Risk of Postoperative Complications in Patients with Obstructive Sleep Apnea following Skull Base Surgery

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Abstract

Objectives. Obstructive sleep apnea (OSA) presents several challenges in skull base surgery, including increased intracranial pressure, worsened OSA with nasal packing, and avoidance of positive airway pressure (PAP) therapy postoperatively. The objective of this study was to examine the risk of postoperative complications in a skull base population with OSA in which PAP therapy is withheld.

Study Design. Retrospective cohort study.

Setting. Tertiary care hospital.

Subjects and Methods. Medical records of 414 adult patients undergoing anterior skull base procedures between January 1, 2014, and January 7, 2017, were retrospectively reviewed. Revision surgeries, skull base infections, sinus surgery, and orbital cases were excluded.

Results. Fifty-four (13.0%) patients with a diagnosis of OSA were identified. While the known patients with OSA were more likely to require postoperative supplemental oxygen (odds ratio [OR], 4.29; 95% confidence interval [CI], 2.38-7.75; P < .001), there was no increased risk of serious respiratory events or cerebrospinal fluid leak (CSF). To address the likely underdiagnosis of OSA in this cohort, subgroup analyses were performed of patients at high risk for OSA (body mass index $\geq$ 30 kg/m² and hypertension) and demonstrated an increased risk of serious respiratory events (OR, 4.41; 95% CI, 1.24-15.7; P = .034) and CSF leak (13.6% vs 4.7%; P = .018).

Conclusions. Skull base patients with known OSA can be successfully managed with diligent care in the perioperative period when PAP therapy is withheld. However, OSA is likely underdiagnosed in the skull base population, and patients at high risk for undiagnosed OSA may be at the greatest risk for respiratory complications and CSF leak. Increased presurgical awareness and implementation of a perioperative management algorithm is needed.

Keywords

skull base surgery, obstructive sleep apnea, postoperative complications

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Obstructive sleep apnea (OSA) refers to intermittent obstruction of the upper airway during sleep and is present in approximately 9% of females and 24% of males in the United States. The increased perioperative risk in patients with OSA is well documented, but recognition, advanced intubation techniques, postoperative admission with monitoring, minimization of sedatives and opiates, and early resumption of positive airway pressure (PAP) therapy minimize this risk. Otolaryngologists frequently encounter scenarios where PAP therapy is purposely withheld postoperatively, such as endoscopic sinus surgery, where there is currently no consensus on the use of postoperative PAP.

Patients with OSA undergoing skull base surgery present several unique challenges inherent to the disease processes, surgical site, and postoperative care. First, tumors themselves may contribute to OSA if the nasal, pharyngeal, and/or nasopharyngeal airway are obstructed by tumor involvement. At baseline, there is also a heightened risk of OSA in several subpopulations treated with skull base surgery, including acromegaly, Cushing’s disease, idiopathic intracranial hypertension with spontaneous cerebrospinal fluid leak.

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of OSA or reported snoring were not considered to have included when available. Patients with a suspected history than 18 years. In this way, only primary cases of the ante-
geries, surgery limited to the sinonasal cavity, or age younger 
ery, orbital or cervical spine pathology, posttraumatic or 
January 1, 2014, through January 7, 2017, was performed. 
patients undergoing anterior skull base surgery from 
stitution review board approval was obtained from the 
Methods

Institutional review board approval was obtained from the University of Pittsburgh. A retrospective chart review of all patients undergoing anterior skull base surgery from January 1, 2014, through January 7, 2017, was performed. Exclusion criteria included prior endonasal skull base sur-
gory, orbital or cervical spine pathology, posttraumatic or infectious (osteomyelitis, invasive fungal sinusitis) etiolo-
gies, surgery limited to the sinonasal cavity, or age younger than 18 years. In this way, only primary cases of the ante-
rior skull base in adults were included. 

The electronic medical record was interrogated for a medical history of OSA, and objective sleep test data were included when available. Patients with a suspected history of OSA or reported snoring were not considered to have OSA. Smoking was defined by documentation of active cigarette use regardless of quantity. Cardiac disease was con-
sidered present if the patient had a history of coronary artery disease with any intervention or an echocardiogram demon-
strating an ejection fraction <55%, congestive heart failure, or pulmonary hypertension. Pulmonary disease was consid-
ered present if the patient carried a diagnosis of interstitial lung disease, active lung cancer, asthma, or chronic obstruc-
tive pulmonary disease on daily medications. Body mass index (BMI) was calculated from the admission weight and 
height; BMIs greater than 30 kg/m², 35 kg/m², and 40 kg/m² were considered class I, II, and III obesity, respectively. 
The O₂ nadir represented the lowest recorded O₂ saturatio-
from 9 pm on postoperative day (POD) 0 until 6 am on 
POD 1. The use of supplemental oxygen was recorded if oxygen was not weaned prior to 6 am on POD 1. Use of supplemental oxygen was used as a proxy for hypoxemia as oxygen is titrated to maintain O₂ saturations above 92%, thereby limiting the utility of O₂ nadir and desaturations. If a patient remained intubated for postoperative night 0, the data were extracted from postoperative night 1 following exubation. If a patient remained intubated for longer than 2 nights, they were considered to have needed supplemental oxygen and the O₂ nadir was recorded from while on the ventilator on POD 0.

A respiratory event was defined as the unexpected need for reintubation, prolonged intubation beyond 2 nights, or a cardiopulmonary-related code. Prolonged intubation was defined as 2 nights to reduce the number of cases that were left intubated following prolonged surgery, which is gener-
only for 1 night. Our skull base patients, regardless of OSA status, follow a standardized airway protocol wherein a laryngeal mask airway (LMA) or endotracheal tube is placed should they require respiratory assistance. PAP ther-
apy was never prescribed prior to 2 weeks postoperatively. CSF leaks and return to the operating room for any reason were noted in the medical record.

To address the presumed underdiagnosis of OSA in the study group, we examined postoperative complications in patients with a high risk of OSA defined as BMI >30 kg/m² as well as preexisting hypertension. These factors were selected given the increased incidence of OSA in obese patients (BMI >30 kg/m²) and those with hypertension. The patients with known OSA were removed from the subgroup comparison of the high- and low-risk cohorts.

SPSS version 24 (SPSS, Inc, an IBM Company, Chicago, Illinois) was used for statistical analysis, with a P value less than .05 considered significant. The χ² test and independent sample t test were used to compare categorical and continu-
ous variables, respectively. Fisher’s exact test was used when appropriate. Multivariable analysis was performed to examine the independent effects of smoking, OSA, and cardiac and pulmonary disease on supplemental oxygen requirement.

Results

A total of 612 patients were identified over the study period, 414 of whom met the study inclusion criteria. The
largest numbers of excluded patients were recurrent/revision cases and/or those younger than 18 years. Mean age of included patients was 53.8 years (18.4-86.6 years), and 56.3% were female. The mean BMI was 30.5 kg/m² (17.0-58.8 kg/m²). The most common pathologies were pituitary adenoma (n = 197), meningioma (n = 54), and sinonasal carcinoma (n = 29).

Fifty-four patients had documented OSA, 22 of whom had a sleep study within our electronic medical record. Of those with available data, 5 had severe OSA (apnea-hypopnea index [AHI] >30 events/h), 7 had moderate OSA (AHI 15-30), and 10 had mild OSA (AHI 5-15). Twenty-four reported active PAP use. Table 1 reports the patient and surgical characteristics in the OSA and non-OSA groups. BMI and diagnosis of meningioma were the only statistically significant differences between the 2 groups.

The patients with OSA were significantly more likely to require oxygen postoperatively (odds ratio [OR], 4.29; 95% confidence interval [CI], 2.38-7.75; P < .001). Overall, there were 15 serious respiratory events (3.6%) consisting of reintubation (n = 10, 2.4%), prolonged intubation (n = 4, 1.0%), and condition for significant desaturations (n = 1, 0.2%). There was no increased risk of serious respiratory events in patients with previously diagnosed OSA (OR, 1.87; 95% CI, 0.50-6.92; P = .408). The risk of respiratory events was not increased in patients with OSA on home PAP (OR, 2.52; 95% CI, 0.54-11.82; P = .227) or those specifically with moderate/severe OSA (OR, 2.52; 95% CI, 0.30-20.89; P = .362). Although patients with OSA were less likely to be extubated in the operating room (OR, 0.34; 95% CI, 0.14-0.81; P = .019), admission to the intensive care unit (ICU) was no different between OSA and patients without OSA (OR, 1.43; 95% CI, 0.80-2.55; P = .222).

A group of 44 patients at high risk for OSA with both a BMI >30 kg/m² and preexisting hypertension were identified (Table 3). This high-risk group demonstrated a significantly increased risk for hypoxemia (OR, 3.16; 95% CI, 0.80-11.05; P = .114).
1.64-6.06; \( P < .001 \) and respiratory events (OR, 4.41; 95% CI, 1.24-15.7; \( P = .034 \)) (Table 4). This increase in serious respiratory events remained significant when controlling for comorbid pulmonary disease (OR, 4.78; 95% CI, 1.33-17.16; \( P = .016 \)). Mean length of stay was prolonged in the high-risk group, albeit nonsignificantly (3.7 vs 4.8 days; \( P = .279 \)). By comparison, patients with BMI \( > 30 \) kg/m\(^2\) alone had an increased risk of hypoxemia (OR, 2.38; 95% CI, 1.45-3.90; \( P < .001 \)) but not respiratory events (OR, 1.69; 95% CI, 0.51-5.64; \( P = .390 \)).

There was a total of 21 CSF leaks (5.1%). CSF leak rate (0% vs 5.8%; \( P = .092 \)) was higher but not significant when controlling for comorbid pulmonary disease (OR, 4.78; 95% CI, 1.33-17.16; \( P = .016 \)) and hypertension (OR, 2.38; 95% CI, 1.45-3.90; \( P < .001 \)) but not respiratory events (OR, 1.69; 95% CI, 0.51-5.64; \( P = .390 \)).

When nonabsorbable tampons (Merocel; Medtronic, Minneapolis, Minnesota) were used (n = 143), however, there was a significant increase in postoperative hypoxemia (OR, 2.58; 95% CI, 1.66-4.01; \( P < .001 \)) and serious respiratory events (OR, 4.00; 95% CI, 1.34-11.94; \( P = .008 \)).

### Discussion

In this large, single-institution study of postoperative skull base patients in whom PAP therapy was universally held postoperatively, we found an increased risk of postoperative hypoxemia in those who had been previously diagnosed with OSA. This is consistent with prior reports in the literature of skull base patients with OSA as well as the OSA population in general, which almost always experiences nocturnal hypoxemia.32,33 This increased risk of hypoxemia may therefore simply represent the OSA patient’s baseline or a true exacerbation of obstructive events in the setting of prolonged anesthetic, use of opiates, nasal obstruction, and withheld PAP therapy. It is also possible that supplemental oxygen, which served as our proxy for hypoxemia, was given “prophylactically” to patients with OSA rather than in response to true desaturations.

The OSA cohort, however, demonstrated no increased risk of serious respiratory complications compared to the non-OSA cohort. However, when nonabsorbable tampons were used, the risk of serious respiratory events increased significantly (OR, 4.00; 95% CI, 1.34-11.94; \( P = .008 \)) when compared to patients who received absorbable tampons (Merocel; Medtronic, Minneapolis, Minnesota) alone (OR, 1.69; 95% CI, 0.51-5.64; \( P = .390 \)).

### Abbreviations

- BMI: body mass index
- CI: confidence interval
- CSF: cerebrospinal fluid
- OR: odds ratio
- OSA: obstructive sleep apnea

### Table 3

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Low Risk (n = 316)</th>
<th>High Risk (n = 44)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>53.7</td>
<td>52.4</td>
<td>.612</td>
</tr>
<tr>
<td>Female, %</td>
<td>55.4</td>
<td>70.5</td>
<td>.058</td>
</tr>
<tr>
<td>BMI, kg/m(^2)</td>
<td>28.5</td>
<td>37.7</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Smoker, %</td>
<td>35.4</td>
<td>38.6</td>
<td>.679</td>
</tr>
<tr>
<td>Cardiac disease, %</td>
<td>7.6</td>
<td>4.5</td>
<td>.464</td>
</tr>
<tr>
<td>Pulmonary disease, %</td>
<td>5.1</td>
<td>11.4</td>
<td>.095</td>
</tr>
<tr>
<td>Pituitary adenoma, %</td>
<td>45.3</td>
<td>54.5</td>
<td>.247</td>
</tr>
<tr>
<td>Meningioma, %</td>
<td>13.9</td>
<td>18.2</td>
<td>.452</td>
</tr>
<tr>
<td>Sinonasal carcinoma, %</td>
<td>8.5</td>
<td>2.3</td>
<td>.227</td>
</tr>
<tr>
<td>Transsellar approach, %</td>
<td>58.9</td>
<td>56.8</td>
<td>.797</td>
</tr>
<tr>
<td>Transplanum approach, %</td>
<td>21.2</td>
<td>27.3</td>
<td>.362</td>
</tr>
<tr>
<td>Transpterygoid approach, %</td>
<td>15.5</td>
<td>11.4</td>
<td>.471</td>
</tr>
<tr>
<td>Transclival approach, %</td>
<td>18.4</td>
<td>6.8</td>
<td>.056</td>
</tr>
<tr>
<td>Nasoseptal flap reconstruction, %</td>
<td>50.9</td>
<td>59.1</td>
<td>.311</td>
</tr>
<tr>
<td>Lumbar drain, %</td>
<td>22.8</td>
<td>22.7</td>
<td>.993</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.

### Table 4

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Low Risk</th>
<th>High Risk</th>
<th>OR (95% CI)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen requirement, %</td>
<td>20.9</td>
<td>45.5</td>
<td>3.16 (1.64-6.06)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Serious respiratory event, %</td>
<td>2.2</td>
<td>9.1</td>
<td>4.41 (1.24-15.7)</td>
<td>.013</td>
</tr>
<tr>
<td>CSF leak, %</td>
<td>4.7</td>
<td>13.6</td>
<td>2.17 (1.16-8.66)</td>
<td>.018</td>
</tr>
<tr>
<td>Mean length of stay, d</td>
<td>3.7</td>
<td>4.8</td>
<td></td>
<td>.279</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; CSF, cerebrospinal fluid; OR, odds ratio; OSA, obstructive sleep apnea.
nonpatients with OSA. Given that patients with OSA frequently endure periods of time without PAP treatment (eg, during travel, illness, equipment malfunction) without serious respiratory events, this finding may be true. Alternatively, the low number of observed airway events may be the result of diligent perioperative nursing, anesthesia, and intensivist care provided to patients with a known diagnosis of OSA.

Chung et al33 used a national database of over 17,000 transsphenoidal surgeries to demonstrate that rates of reintubation, hypoxemia, tracheostomy, and pneumonia were less than 2% in patients with OSA. While this study design is limited by appropriate entry of International Classification of Diseases (ICD) codes and the inability to review individual cases, it raises the likelihood that our single-institution, 3-year retrospective review may have been underpowered to detect differences in the relatively uncommon respiratory complications. However, in our study, the rates of postoperative hypoxemia and serious respiratory events in our OSA study patients far exceeded 2%: 57.4% and 7.4%, respectively.

Given that our rate of OSA was only 13.0% in a population expected to have a heightened prevalence of OSA, OSA is almost certainly underdiagnosed in this skull base cohort. Accordingly, we analyzed a subgroup of high-risk patients with 2 independent predictors of OSA (BMI >30 kg/m² and preexisting hypertension) to increase the likelihood of capturing patients with undiagnosed OSA. This high-risk group demonstrated a significantly increased risk of respiratory events (OR, 4.41; 95% CI, 1.24-15.7; P = .034), greater than the risk of patients with BMI >30 kg/m² alone (OR, 1.69; 95% CI, 0.51-5.64; P = .390). If, in fact, patients within this cohort had undiagnosed OSA, the lack of awareness of a diagnosis may have resulted in less attentive postoperative treatment leading to these respiratory complications compared to the patients with known OSA.

This raises the concern that it is the patient with undiagnosed OSA who may be the most vulnerable to postoperative airway events, and we therefore feel that it is of utmost importance to identify at-risk individuals preoperatively so that their perioperative management can be adjusted appropriately. This can be achieved by early administration of instruments such as the STOP-BANG42 and pursuit of formal sleep testing when OSA is suspected and time allows.

Once a diagnosis of OSA is uncovered or a patient is deemed high risk, we strongly encourage skull base centers to establish a perioperative algorithm for the management of skull base surgery patients with OSA. As shown in Table 5, strategies for caring for patients with OSA include advanced intubation techniques, extubation when fully awake,9,45 use of nonopiate analgesics,46 discontinuation of sedatives and hypnotics,47 use of continuous pulse oximetry or cardiac monitoring,46,48 oronasal airflow monitoring/capnography (as is used with patient-controlled anesthesia [PCA] pumps),49,50 head of bed elevation,46 room placement close to nursing stations, and increased nursing-to-patient ratios (ICU or otherwise).51 Perioperative treatment with temporary oral appliance therapy is an alternative strategy to PAP, although the potential benefit in this setting has not been studied to date, and adherence may be adversely affected by nasal obstruction.

In this study, we also found that more obstructive nasal packing (Merocel tampons) increased the risk of postoperative hypoxemia and respiratory events, whereas the less obstructive nasal packing (nasal Foley balloon) did not. In our center, the Foley balloon is placed high in the posterior septectomy/sphenoid cavity and therefore minimally obstructs the true nasal airway. This finding is consistent with the existing literature and current understanding of nasal breathing at night, the Starling resistor model, and the nasal-ventilatory cycle.21 Along with the abovementioned recommended precautions, using the least obstructive nasal packing possible or inserting nasal trumpet airways inferior to packing may be of benefit in patients with OSA.

Interestingly, no CSF leaks occurred in the known OSA group, which is consistent with the large national database

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Table 5. Considerations for a Perioperative Algorithm to Minimize Complications Related to OSA.

<table>
<thead>
<tr>
<th>Preoperative</th>
<th>Intraoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Identify at-risk patients (eg, STOP-BANG)</td>
<td>• Advanced intubation techniques</td>
<td>• Observe in PACU or ICU until adequate control of breathing and oxygen saturations documented</td>
</tr>
<tr>
<td>• Sleep laboratory or home portable sleep apnea testing if time allows</td>
<td>• Avoid atelectasis/hypventilation to maintain lung volume</td>
<td>• Minimize opiates, benzodiazepines, and other agents that impair central or peripheral control of breathing</td>
</tr>
<tr>
<td>• Fit for mandibular advancement device</td>
<td>• Minimize obstructive nasal packing</td>
<td>• Cardiac monitoring with continuous pulse oximetry and supplemental O₂ as needed</td>
</tr>
<tr>
<td>• Optimize PAP therapy leading up to surgery date</td>
<td>• Placement of nasal trumpet airways inferior to packing</td>
<td>• Positional therapy with head of bed elevation, lateral decubitus positioning as needed</td>
</tr>
<tr>
<td>• Weight loss if applicable/possible</td>
<td>• Exutbate when anesthetics reversed and fully awake</td>
<td>• Early ambulation to minimize atelectasis (no incentive spirometry)</td>
</tr>
<tr>
<td>• Educate on perioperative OSA risks and management strategies</td>
<td>• Consideration of lumbar drain placement</td>
<td>• Early resumption of PAP therapy once safe</td>
</tr>
</tbody>
</table>

Abbreviations: ICU, intensive care unit; OSA, obstructive sleep apnea; PACU, postanesthesia care unit; PAP, positive airway pressure therapy.
study by Chung et al., which also did not uncover an increased rate of CSF leaks. There was, however, a significantly increased CSF leak rate in the high-risk group (Table 4). Although CSF leaks were uncommon (5.1% overall) in this primary skull base surgery population, it seems that the increased and fluctuating intracranial pressure (ICP) in untreated patients with OSA and decreased wound-healing abilities may subject patients with OSA to an increased risk of CSF leak. This further supports the need for preoperative identification of patients with OSA and implementation of conservative measures to reduce obstructive events as ICP elevations are directly correlated with the duration of apnea. Consideration of regular lumbar drain use in OSA or in high-risk patients may be of benefit in reducing CSF leaks but has not been studied.

While this study is limited by several factors discussed above, it does bring to light a number of areas in need of future research and change in clinical practice. Given that most centers view PAP therapy as contraindicated in postoperative skull base patients, prospective study of an implemented structured algorithm for the management of postoperative skull base patients is needed. The effectiveness of oral appliance therapy, sleep positioning adjuncts, or nasal trumpet airways in this setting is also of interest. The findings of these and related studies may also benefit other otolaryngologic populations such as tympanoplasty, lateral skull base surgery, transoral robotic surgery (TORS), and endoscopic sinus surgery where PAP therapy also presents challenges when implemented postoperatively.

Conclusions
Patients with OSA undergoing skull base surgery present multiple challenges with respect to perioperative management and mitigation of postoperative complications. Although it seems that skull base patients with previously diagnosed OSA can be successfully managed with diligent care in the perioperative period, OSA is likely underdiagnosed in the skull base population, and patients at high risk for undiagnosed OSA may be at the greatest risk for respiratory complications and CSF leak. Increased presurgical awareness and implementation of a structured perioperative management algorithm are needed.

Author Contributions
Phillip Huyett, study conception/design, data acquisition/analysis/interpretation, manuscript preparation/final approval, accountability for accuracy and integrity; Ryan J. Soose, study design, data acquisition, critical revisions and final approval of manuscript, accountability for accuracy and integrity; Amy E. Schell, study design, data acquisition, manuscript preparation, critical revisions and final approval of manuscript, accountability for accuracy and integrity; Juan C. Fernandez-Miranda, study design, data acquisition, manuscript preparation/final approval, accountability for accuracy and integrity; Paul A. Gardner, study design, data acquisition, critical revisions and final approval of manuscript, accountability for accuracy and integrity; Carl H. Snyderman, study conception/design, data acquisition/analysis/interpretation, manuscript preparation/final approval, accountability for accuracy and integrity; Eric W. Wang, study conception/design, data acquisition/analysis/interpretation, manuscript preparation/final approval, accountability for accuracy and integrity.

Disclosures
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References


