Risk Factors for Serious Complication After Uvulopalatopharyngoplasty

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Objective: To test the hypothesis that comorbidity, performance of concurrent sleep apnea procedures in addition to uvulopalatopharyngoplasty, body mass index, apnea-hypopnea index, and lowest oxygen saturation are risk factors for serious perioperative complications after uvulopalatopharyngoplasty.

Design: Prospective cohort and nested case-control studies.

Setting: United States Veterans Affairs medical centers.

Patients: A prospective cohort of 3130 consecutive adult inpatients who underwent uvulopalatopharyngoplasty from 1991 to 2001 was retrospectively analyzed from the Veterans Affairs National Surgical Quality Improvement Program database to determine the relationship between perioperative complications and both concurrent procedures and medical comorbidity. A nested case-control analysis was conducted on 43 cases with complications and 212 controls without complications from the cohort. Controls were matched on age, sex, year of operation, and concurrent surgery; this case-control analysis enabled the study of body mass index, apnea-hypopnea index, and medical comorbidity, which were not available in the cohort database. Multivariate logistic regression measured associations between risk factors and complications, adjusting or controlling for age, sex, race, smoking status, year of uvulopalatopharyngoplasty, and presence of any concurrent procedure.

Main Outcome Measure: Sixteen specific serious perioperative complications, including 30-day mortality.

Results: The cohort included 3130 veterans (97% were men aged 50 ± 11 [mean ± SD] years). In the cohort study, comorbidity was associated with serious complication: the adjusted risk ratio was 1.96 (95% confidence interval, 1.16-3.18) for each increase in American Society of Anesthesiologists class. Concurrent nonnasal procedures increased the risk of complication compared with no concurrent procedures (adjusted risk ratio, 4.94; 95% confidence interval, 2.34-10.4). In the case-control analyses, the apnea-hypopnea index, body mass index, and medical comorbidity were each associated with serious complication after adjustment for confounding variables, but this study had insufficient power to determine if these risk factors were independent of each other. Concurrent retrolingual procedures demonstrated an independent association with complication after adjustment for confounders. The lowest oxygen saturation was not associated with serious complication.

Conclusions: Apnea-hypopnea index, body mass index, and medical comorbidity were each associated with serious complication; however, the low complication rate precluded demonstration of associations independent of each other. Concurrent retrolingual procedures were also associated with serious complication, but the cumulative risk of separate retrolingual procedures is unknown.

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Obstructive sleep apnea syndrome (hereafter known as sleep apnea) is a disorder of symptomatic, repeated upper airway obstruction during sleep. This disorder results in increased mortality, cardiovascular disease, and quality-of-life deficits. Because the retropalatal region is the most common site of obstruction, uvulopalatopharyngoplasty (UPPP) is the most common operation performed for sleep apnea. Other operations address obstruction in the nasal or retrolingual airway. These procedures can be performed concurrently with UPPP or in a staged fashion.

Previous evaluation of a large, multisite cohort of patients who underwent UPPP revealed an overall 1.6% rate of serious complication, including a 0.2% 30-day mortality rate. Anatomical and physiological abnormalities associated with sleep apnea may affect the risk of perioperative complication; however, previous reports are conflicting. Esclamado et al explored data from 135 patients that suggested that patient weight, apnea-hypopnea index (AHI), and lowest oxygen saturation (LSAT) on preoperative sleep study, as well as amount of narcotic administered intraoperatively, were all associated with perioperative complications. The risk of complication was not associated with patient age or a set of several
Investigating these potential risk factors required 2 study designs—a cohort study and a nested case-control study—because some of the risk factor data were available only in the cohort database, and other risk factor data were available only in individual patient records. These studies received approval from the Human Subjects Division (institutional review board) of the University of Washington, Seattle; the Veterans Affairs Puget Sound Research and Development Committee, Seattle; and the Veterans Affairs National Surgical Quality Improvement Program (NSQIP) Executive Committee. The methods and results will be described for each study design separately.

PART 1: COHORT STUDY

Subjects

The cohort population consisted of adults undergoing inpatient UPPP for sleep apnea in US Veterans Affairs medical centers from 1991 to 2001. Uvulopalatopharyngoplasty was defined by a Current Procedural Terminology code of 42145 or 42298; patients who underwent other concurrent oncologic surgery of the head and neck were excluded (n=61).

Data

The patients were identified in the NSQIP database. At each Veterans Affairs medical center, trained nurse reviewers prospectively collected data on preoperative characteristics, operative variables, 30-day mortality, and perioperative complications; with the exception of 30-day mortality, the electronic database includes information solely related to the surgical procedure and the associated inpatient stay and does not incorporate other inpatient or outpatient visits. The database contains no data on BMI or sleep apnea disease severity (AHI or LSAT); therefore, the nested case-control study was required to consider these as potential risk factors for complication.

Risk Factors

Comorbidity in this cohort was measured in 2 ways. The American Society of Anesthesiologists (ASA) class was reported for all patients and was available in the database. Also, a simple count was made of 13 major medical comorbidities that are also reported in the database: acute renal failure or currently receiving dialysis, alcohol intake greater than 2 drinks daily, ascites, bleeding disorders, transfusion of more than 4 U of packed red blood cells within 72 hours before surgery, congestive heart failure, diabetes mellitus, disseminated cancer, impaired sensorium, severe chronic obstructive pulmonary disease, transient ischemic attack history, and ventilator dependence.

Outcome Variables

Sixteen specific serious complications were identified in the database. Complication data included 30-day mortality; respiratory events, including reintubation, pneumonia, prolonged ventilation (>48 hours), emergent tracheotomy, or pulmonary edema; cardiovascular events, including cardiac arrest, myocardial infarction, cerebrovascular accident, or pulmonary embolism; and other complications, including hemorrhage of more than 4 U of packed red blood cells, coma, wound infection, deep venous thrombosis, renal failure, or systemic sepsis.

Covariates

Demographic and health variables, which were collected prospectively for the entire cohort, included age, sex, race, smoking status, and year of operation. Current smokers were defined as those patients who had smoked within the year before surgery. Year of operation is considered a potential confounder because of temporal trends associated with practice patterns.

Analyses

Bivariate analyses were used to identify significant associations between risk factors and outcomes. For subgroup analyses of ASA class and concurrent procedures, the Fisher exact test was used to test for a difference between each subgroup and the remainder of the whole cohort. Simple logistic regression was used to calculate odds ratios (and estimate risk ratios) of serious complications associated with each category of concurrent procedure.

Multivariate logistic regression was used to determine the association between specific risk factors and perioperative complications after adjustment for the covariates. Odds ratios approximate risk ratios, also known as relative risk, because the risk of complication is less than 10%. Risk ratios are reported with 95% confidence intervals (CIs). Based on the sample size of 3130 patients in the cohort study and an approximate complication rate of 2%, we have 90% power to detect an odds ratio for the independent variable of interest (concurrent procedure) of 0.6 or lower, or an odds ratio of 1.7 or higher, at the .05 (2-sided) significance level. A P value of less than .05 was considered statistically significant for multivariate models, and the Bonferroni correction was applied for bivariate analyses of ASA class (+ classes) and concurrent procedures (11 groups and subgroups).
PART 2: NESTED CASE-CONTROL STUDY

The cohort database did not include data on BMI or sleep apnea severity (AHI or LSAT). Therefore, a nested case-control study design, with medical chart data extraction, was used to test these variables as risk factors for perioperative complication.

Subjects

The patient sample for the nested case-control study was derived from the above-described cohort of all adult inpatients who underwent UPPP. All 51 patients with serious complication in the NSQIP cohort were selected as cases. Approximately 4 control subjects (controls) were randomly selected from the cohort for every case (n=212 controls). Controls were matched to cases according to a set of variables present in the NSQIP database: age (10-year intervals), sex, any concurrent procedure, and year of surgery. Although cases and controls were matched by the presence of a concurrent procedure, there was no matching based on the type of concurrent sleep apnea procedure.

Data

Medical charts for the cases and controls were reviewed to obtain additional data on medical comorbidity, BMI, and sleep apnea severity (AHI and LSAT on preoperative sleep study).

Risk Factors

Comorbidity was measured with an additional, validated metric. The Charlson Comorbidity Index (CCI) is a weighted index of comorbidity based on the 1-year mortality associated with specific medical conditions.17 It is a composite measure of comorbidity that is validated and used widely in clinical epidemiology. Medical records were extracted for medical conditions documented in the 1 year before UPPP in order to formulate this index for each case and control. The BMI was derived from height and weight data recorded in the medical record at the time of UPPP. The AHI and LSAT were extracted from the most recent diagnostic sleep study (of any type) before UPPP.

Outcome Variables

Complications data were derived from the parent cohort database.

Covariates

Age, sex, and procedure year were not analyzed as independent covariates in the case-control study because these variables were controlled for by matching the controls to the cases. Race and smoking status were included as covariates, and the data were available in the parent cohort database.

Analyses

Demographic and risk factor variables were compared between cases with complication and controls without complication using the t test (normally distributed continuous variables), the Mann-Whitney U test (nonparametric continuous variables), or the Fisher exact test (dichotomous variables and proportions). Linear regression was performed to evaluate the potential association between the following risk factors: BMI, AHI, and LSAT. Coefficient estimates are reported with 95% CIs.

Multivariate logistic regression was used to model the association between each potential risk factor (AHI, LSAT, BMI, and CCI) as the independent variable and serious perioperative complication as the dependent outcome variable. Because of the potential for collinearity, only 1 variable that measures sleep apnea severity (AHI and LSAT) was included in the same multivariate regression model. All models were already controlled for age, sex, year of UPPP, and any concurrent procedure by the case-control matching strategy described in the “Subjects” section. Four sets of models were created, with progressively more adjustment for covariates. The first model for each risk factor was not adjusted. The second model for each risk factor was adjusted for race and smoking status. The third model included the risk factors (AHI [or LSAT], CCI, and BMI) simultaneously and was also adjusted for race and smoking status. A fourth model included the performance of any concurrent retrolingual procedure as an additional risk factor (and adjustment variable). Because the cases and controls were matched regarding the presence or absence of any concurrent procedure, we analyzed concurrent retrolingual procedure as a risk factor separately. Each risk factor was analyzed as a continuous variable. The odds ratios were expressed for standard clinical increments of BMI (calculated as weight in kilograms divided by height in meters squared) (5 kg/m²), AHI (15 events per hour), and LSAT (10% desaturation). Odds ratios are reported with 95% CIs. A P value of less than .05 was considered statistically significant.

For the univariate analyses, post hoc power analysis showed that the case-control study had 95% power to detect a BMI difference of 5, 52% power to detect an AHI difference of 15 events per hour, and 47% power to detect a LSAT difference of 10% between cases and controls (at the α = .05 [2-sided] significance level). To estimate the statistical power of the multivariate regression model that included the risk factors of model 3 (AHI, BMI, CCI, race, and smoking status), a post hoc calculation18 indicated that the case-control sample had 78% power to detect a BMI difference of 5 and 45% power to detect an AHI difference of 15 events per hour between cases and controls (at the α = .05 [2-sided] significance level). All available cases in the NSQIP database were used in the case-control study. No additional cases could be identified; therefore, it was not possible to increase the statistical power of this 10-year, nationwide sample.

RESULTS

PART 1: COHORT STUDY

Details about the cohort were reported previously.11 There were 3130 UPPP inpatients at Veterans Affairs medical centers from 1991 to 2001. The mean ± SD age of the patients was 50 ± 11 years, 97.0% were male, and 30.6% were current smokers. Most patients were ASA class 2 or 3 (Table 1).

Table 1. American Society of Anesthesiologists (ASA) Class vs Serious Complication Incidence

<table>
<thead>
<tr>
<th>ASA Class</th>
<th>Whole Cohort</th>
<th>Patients Without Complication</th>
<th>Patients With Complication</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>130</td>
<td>130 (100)</td>
<td>0</td>
<td>.27</td>
</tr>
<tr>
<td>2</td>
<td>1523</td>
<td>1503 (98.7)</td>
<td>20 (1.3)</td>
<td>.20</td>
</tr>
<tr>
<td>3</td>
<td>1424</td>
<td>1397 (98.1)</td>
<td>27 (1.9)</td>
<td>.32</td>
</tr>
<tr>
<td>4</td>
<td>53</td>
<td>49 (92.4)</td>
<td>4 (7.6)</td>
<td>.01</td>
</tr>
<tr>
<td>Total</td>
<td>3130</td>
<td>3079 (98.4)</td>
<td>51 (1.6)</td>
<td></td>
</tr>
</tbody>
</table>

*The Fisher exact test was used to compare the proportion of patients with serious complication in each ASA class with the proportion with complication in the remainder of the cohort. P < .01 was considered statistically significant (Bonferroni correction).
The majority of patients had few major comorbid conditions: 79% had 0, 14% had 1, 6% had 2, and 1% had more than 2 major comorbid conditions. Approximately 50% of the patients underwent at least 1 concurrent upper airway procedure with UPPP, most commonly a nasal procedure (Table 2). Both ASA class 4 and concurrent nonnasal procedures (as a group, the subgroup of retrolingual procedures, and certain individual retrolingual procedures) were associated with the incidence of serious complications on bivariate analysis (Tables 1 and 2).

Multivariable logistic regression showed that the relative risk for serious complication after UPPP was 1.98 (95% CI, 1.50-2.61) for each additional comorbid condition after adjustment for age, sex, race, smoking status, year of operation, and all concurrent sleep apnea procedures.

Table 3 presents the multivariate logistic regression results for the association between serious complication and procedures performed in addition to UPPP. Overall, there was no statistically significant effect of concurrent sleep apnea procedures in the risk of serious complication after adjustment for age, sex, race, smoking status, year of operation, and ASA class. There was no adjustment for BMI or sleep apnea severity because the data were not available in the cohort database. Based on the finding that the largest fraction of concurrent procedures comprised nasal procedures, separate evaluations were performed to test for an association between complications and concurrent nasal procedures and for other additional upper airway procedures. There was no statistically significant association between nasal procedures and serious complications; however, the risk of serious complication was higher (relative risk; 4.80; 95% CI, 2.32-9.14) when concurrent nonnasal upper airway procedures (as a group, the subgroup of retrolingual procedures, and individual procedures) were performed compared with UPPP alone.

PART 2: NESTED CASE-CONTROL STUDY

Charts were available for 43 (84%) of 51 case patients and 212 matched control patients. The pretreatment and concurrent surgery variables for cases and controls are presented in Table 4. Matching on the basis of age, sex, performance of any concurrent procedure, and year of surgery was successful; there were no differences between cases and controls for these matched variables. Cases with serious complication, on average, had greater preoperative BMIs and AHIs than controls without complication. Pre-

### Table 2. Concurrent Airway Procedures vs Serious Complications

<table>
<thead>
<tr>
<th>Concurrent Procedure</th>
<th>Cohort Patients, No. (%)</th>
<th>Patients Without Complication</th>
<th>Patients With Complication</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire cohort</td>
<td>3130 (100)</td>
<td>3079 (98.4)</td>
<td>51 (1.6)</td>
<td>. . .</td>
</tr>
<tr>
<td>Tonsillectomy†</td>
<td>1142 (36.0)</td>
<td>1126 (98.8)</td>
<td>16 (1.4)</td>
<td>.45</td>
</tr>
<tr>
<td>At least 1 concurrent OSA procedure, not counting tonsillectomy</td>
<td>1560 (50.0)</td>
<td>1529 (98.0)</td>
<td>31 (2.0)</td>
<td>.12</td>
</tr>
<tr>
<td>Concurrent nasal procedure</td>
<td>1401 (45.0)</td>
<td>1380 (98.5)</td>
<td>21 (1.5)</td>
<td>.60</td>
</tr>
<tr>
<td>Septoplasty</td>
<td>1177 (38.0)</td>
<td>1158 (98.4)</td>
<td>19 (1.6)</td>
<td>.96</td>
</tr>
<tr>
<td>At least 1 concurrent nonnasal upper airway procedure</td>
<td>228 (7.3)</td>
<td>213 (93.4)</td>
<td>15 (6.6)</td>
<td>.001</td>
</tr>
<tr>
<td>At least 1 concurrent retrolingual procedure</td>
<td>104 (3.3)</td>
<td>94 (90.4)</td>
<td>10 (9.6)</td>
<td>.001</td>
</tr>
<tr>
<td>Mandibular/genioglossus advancement</td>
<td>59 (1.8)</td>
<td>52 (88.0)</td>
<td>7 (12.0)</td>
<td>.001</td>
</tr>
<tr>
<td>Tongue excision</td>
<td>26 (0.8)</td>
<td>23 (88.0)</td>
<td>3 (12.0)</td>
<td>.001</td>
</tr>
<tr>
<td>Hyoid suspension</td>
<td>14 (0.4)</td>
<td>14 (100)</td>
<td>0</td>
<td>.63</td>
</tr>
<tr>
<td>Epiglottectomy</td>
<td>1 (0.03)</td>
<td>1 (100)</td>
<td>0</td>
<td>.90</td>
</tr>
<tr>
<td>Maxillomandibular advancement</td>
<td>10 (0.3)</td>
<td>10 (100)</td>
<td>0</td>
<td>.68</td>
</tr>
<tr>
<td>Tracheotomy</td>
<td>132 (4.2)</td>
<td>124 (93.9)</td>
<td>8 (6.1)</td>
<td>.001</td>
</tr>
<tr>
<td>At least 1 concurrent non-OSA procedure</td>
<td>170 (5.4)</td>
<td>168 (98.8)</td>
<td>2 (1.2)</td>
<td>.99</td>
</tr>
</tbody>
</table>

Abbreviation: OSA, obstructive sleep apnea.

*The Fisher exact test was used to compare the proportion of patients with serious complication in each procedure subgroup with the proportion with complication in the remainder of the cohort. P < .01 was considered statistically significant (Bonferroni correction).

†Tonsillectomy was considered part of uvulopalatopharyngoplasty (ie, not a concurrent procedure) in all analyses.

### Table 3. Adjusted Association Between Concurrent Airway Procedures (Independent Variable) and Serious Complication (Dependent Variable) in the Full Cohort

<table>
<thead>
<tr>
<th>Concurrent Procedure (Independent Variable)</th>
<th>Risk Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No concurrent procedure</td>
<td>1.00 (1.00)</td>
</tr>
<tr>
<td>Any concurrent OSA procedure</td>
<td>1.57 (0.89-2.77)</td>
</tr>
<tr>
<td>Concurrent nasal procedure</td>
<td>0.86 (0.49-1.51)</td>
</tr>
<tr>
<td>Concurrent nonnasal procedure</td>
<td>5.61† (3.02-10.4)</td>
</tr>
<tr>
<td>Concurrent retrolingual procedure</td>
<td>7.75† (3.77-15.9)</td>
</tr>
<tr>
<td>Genioglossus advancement</td>
<td>9.27† (3.99-21.5)</td>
</tr>
<tr>
<td>Tongue excision</td>
<td>8.31† (2.41-28.6)</td>
</tr>
<tr>
<td>Tracheotomy</td>
<td>4.44† (2.04-9.64)</td>
</tr>
</tbody>
</table>

Abbreviation: OSA, obstructive sleep apnea.

*Adjusted for age, sex, race, smoking status, year of operation, and American Society of Anesthesiologists class.

†P < .004 (Bonferroni-corrected significance level).
operative medical comorbidity was higher in cases than in controls. Although the selection of cases and controls included matching on the basis of concurrent procedures on the whole, a larger proportion of cases than controls underwent concurrent nonnasal sleep apnea procedures and, in particular, concurrent retrolingual procedures (on which matching did not occur specifically).

Data for the CCI (range, 0-6) were available in all 255 patients (43 cases and 212 controls). The majority of patients had a CCI less than 3, with decreasing prevalence with increasing index scores: index 0 (59%), index 1 (21%), index 2 (9%), and index 3 or more (11%). Greater comorbidity was associated with higher BMI and greater sleep apnea severity. Each unit increase in ASA class was associated with an increase in BMI of 2.73 (95% CI, 1.35-4.11), an increase in AHI of 11.5 events per hour (95% CI, 1.9-21.0), and a decrease in LSAT of 7.0% (95% CI, 3.6-10.4). Similar results were found for the CCI (data not shown).

The associations between serious complication and sleep apnea severity, BMI, and comorbidity are summarized in Table 5. In the logistic regression models reported in the table, sleep apnea severity was measured with the AHI, and comorbidity was measured with the CCI. Models 1 and 2 present results for the association of serious complication with the risk factors AHI, LSAT, BMI, and CCI considered in separate regression equations. The AHI, BMI, and CCI were each significantly associated with serious complications, even after matching for age, sex, year of operation, and presence of any concurrent procedure (models 1A, 1C, and 1D). The LSAT was not associated with serious complication. After race and smoking status were also adjusted for, sleep apnea severity (AHI) and BMI showed a trend toward a significant association with serious complication (models 2A and 2C), and the CCI was still significantly associated with serious complication (model 2D). The LSAT continued not to be associated with serious complication (model 2B).

Model 3A in Table 5 includes the AHI, BMI, and CCI together in the same model, and the results suggest that these are not risk factors independent of each other. Model 3B substituted LSAT for AHI in model 3A; the LSAT was not associated with serious complication. A fourth model (not shown in Table 5) added the performance of a concurrent retrolingual procedure as another risk factor to model 3A. As in the cohort study, the presence of a concurrent retrolingual procedure was independently associated with an increased risk of serious complication (adjusted odds ratio, 4.89; 95% CI, 1.08-22.20; P = .04). The coefficient point estimates for the other risk factors (AHI, BMI, and CCI) were largely unchanged from model 3A,
with P values still greater than .05. The results shown in Table 5 were similar when the ASA class or the count of comorbid medical conditions instead of the CCI was used as a measure of medical comorbidity (data not shown).

**COMMENT**

This study attempted to overcome limitations in the few previous studies that examined risk factors for post-UPPPP complications. The large, nationwide, multiyear cohort provided greater statistical power than smaller, single-site samples. This greater power allowed control of potential confounding variables such as age, sex, race, year of UPPP, and smoking status. Also, the study tested a priori hypotheses about potential risk factors rather than simply exploring data for variables associated with complication. It is challenging to test these hypotheses because the rare incidence of serious complication limits the statistical power, particularly for analyses incorporating multiple potential risk factors, even in cases accumulated from this nationwide, multisite, and multiyear cohort.

Body mass index data were available only from medical records. For the rare complication outcomes, the case-control study design was the only feasible method to test this risk factor. In the nested case-control analyses, BMI was associated with the occurrence of serious complication in simple regression analysis after controlling (by matching) for age, sex, year of surgery, and presence of any concurrent procedures. However, after adjustment for AHI and comorbidity in multivariate regression, the BMI coefficient suggested that there was a relationship, although the result showed only a statistical trend. The results of previous research evaluating this risk factor are mixed. Haavisto and Suonpaa found that weight greater than 93 kg was associated with respiratory complications, while Mickelson and Hakim reported no increased risk of complication with increases in BMI. This latter study of 347 patients may have had inadequate statistical power to detect an association between BMI and complication. The former study was limited by the use of absolute weight rather than the height-adjusted BMI variable. Relative to body weight alone, BMI is a more accurate measure of obesity and is more strongly associated with sleep apnea.

Like BMI data, AHI data were only available from the medical records. Thus, this risk factor was also tested with a case-control study design. In the nested case-control analyses, AHI was associated with serious complication in simple regression analysis after controlling (by matching) for age, sex, year of UPPP, and presence of any concurrent procedures. After adjustment for BMI and comorbidity in multivariate regression, the coefficient point estimate (as for BMI) suggested an association but only showed a statistical trend. The LSAT was not significantly associated with complication in any of the analyses. These results disagree with the findings of Haavisto and Suonpaa, who reported a relationship between comorbidities and LSAT, and disagree to some extent with those of Mickelson and Hakim, who found no relationship between serious complication and preoperative sleep study results such as AHI or LSAT. However, the results agree somewhat with those of Esclamado et al, who found an association between complications and sleep apnea severity (apnea index and LSAT). Because the latter authors did not perform multivariate regression to adjust for other variables, it is unclear whether the observed relationship would have persisted after adjustment for potential confounding variables. It should be noted that our nested case-control sample had limited statistical power and that these studies with smaller samples have even less statistical power. The nearly statistically significant independent association of AHI and BMI with serious complication despite low statistical power suggests that a real association likely exists.

Comorbidity data were available in the cohort database (ASA class and the list of 13 comorbidities) and in the medical records (CCI). We analyzed comorbidity all 3 ways because each comorbidity analysis had a limitation: (1) the ASA class is the least detailed scale of comorbidity; (2) the list of 13 comorbidities has not been independently validated outside of veteran patient samples in the NSQIP; and (3) the CCI data were available only in our case-control study design, which had lower statistical power.

In the cohort analyses, each measure of comorbidity (ASA class and the list of 13 comorbid conditions) was significantly associated with serious complication, even after adjustment for age, sex, race, smoking status, year of operation, and concurrent procedures. In the nested case-control study, comorbidity (CCI) was associated with serious complication after controlling (by matching) for age, sex, year of UPPP, and any concurrent procedure and after adjustment for age and smoking status. However, when AHI and BMI were included in the multivariate model, comorbidity was no longer significant (P = .97), suggesting that it may not be a risk factor independent of AHI and BMI. It is possible that severe sleep apnea increases risk largely because it is associated with poorer overall baseline health. The review of Esclamado et al found no association between complications and certain specific cardiopulmonary conditions, but the larger sample from our study—combined with the consistency of an association for different validated measures of comorbidity—suggests that comorbidity is an important risk factor for serious perioperative complication.

This finding in patients who undergo sleep surgery is consistent with that seen in patients who undergo other types of surgery. Concurrent sleep apnea procedures in general and concurrent nasal procedures in particular were not significantly associated with an increased risk of serious complication. The latter finding disagrees with that of Mickelson and Hakim. However, the cohort described herein differs from theirs. Compared with their patient population, a much larger fraction of patients in our cohort underwent additional procedures besides UPPP (primarily nasal procedures). Also, a smaller fraction of our cohort underwent concurrent nonnasal procedures. Finally, there were differences between their study and ours in the definition of perioperative complications. Mickelson and Hakim report many less-serious complications (such as shortness of breath treated with supplemental oxygen and post-
operative ileus) in their series that would not have been included in our count of serious perioperative complications reported in the cohort database. Concurrent nonsal upper airway procedures and, especially, concurrent retrolingual procedures showed significant independent associations with serious complication in both the cohort and nested case-control analyses. However, it is not clear whether these increased risks are greater or less than the cumulative risks of performing UPPP and the other procedure(s) separately.

There are limitations to the analyses. The prospective cohort database lacked data on sleep apnea severity (AHI and LSAT) and obesity (BMI). The case-control study depended on the accuracy of recording of sleep study results, medical comorbidity, and BMI in the medical records. The heterogeneous sleep study techniques and AHI definitions are inherent in multisite observational studies on sleep apnea and limit our interpretation of the impact of AHI. However, there is a severe lack of standardization of sleep study techniques and AHI definitions in the routine clinical practice of sleep medicine, so the heterogeneity of sleep study methods in our study contributes to generalizability.

Perioperative management may play a substantial role in the likelihood that serious complications will develop. Data on perioperative management were not abstracted in the NSQIP cohort database. One aspect of perioperative management is the planned use of a postoperative intensive care unit. Planned postoperative intensive care was not controlled for in these analyses and might confound the association between our hypothesized risk factors and complication outcomes. Planned postoperative intensive care is probably more likely in patients with greater AHI, BMI, or comorbidity, and it should decrease the risk of serious complication. Thus, we might have underestimated the actual association between these risk factors and serious complication. The impact of postoperative intensive care on the risk of serious complication is an important one that cannot be addressed in this study.

Despite the large sample size, the rare outcome of serious post-UPPP complication may render this study inadequately powered to isolate the independent significance of various risk factors. All attempts were made to maximize statistical power: all serious complications were identified for this multisite, multiyear, multi-institutional cohort; the case-control sample included all patients from the NSQIP cohort for whom medical records could be located; and each case patient was matched with 4 control patients (increasing the number of matched controls per case would not produce a substantial increase in power). For the simple regression models, the case-control sample had 47% power to detect a difference in LSAT of 10% between patients with and without serious complication, but it had lower power to detect smaller differences in LSAT. More importantly, the power of the multivariate regression analyses that incorporate multiple risk factors is lower; therefore, the sample has insufficient power to test the independent association of these risk factors. Because the AHI, BMI, and comorbidity index coefficient estimates did not change markedly in these multivariate regression models (models 1 through 3 in Table 5), the results suggest that these risk factors are associated with the complication outcome. Nevertheless, it would be valuable to reassess the risk associated with sleep apnea severity, BMI, and medical comorbidity in an even larger cohort that includes these data. It will be a challenge to identify such a cohort, so the current study may offer the most statistical power available at this time.

Finally, the data are exclusively from inpatient veterans and may not be generalizable to all adult patients who undergo UPPP. For example, veterans, on average, are sicker than the general population.23 However, the large cohort size, broad geographic distribution, inclusion of all UPPP procedures, and multitude of surgeons all add to the generalizability of this study.

### CONCLUSIONS

Medical comorbidity, AHI, and BMI are risk factors for serious complication after UPPP, but they might not be independent of each other. The LSAT was not associated with serious complication, although the sample size was inadequate to rule out a small effect. The risk of serious complication was also associated with concurrent retrolingual (nonsal) procedures; however, the cumulative risk of separate retrolingual procedures is unknown.
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