence, sepsis, septic shock, urinary tract infection, and mortality.

Primary and Secondary Outcomes

The need for an unexpected delayed extubation, defined as extubation after leaving the operating room, was selected as the primary outcome in this study. Unexpected delayed extubation was selected as the primary outcome because it is well recognized that there are additional challenges in airway management in this patient population in the perioperative period. OSA was determined through the *International Classification of Diseases, Ninth Revision* and *International Classification of Diseases, Tenth Revision* codes 327.23, 327.21, 327.20, 327.29, G473, G473.0, G473.1, and G473.3 across all patients who underwent PCDF during the study period and confirmed with individual examination of patients' medical records. Secondary outcomes included admission to the intensive care unit (ICU), any complication, extended hospitalization (defined as cases with length of stay greater than the 75th percentile across the entire study population), nonhome discharge (defined as any discharge that was not home), and 30- and 90-day hospital readmissions and emergency room visits.

Statistical Methods

SAS (SAS Institute Inc., Cary, NC, USA) was used for statistical analysis in this study. χ^2 tests were implemented to analyze categorical variables. Fisher's exact test was used for contingency tables containing an expected count less than 1 under the null hypothesis of independence. The means for any continuous variables were compared using 2-sided, 2-sample *t* tests. Univariate regression models for OSA and non-OSA cohorts were constructed to better understand the data by evaluating the relationships between certain perioperative and postoperative variables and various measures of clinical outcome. Finally, multivariable linear and logistic regression models were constructed to control for demographic and relevant clinical comorbidity variables that significantly differed between the 2 groups, or if they were well-established clinical factors known to affect surgical outcomes. In this particular study, models controlled for age, sex, ASA status, ECI score, number of segments fused, obesity, and whether intubation was performed before induction of anesthesia. Model multicollinearity was assessed using the variance inflation factor.

Sequential modeling was utilized in the analyses of direct costs, such that models including successively increasing numbers of factors that contribute to cost were created to understand the point at which sleep apnea was no longer a contributing factor to increased direct costs. A *P* value less than 0.05 was set in advance as a threshold for determining statistical significance.

Table 1. Demographics of the study population by history OSA.

Demographic	No History of OSA ($n = 1098$)	OSA ($n = 93$)	*P* Value
Age, y, mean ± SEM	58.8 ± 0.4	53.6 ± 1.2	0.4252
Sex, *n* (%)			0.1218
Male	654 (59.6)	63 (67.7)	
Female	444 (40.4)	30 (32.3)	
Obesity, *n* (%)			<0.0001[a]
BMI <30	1011 (92.1)	50 (53.8)	
BMI 30–40	65 (5.9)	23 (24.7)	
BMI >40	22 (2.0)	20 (21.5)	
ASA status, *n* (%)			<0.0001[a]
I	29 (2.6)	0 (0.0)	
II	512 (46.6)	16 (17.2)	
III	505 (46.0)	70 (75.3)	
IV	50 (4.6)	7 (7.5)	
ASA status (reference: <2), n (%)			
>2	556 (50.6)	77 (82.8)	<0.0001[a]
Admission type, *n* (%)			0.1261
Elective	1071 (97.5)	93 (100.0)	
Nonelective	27 (2.5)	0 (0.0)	
Segments operated, mean ± SEM	3.9 ± 0.06	4.2 ± 0.21	0.1066
Length of surgery, min, mean ± SEM	156.4 ± 13.7	164.6 ± 15.9	0.8624
Awake intubation, *n* (%)	61 (5.6)	9 (12.9)	0.1047
Elixhauser Comorbidity Index, *n* (%)			0.7373
<0	138 (12.6)	15 (16.1)	
0	761 (69.3)	62 (66.7)	
1–4	63 (5.7)	4 (4.3)	
>4	136 (12.4)	12 (12.9)	

Abbreviations: ASA, American Society of Anesthesiologists physical status classification system; BMI, body mass index; OSA, obstructive sleep apnea; SEM, standard error of the mean.

[a] $P < 0.05$ was used as a threshold for statistical significance.

RESULTS

Study Population Characteristics

A total of 1191 patients who underwent a PCDF procedure were included in this study. Of the total patient cohort, 93 patients (7.81%) had a recorded history of OSA and 1098 patients (92.19%) did not. The 2 patient cohorts were similar in age, sex, admission type, number of segments involved in the procedure, and overall comorbidities (demonstrated by ECI; [Table 1]). However, the OSA patient cohort differed significantly in terms of their rates of obesity and the distribution of their ASA classification status. In the OSA cohort, 46.2% of patients had a BMI greater than 30 kg/m^2 compared with only 7.9% in the control cohort ($P < 0.0001$). ASA status was also significantly different between the 2 groups, with 82.8% of patients with OSA having an ASA score of greater than 2, indicating severe systemic disease or severe systemic disease that is a constant threat to life, compared with 50.6% in the control cohort ($P < 0.0001$).

Morbidities and mortality were reviewed by organ system, and the incidence of each morbidity was compared between patient cohorts. Table 2 displays all of the morbidities reviewed for this study and the all-cause mortality rates at the end of the study period. Patients undergoing PCDF with a history of OSA had significantly higher rates of posthemorrhagic anemia (22.6%) compared with patients without a history of OSA (12.2%) ($P = 0.0043$) and respiratory failure (4.3% vs 1.4%, $P = 0.0301$). There was no difference in the rate of mortality between the 2 cohorts ($P = 0.6138$).

Primary and Secondary Outcomes

Univariate logistic regression modeling was used to determine how a history of OSA related to individual clinical outcomes (Figure; Tables 3 and 4). When examining the primary outcome, delayed extubation, we observed that patients with a history of OSA did not have prolonged extubation compared with the control cohort (OR = 0.66, 95% CI: 0.21–2.07; $P = 0.4773$). Of note, at the univariate level, the number of cases admitted to the neuroscience intensive care unit (NSICU) postoperatively was greater in the OSA group (33.3%) compared with the control cohort (16.8%) ($P < 0.0001$), as was the number of overall complications (29.0% vs 19.0%, $P = 0.0202$) and respiratory complications (12.9% vs 6.6%, $P = 0.0217$).

At the multivariate level, delayed extubation remained nonsignificant ($P = 0.4773$) while the odds

Table 2. Morbidity and mortality of the study population by history of OSA.

Variable, *n* (%)	No History of OSA (n = 1098)	OSA (n = 93)	*P* Value
Morbidity by organ system			
Airway	1 (0.1)	0 (0.0)	0.7709
Acute respiratory distress syndrome	1 (0.1)	1 (0.0)	0.7709
Atelectasis	53 (4.8)	8 (13.1)	0.1128
Posthemorrhagic anemia	134 (12.2)	21 (22.6)	0.0043[a]
Renal failure	16 (1.5)	1 (1.1)	0.7656
Myocardial infarction	7 (0.6)	2 (2.2)	0.1057
Cardiac arrest	9 (0.8)	2 (2.2)	0.1977
Cerebrovascular attack	1 (0.1)	0 (0.0)	0.7709
Deep venous thrombosis	2 (0.2)	0 (0.0)	0.6804
Obesity-related hypoventilation syndrome	1 (0.1)	0 (0.0)	0.7709
Pneumonia	29 (2.6)	4 (4.3)	0.3491
Pulmonary edema	1 (0.9)	0 (0.0)	0.7709
Pulmonary embolism	3 (0.3)	0 (0.0)	0.6138
Pulmonary insufficiency	4 (0.4)	0 (0.0)	0.5599
Respiratory failure	15 (1.4)	4 (4.3)	0.0301[a]
Wound dehiscence	2 (0.2)	0 (0.0)	0.6804
Sepsis	8 (0.7)	0 (0.0)	0.4088
Septic shock	3 (0.3)	0 (0.0)	0.6138
Urinary tract infection	13 (1.2)	1 (1.1)	0.9256
Overall mortality	3 (0.3)	0 (0.0)	0.6138

Abbreviation: OSA, obstructive sleep apnea.

[a] $P < 0.05$ was used as a threshold for statistical significance.

of NSICU admission remained significantly increased (OR = 2.17, P = 0.0046) in the OSA cohort. Interestingly, the OSA group was found to have lower odds of nonhome discharge (OR = 0.50, P = 0.0181) when compared with the patients who did not have a history

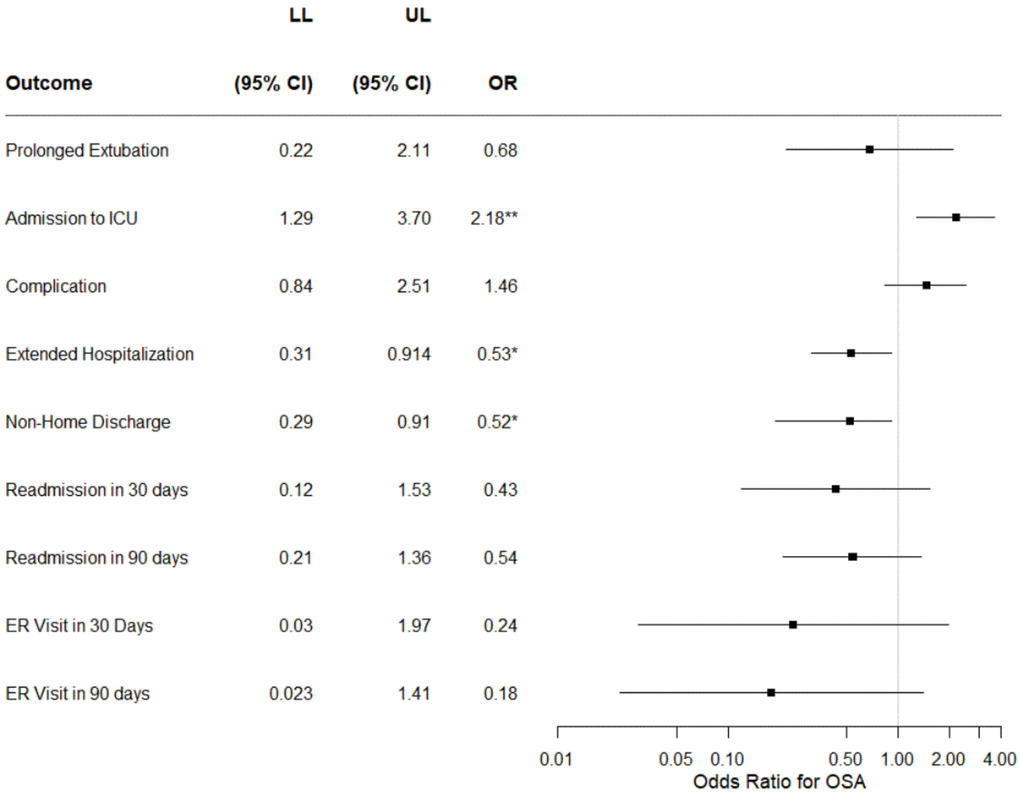

Figure. Forest plot depicting OR of experiencing adverse clinical outcomes between patients with and without a history of obstructive sleep apnea (OSA). OSA does not impact the odds of having prolonged extubation; however, it does increase the odds of a postoperative admission to the intensive care unit (ICU). A history of OSA also decreases the odds of an extended hospitalization and nonhome discharge in our study population. OR obtained through multivariate logistic regression analysis. *P* value <0.05 was set as a threshold for statistical significance. *indicates <0.05; ** indicates <0.01; *** indicates <0.0001. ER, emergency room; LL, lower limit; UL, upper limit.

Table 3. Comparison of relevant clinical outcome measures based on the presence of OSA.

Variable, *n* (%)	No History of OSA ($n = 1098$)	OSA ($n = 93$)	*P* Value
Prolonged extubation	71 (6.5)	4 (4.3)	0.4092
Admitted to the intensive care unit	184 (16.8)	31 (33.3)	<0.0001[a]
Complication	209 (19.0)	27 (29.0)	0.0202[a]
Respiratory complication	72 (6.6)	12 (12.9)	0.0217[a]
Nonhome discharge	337 (30.7)	24 (25.8)	0.3017
Prolonged length of stay	343 (31.2)	28 (30.1)	0.8211
Readmission within 30 d	52 (4.7)	3 (3.2)	0.5053
Readmission within 90 d	86 (7.8)	6 (6.5)	0.6320
Emergency room visit within 30 d	33 (3.0)	1 (1.1)	0.2832
Emergency room visit within 90 d	46 (4.2)	1 (1.1)	0.1386

Abbreviation: OSA, obstructive sleep apnea.

[a] $P < 0.05$ was used as a threshold for statistical significance.

of OSA. All other clinical outcome variables had no statistical difference between the 2 cohorts (Table 4).

For the sequential modeling of cost, the first model simply looked at OSA as a binary variable to predict total cost utilization, which did not demonstrate a significant effect ($\beta = 1125.66$, $P = 0.5130$). The second model, which assessed the impact of OSA while controlling for a number of patient-level factors, also did not demonstrate that OSA had a significant effect on direct costs ($\beta = -1155.54$, $P = 0.4709$). Furthermore, a history of OSA did not significantly predict increased direct costs while controlling for other resource utilization and length of stay variables (model 3: $\beta = -297.31$, $P = 0.8355$, model 4: $\beta = 632.78$, $P = 0.4182$). Interestingly, while OSA did not significantly predict direct costs in any of our multivariate models, other variables did appear to predict increased direct cost in these models. In the most comprehensive model, variables that predicted increased direct cost, when controlling for all covariates, included female sex ($P = 0.0018$), number of segments involved in the procedure ($P < 0.0001$), length of the surgery (operating time; $P < 0.0001$), total volume of cryoprecipitate ($P < 0.0001$), total volume of fresh frozen plasma ($P = 0.0016$), longer length of hospital stay ($P < 0.0001$), and length of NSICU stay ($P < 0.0001$) (Table 5).

Table 4. Multivariate logistic regression models evaluating the impact of obstructive sleep apnea on relative clinical outcome measures.

Outcome	OR (95% CI)	*P* Value
Prolonged extubation	0.66 (0.21–2.07)	0.4773
Admission to intensive care unit	2.17 (1.27–3.70)	0.0046[a]
Complication	1.40 (0.82–2.39)	0.2201
Respiratory complication	1.36 (0.64–2.91)	0.4224
Extended hospitalization	1.36 (0.39–4.67)	0.6287
Nonhome discharge	0.50 (0.28–0.89)	0.0181[a]
Readmission in 30 d	0.43 (0.12–1.53)	0.1937
Readmission in 90 d	0.54 (0.21–1.36)	0.1908
Emergency room visit in 30 d	0.25 (0.03–1.99)	0.1882
Emergency room visit in 90 d	0.18 (0.02–1.39)	0.0997

Note: Models control for demographic and intraoperative variables, including age, sex, American Society of Anesthesiologists physical status classification system status, Elixhauser Comorbidity Index, number of segments operated on, obesity, and awake intubation.

[a] $P < 0.05$ was used as a threshold for statistical significance.

DISCUSSION

Study Population

OSA is increasingly common in the United States and is highly associated with a number of other comorbidities. Specifically, obesity contributes to increased neck fat and tissue volume surrounding the upper airway.[24] Patients with a BMI greater than 30 are more likely to report a history of OSA compared with individuals who have BMI in the normal range.[25] In our study, we found that a significant number of patients within the OSA cohort also had a BMI greater than 30. Of these 93 patients, nearly half had a BMI between 30 and 40 and nearly a quarter had a BMI greater than 40, compared with the control cohort who only had 7.9% of patients with a BMI greater than 30. It has been well documented in the literature that OSA and obesity are commonly comorbid,[25–30] which is evident in our study as well.

Upon analysis of different morbidities that patients experienced postoperatively, we found postoperative bleeding and respiratory failure to be the only complications to have significant differences between the OSA and control cohorts (Table 2). In particular, the rate of respiratory failure was nearly 3 times as high in the OSA cohort compared with the control cohort, which may be related to the known challenges of airway management and respiration in this patient population. In addition, the rate of postoperative, posthemorrhagic anemic events was almost twice as high in the OSA cohort compared with the control cohort (Table 2). It is possible that the comorbid obesity and potentially restricted muscle relaxation that are enriched in the OSA cohort may affect surgical dissection and enhance the intraoperative and postoperative bleeding,

Table 5. Multivariate linear regression model evaluating the impact of a number of demographic, clinical, and perioperative factors on predicting direct cost.

	β (SE)	95% CI	*P* Value
Total Direct Cost (Model 4)		($R^2 = 0.83$, $P < 0.0001$[a])	
Age	−27.00 (15.43)	−57.3 to 3.3	0.0805
Sex (male)	−1252.57 (399.43)	−2036.2 to −468.9	0.0018[a]
American Society of Anesthesiologists physical status classification system status	−209.29 (347.25)	−890.6 to 472.0	0.5468
Elixhauser Comorbidity Index	23.86 (56.87)	−87.7 to 135.4	0.6749
Number of segments operated	1830.24 (107.74)	1618.9–2041.6	<0.0001[a]
Obesity	−409.93 (479.36)	−1350.4 to 530.6	0.3926
Obstructive sleep apnea	632.78 (781.3)	−900.1 to 2165.7	0.4182
Length of surgery	31.37 (3.04)	25.4–37.3	<0.0001[a]
Crystalloids	0.23 (0.23)	−0.22 to 0.68	0.3260
Colloids	3.97 (2.45)	−0.84 to 8.8	0.1054
Red blood cells	0.51 (1.30)	−2.0 to 3.1	0.6928
Platelets	10.28 (5.88)	−1.3 to 21.8	0.0806
Fresh frozen plasma	−5.82 (1.84)	−9.4 to −2.2	0.0016[a]
Cryoprecipitate	352.91 (33.68)	286.8–419.0	<0.0001[a]
Length of stay	1301.54 (47.23)	1208.9–1394.2	<0.0001[a]
Intensive care unit length of stay	1229.41 (111.55)	1010.6–1448.3	<0.0001[a]
Awake intubation	858.09 (833.25)	−776.7 to 2492.9	0.3033

Abbreviation: SE, standard error.

Note: Multiple models were constructed to evaluating a variety of clinical factors. The table presents model 4 from Table 6 and is the most comprehensive model.

[a] $P < 0.05$ was used as a threshold for statistical significance.

leading to the observed increase in posthemorrhagic anemia in this cohort. However, it has also been previously shown that patients with OSA can experience a number of thrombotic or coagulopathic events thought to be related to chronic episodes of nocturnal hypoxia.[31] However, it has been commonly found that patients with OSA experience prothrombotic events, such as deep venous thromboses, without good evidence as to why these coagulopathies develop. In these cases, it has frequently been shown that the severity of sleep apnea is strongly correlated with the severity of the coagulopathy.[32–34] Therefore, in our study the patients in the OSA cohort may have a range of severity, with a nonsignificant subset having severe OSA, which may indicate why we do not see any hypercoagulable events in these patients. Given that patients with OSA do have a variety of changes occurring within clotting and fibrinolytic factors throughout their disease course,[32] more targeted studies are needed to identify specific changes and cellular mechanisms across all severities of OSA.

Primary Outcome: Need for Delayed Extubation

The need for delayed extubation is a variable that provides a number of insights into the patient's postoperative condition as well as their resource utilization in the operative setting. Previous studies have demonstrated an increased incidence of postoperative airway complications, including obstruction and oxygen desaturation, in OSA patients, which may complicate the decision to extubate in the operating room.[35,36] Interestingly, we found that OSA patients did not have a significant increase in delayed extubation compared with the control cohort (4.3% vs 6.5%, $P = 0.4092$). Overall, delayed extubation was relatively low in both groups and is rare in elective cervical decompression and fusion procedures.[37] Therefore, a low rate of events, while signifying the relative safety of posterior cervical procedures in regard to delayed extubation, could also have prevented a difference between the 2 cohorts from being uncovered. Clinically, patients who fail extubation have higher rates of respiratory complications, including higher rates of tracheostomy and mortality.[38] Delayed extubation can also lead to significant increased resource utilization including time in the OR, use of a ventilator, and admission to the ICU.[39–41] Previous studies that assess the impact of OSA in both spine and joint procedures have found that patients with OSA are more commonly admitted to the ICU and have higher overall complication rates.[34,37,42,43] However, it is unclear what the etiology of these ICU admissions was, in most cases, meaning that a connection between delayed extubation and increased complications is still entirely possible in the OSA cohort. While the present results do not suggest this, further studies with larger cohorts are needed to confirm the lack of a connection.

Secondary Outcomes: Clinical Outcomes and Direct Cost Analysis

At the univariate level, we identified that both overall complications, respiratory complications, and ICU admissions were greater for the OSA cohort (Table 3). These 3 outcomes are consistent across multiple studies that have looked at both elective spine procedures and orthopedic procedures. Two studies that reviewed the

National Inpatient Sample database found a significant increase in complications, involving multiple organ systems, including respiratory, cardiac, renal, pulmonary, as well as overall complications for patients with OSA.[34,42] However, Gupta et al performed a retrospective case control study on patients with OSA undergoing different orthopedic joint procedures, and identified that patients with OSA had higher rates of admission to the ICU and total complications, but no difference in specific organ system complications.[43] In our study, we find a similar effect after multivariate analysis, demonstrating that patients with a history of OSA are twice as likely to have an ICU admission than the control cohort ($P = 0.0038$). A larger prospective registry may allow for a more sensitive screen of organ system morbidities given the overall rare occurrence of these events in elective spine procedures.

At the multivariate level, a history of OSA makes a patient 2.17 times more likely to have an admission to the ICU, which is consistent with previous literature in both spine and orthopedic procedures (Table 4).[34,42,43] However, we see an unexpected effect of OSA on both extended hospitalization and nonhome discharge. A history of OSA was associated with significantly lower odds of a nonhome discharge ($P = 0.0181$). This finding in our retrospective cohort is not consistent with what has been reported in previous studies, which have found that OSA is associated with increased length of stay, increased odds of extended hospitalization, and nonhome discharge following posterior lumbar fusion and total knee and hip arthroplasty.[34,42,43] This effect could be a result of the small number of OSA patients ($N = 93$) compared with the control cohort ($N = 1098$). A prospective, control-matched study may further elucidate the impact of OSA on hospitalization length and patient discharge disposition.

Upon cost analysis, a history of sleep apnea did not have a significant impact on direct costs at the patient level (Tables 5 and 6). This is likely due to the main drivers of cost in patients undergoing cervical spine surgery, which have been shown previously to be length of stay, number of segments involved in the procedure, and length of procedure.[44–46] Similarly, in our study we found that patients who had more extensive operations, indicated by a greater number of segments involved ($P < 0.0001$) and the length of procedure ($P < 0.0001$), had a greater likelihood of increased cost. Other drivers included increased hospital resource utilization and longer lengths of stay ($P < 0.0001$), which are likely unrelated to a patient's history of OSA and more likely associated with the size of the procedure performed. However, patients with a history of OSA may require increased lengths of stay in the ICU or in the hospital due to any respiratory complications or prolonged intubation. Given the findings of increased ICU stays and decreased odds of prolonged length of stay in OSA patients, it is possible that these costs offset the cohort to result in minimal differences from the control cohort on the basis of cost. Further study is warranted to determine the association of OSA and the common drivers of increased cost utilization in cervical spine surgery.

Table 6. Multivariate linear regression models evaluating the impact of a history of obstructive sleep apnea on predicting direct cost while controlling for a number of perioperative variables.

	β (SE)	95% CI	P Value
Total Direct Cost			
Model 1	1125.66 (1720.14)	−2249.18 to 4500.50	0.5130
Model 2	−1155.54 (1602.16)	−4298.93 to 1987.85	0.4709
Model 3	−297.31 (1431.57)	−3106.04 to 2511.42	0.8355
Model 4	632.78 (781.29)	−900.12 to 2165.68	0.4182

Abbreviation: SE, standard error.

Note: Multiple models were constructed to evaluating a variety of clinical factors. Model 1 had only sleep apnea as an independent variable to predict cost as the dependent variable. Model 2 included model 1 plus age, sex, American Society of Anesthesiologists physical status classification system status, Elixhauser Comorbidity Index, number of segments, and obesity. Model 3 included model 2 plus length of surgery, total volume of crystalloids, total volume of colloids, total volume of red blood cells, total volume of platelets, total volume of fresh frozen plasma, and total volume of cryoprecipitate. Model 4 included model 3 plus length of hospital stay and length of intensive care unit stay.

Limitations

First, given that this study is retrospective, it is difficult to assess temporal relationships between variables. In addition, a limited sample of patients was included in this study, which may mean that certain analyses lacked the power to detect significance for variables, and certain variables, including intraoperative estimated blood loss, were unable to be included in the study. Selecting OSA as a binary variable is limiting given that it is a chronic condition that ranges in severity over time, and the severity of disease may have variable influences on clinical outcomes. While a grading scale, such as the Apnea Hypopnea Index, was not commonly used for the patients in this dataset and could not be retroactively applied given the available information, incorporation of such grading scales may provide additional valuable insights in future analyses. Furthermore, any patients with undiagnosed OSA would likely cause any differences in demographics or outcomes to be statistically less significant, meaning that the present study likely underestimates any differences in outcomes of patients with OSA. In addition, while review of patient records did not yield any mention of prominent osteophytes, rheumatoid arthritis, or altered C0-C2 angle that could have acutely changed the severity of the patients' OSA postoperatively, this cannot be ruled out for certain, and thus, it is possible that the presence or absence of some anatomical factors in certain patients may have also affected their airways, which could confound some of the outcomes examined in this study. Similarly, surgical correction of a previously existing anatomic factor that may have predisposed certain patients to OSA could also potentially confound some of the reported outcomes. Finally, the data in this study were obtained from a single institution. As such, it is subject to institution-level differences and preferences in surgical practice and patient management.

CONCLUSION

In this study, OSA was found to have a greater comorbidity burden preoperatively and increased rates of complications postoperatively in patients undergoing posterior cervical decompression and fusions. Of note, OSA was not an independent predictor of delayed extubation, respiratory complications, or increased direct costs. Taken together, the results from this study suggest that while OSA may be indicative of poorer overall health, OSA status alone is not a risk factor for poor primary and secondary clinical outcomes following posterior cervical fusion procedures. While patients with OSA and associated comorbidities may warrant closer attention from surgeons during procedures on the cervical spine, our analysis suggests that it can be performed both safely and effectively in this patient population.

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