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What is This?
Correlation between Nasal Anatomy and Objective Obstructive Sleep Apnea Severity

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No sponsorships or competing interests have been disclosed for this article.

Abstract

Objectives. To determine if a correlation exists between nasal anatomical obstruction and obstructive sleep apnea severity as measured by overnight polysomnogram (PSG).

Study Design. Cross-sectional study.

Setting. Tertiary medical center.

Subjects and Methods. Subjects were recruited immediately prior to an overnight, in-lab PSG. All subjects who agreed to participate underwent a standardized nasal examination performed by the senior author and then completed the Nasal Obstruction Symptom Evaluation (NOSE) questionnaire, the Snore Outcomes Survey (SOS), and the Epworth Sleepiness Scale (ESS) prior to their sleep study. In addition, tonsil size, Mallampati score, Friedman tongue position, neck circumference, uvula length, and occlusion were assessed and documented. Nasal anatomy assessments were then compared with PSG, NOSE, SOS, and ESS results. Bonferroni correction was used to account for multiple comparisons.

Results. One hundred subjects were included in the study. Fifty-nine subjects (59%) were found to have obstructive sleep apnea syndrome (OSAS) (mean apnea-hypopnea index, 13.1; range, 0-64). Severity of OSAS was associated with age (Spearman’s ρ = 0.386, P = .0001). No single nasal anatomy measurement or combined nasal anatomy index was found to correlate with objective sleep-disordered breathing severity measured by PSG. The sample size should have provided 90% power to detect a significant correlation if one existed. After accounting for multiple comparisons, turbinate hypertrophy was found to correlate with the NOSE score (0.3577, P = .0305 corrected), and external and internal nasal valve collapse correlated with each other (0.4986, P < .0001 corrected).

Conclusions. Objectively assessed abnormal nasal anatomy was not found to be significantly correlated with PSG-measured OSAS severity. Specific objective measurements of obstructive nasal anatomy were correlated to subjective measures of nasal obstruction.

Keywords

nasal anatomy, obstructive sleep apnea, nasal obstruction, snoring, NOSE, SOS, OSA

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Obstructive sleep apnea syndrome (OSAS) affects between 2% and 17% of the adult population.¹ It is associated with poor sleep quality, excessive daytime sleepiness, depression, weight gain, and increased cardiovascular morbidity and mortality.¹ Obstructive sleep apnea syndrome is caused by an inability to move air through the upper airways during sleep. The gold standard for the treatment of OSAS is through the use of a continuous positive airway pressure (CPAP) device to stent open the upper airway and improve oxygen delivery to the distal airspaces. Continuous positive airway pressure is an effective treatment when patients tolerate the device; however, its efficacy is limited by poor compliance.²⁻⁴ Many patients then turn to surgical correction, which currently also has a limited success rate. The combination of low compliance and low overall surgical success rates leaves many patients undertreated.

Despite the fact that the nasal airway is an inherent component of the upper airway, its contribution to OSAS...
severity is poorly understood. Some surgeons advocate correlation of nasal obstruction as a modality to improve CPAP compliance or even claim improvement in OSAS severity. In contrast to oropharyngeal obstruction, the association between nasal airway obstruction and sleep-disordered breathing (SDB) has not been as well elucidated, nor have staging systems been developed to evaluate nasal airway obstruction. To improve patient selection and expectant surgical success, Friedman et al developed a clinical staging system using palate position, tonsil size, and body mass index (BMI) to help predict the presence and severity of obstructive sleep apnea (OSA) and to improve patient selection for uvulopalatopharyngoplasty (UPPP) surgery. This clinical staging system clarified patient selection, and subsequently the overall success of UPPP surgeries was demonstrated to increase for appropriately selected patients. If a similar understanding of the key components of nasal anatomical abnormalities can be gained, then perhaps nasal therapy with both medical and surgical approaches could lead to improved patient outcomes.

The purpose of this study is to assess the relationship between nasal obstruction as determined by a detailed nasal physical examination and the Nasal Obstruction Symptom Evaluation (NOSE) survey, as well as OSAS as determined by polysomnography (PSG), while controlling for confounding variables such as the Friedman tongue position (FTP), dental maloclusion, neck circumference, and BMI. Determining an association between nasal anatomic factors, subjective nasal obstruction, and OSAS is critical to determining the appropriate management for patients with OSAS. To achieve this goal, our primary objectives were to create a standardized nasal examination that can be used to quantitatively evaluate nasal anatomic issues, to determine if certain nasal examination findings were predictive of high levels of subjective nasal obstruction (snoring and sleepiness), and then to determine if a correlation exists between objective and subjective nasal dysfunction and the severity of OSAS.

Methods

The Walter Reed National Military Medical Center Institutional Review Board approved the study protocol, and all participants provided informed consent. Subjects were recruited prior to undergoing overnight PSG. Inclusion criteria were (1) 18 years old or older, (2) willing to complete surveys, (3) consent to a physical examination, and (4) undergoing a diagnostic PSG. Exclusion criteria consisted of (1) younger than 18 years and (2) indication for PSG other than possible diagnosis of OSAS (eg, CPAP titration).

Immediately prior to PSG, all subjects underwent a detailed nasal and pharyngeal examination by the senior author (R.W.L., a board-certified facial plastic surgeon) (Figure 1). The severity of external nasal valve (ENV) narrowing and collapse was determined on external nasal examination at rest and with inspiration. Anterior rhinoscopy was performed to evaluate for turbinate hypertrophy (TH), septal deviation (SD), and the status of the internal nasal valve (INV) at rest and with inspiration. The subject’s nares was closed on one side by finger compression during nasal inspiration. A cotton tip applicator was then used to laterally displace the nasal sidewall, and the subject was asked to inhale again and asked if his or her breathing improved. This was performed on both sides and then repeated with lateral displacement of the cheek (Cottle maneuver). One puff of oxymetazoline was sprayed into each nare, and the inferior turbinates were reexamined after the pharyngeal measurements were completed. Pharyngeal measurements included occlusion, tonsil size (TS), Mallampati scale (MS), FTP score, and uvula size. Other pertinent information was also collected, including history of allergic rhinitis, chronic sinusitis, nasal trauma or nasal surgery, age, sex, neck circumference, and height/weight for calculation of BMI. All subjects were also asked to complete the validated NOSE questionnaire, the Snore Outcomes Survey (SOS), and the Epworth Sleepiness Scale (ESS) questionnaires.

All PSG studies were performed in accordance with guidelines published by the American Academy of Sleep Medicine. Subjects underwent an attended, overnight PSG using a 16-channel montage (Sensormedics Alpha Somnostar system; Sensormedics, Yorba Linda, California). All studies were scored by a registered PSG technician and reviewed and interpreted by a physician board certified in sleep medicine. Statistical analysis was performed with the assistance of computer software (Stata version 8.2; StataCorp, College Station, Texas). The data were evaluated using descriptive statistics, linear correlation (using both parametric and nonparametric methods), Student t test, and multivariate linear regression. The primary method of individual analysis was the Spearman’s ρ correlation coefficient as most of the anatomical data were placed in ordinal categories. Total anatomical composite scores (eg, total TH score, total SD score, total Cottle maneuver score, change in turbinate with afrin, and 7 composite nasal anatomical measurements (total septal deviation, total turbinate hypertrophy, total ESV collapse, total INV collapse, change in turbinate with afrin, total Cottle maneuver score, and total nasal anatomy score). As the total nasal score was composed as a summation of the turbinate hypertrophy, septal deviation, and valve collapse scores, its correlation with its summative components was ignored.
Results

Demographics and Baseline Measurements

One hundred subjects were included in the study. Fifty-nine subjects (59%) were found to meet the diagnostic criteria for OSAS of an AHI of greater than 5 events per hour. Additional demographic data are shown in Table 1. Given the study population represents patients presenting to an overnight sleep laboratory for a PSG for possible OSAS, it is distinctly different from a general population in that there are more male patients and more self-reported allergic rhinitis, sinusitis, and snoring. Severity of OSAS, quantified by the AHI as measured by overnight PSG, was significantly associated with increasing age (correlation coefficient = 0.3632, \( P = .0291 \) with Bonferroni correction) (Table 2). As expected, neck circumference was associated with male sex (0.6437, \( P < .0001 \) corrected) and BMI (0.6745, \( P < .0001 \) corrected). Age, sex, and BMI were carefully considered as possible confounding factors and/or effect modifiers throughout the subsequent analysis. Some analyses (as indicated) were performed only on subjects with OSAS and some on all included subjects without or without OSAS. Categorical variables such as self-reported allergic rhinitis, sinus disease, nasal trauma, tobacco use, and snoring were not associated with an OSAS diagnosis or OSAS severity on PSG.

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**Figure 1.** Nasal anatomical examination worksheet.
Association of Nasal Anatomical Measurements to Objective OSAS Severity

No single nasal anatomy measurement was found to correlate with the AHI (total, supine, or nonsupine) or ESS results (analysis completed separately for all subjects and for subjects with OSAS only). Various calculated indices of several nasal anatomy measurements grouped together, including a total nasal anatomy abnormality score, were also not found to correlate with any measurement of OSAS severity or ESS (Figure 2). Nasal anatomy measurements were not found to be correlated with age, sex, or BMI. Possible confounding by age, sex, and BMI was extensively explored with no significant findings. Post hoc power analysis indicates that the sample size should have provided more than 90% statistical power to detect a significant association between nasal anatomy and the AHI, if one existed.

Association of Nasal Measurements to Subjective Nasal Obstruction Severity (NOSE Instrument) and Subjective Snoring (SOS Instrument)

For all subjects (with and without OSAS), the NOSE score significantly correlated with total TH score (correlation coefficient = 0.3577, \( P = .0305 \) with Bonferroni correction) only. This association was present in subjects with and without a diagnosis of OSAS on PSG. NOSE scores were not significantly correlated with age, sex, BMI, AHI (total, supine, or nonsupine) or tobacco use, history of nasal trauma, or history of nasal surgery.

For all subjects (with and without OSAS), associations between subjective snoring assessments using the SOS were also explored. The SOS instrument produces a score between 0 (worse snoring) and 100 (no snoring). Therefore, negative correlations would be expected between anatomical measurements and snoring severity as quantified by the SOS score. The SOS score was not significantly correlated with age, sex, BMI, AHI (total, supine, or nonsupine), or any nasal anatomical measurement. In addition, self-reported tobacco use, history of nasal trauma, or history of nasal surgery was also not found to be correlated with SOS score.

Association among Nasal Anatomical Measurements

The total ENV and INV collapse scores were strongly correlated with each other (correlation coefficient = 0.4986, \( \text{P} < .0001 \) with Bonferroni correction) (Figure 3). No other associations were found after Bonferroni adjustment.

Multivariate Linear and Logistic Regression

Multivariate linear regression was used to assess the contribution of multiple covariates in the prediction of the total AHI. Multiple models were developed using both forward and backward stepwise approaches as well as interaction terms. Age, BMI, and male sex were included in all models due to their known association with AHI. No nasal or pharyngeal measurements were found to be significant covariates in any of the multivariate models. Logistic regression modeling using both an OSAS diagnosis (AHI >.5) and a moderate to severe OSAS diagnosis (AHI >.15) as the (yes/
no) binary outcome produced identical results with no significant nasal or pharyngeal measurement covariates after adjustment for age, sex, and BMI.

Discussion

Obstructive sleep apnea syndrome is a common, chronic medical condition associated with significant morbidity and mortality. Nasal obstruction has been mentioned as an etiologic factor for SDB; however, its contribution as an anatomic factor has not been elucidated.\(^8,15\) The nose accounts for more than half of the total upper respiratory system resistance.\(^15\) Based on physiologic studies in healthy subjects, breathing during sleep is primarily nasal except when a nasal airway obstruction exists.\(^16,17\) One study demonstrated that when nasal obstruction exists, oral breathing is favored, resulting in a narrowed hypopharyngeal space and more frequent apneic and hypopneic episodes\(^16;\) however, research examining the correlation between nasal obstruction and polysomnography is limited, especially with regard to objective measures of nasal obstruction. The goal of this study was to improve the understating of the association between SDB and nasal airway obstruction through the use of a standardized nasal examination prior to PSG to assess the relationship between anatomical nasal obstruction, patient-reported symptoms of nasal obstruction, and OSA.

Research to date has shown inconsistent relationships between nasal obstruction and SDB. Previous studies by Suratt et al,\(^18\) Zwillich et al,\(^19\) and Taasan et al\(^20\) have shown that iatrogenically induced nasal obstruction in healthy adults has resulted in a significant increase in apnea during sleep, although these studies were based on small sample sizes (Suratt, N = 8; Zwillich, N = 10; and Taasan, N = 7). In 2011, Friedman and colleagues\(^21\) conducted polysomnogram testing on 49 patients with OSAS who underwent nasal surgery with packing. The authors concluded that patients with mild OSAS showed an increase in respiratory distress index, AHI and snoring with nasal obstruction. Measures of snoring were not aggravated in patients with severe OSAS, consistent with previous reports of nasal surgery being ineffective for reducing measures of snoring in patients with SDB. These findings are consistent with the work of Virkkula et al,\(^22\) who failed to show improvement in snoring time or intensity after nasal surgery in patients with nasal obstruction and SDB.

Unlike the Mallampati classification and the FTP assessment technique, which are significantly correlated with increasing OSA severity,\(^23\) a uniform staging system for the nasal airway has not been developed. Furthermore, a standardized nasal examination does not currently exist to evaluate the septum, turbinates, and the INV and the ENV. Most studies notate SD but make no mention of the location of the deviation or the status of the nasal valve or turbinates. For this study, we created a nasal examination worksheet to attempt to quantify distortion at key anatomic levels. Focus was placed on the level of TH with and without nasal decongestion, the amount of static narrowing of the INV and the ENV, the region and severity of septal deviation, the level of collapse of the INV and ENV on inspiration, and the patient response to the Cottle and Q-tip maneuvers.

Multiple disease-specific quality-of-life (QOL) surveys have been developed and are already frequently used to evaluate nasal obstruction, snoring, and sleepiness.\(^24\) In this study, we used the NOSE survey, the SOS, and the ESS to evaluate subjects prior to in-laboratory PSG. The NOSE scale is a valid, reliable, and responsive instrument that evaluates nasal obstruction as it affects QOL.\(^9\) The SOS is also a validated, reliable, and responsive instrument that evaluates the duration, severity, frequency, and consequences of problems associated with SDB and snoring in particular.\(^13\) The ESS is a validated screening tool for excessive daytime sleepiness.\(^14\) This study demonstrated a correlation between measured nasal abnormalities and nasal obstructive QOL. A correlation between measured nasal abnormalities and subjective snoring was not found. The

![Figure 2](image2.png)

**Figure 2.** Scatter plot of the total nasal anatomical abnormality score and the total apnea-hypopnea index (AHI). There is no discernible relationship. Spearman’s $p = -0.006$, $P = .9529$.

![Figure 3](image3.png)

**Figure 3.** Scatter plot of the total internal and external valve obstruction scores. As expected, there is a strong positive correlation. Spearman’s $p = 0.4852$, $P < .0001$. 
NOSE score was correlated with TH, validating the association of the observed anatomical nasal obstruction with the subjects’ perceived nasal obstruction.

This study has some important limitations to consider. First, the cohort was 80% male. Although concerning in terms of generalizability, this is not unusual for OSA studies and may be a result of a true biologic preponderance, a selection bias of a US military population, or a selection bias that more male patients (perhaps urged by a female companion) seek evaluation and treatment for OSAS. Regardless, the analysis was stratified by sex, and there was still no association between nasal anatomical abnormalities and OSAS diagnosis or severity for males or females. The conservative Bonferroni correction approach that was used in the analysis should result in only robust, appropriate associations to be notated as statistically significant. However, it should be noted that this approach could also result in an increase in the possibility of a type II error as other valid associations could have been present but by this method were excluded. Another limitation of the study is that the nasal anatomic worksheet has not been assessed in terms of validity or reliability. Although validity was not the directed goal of this study, the fact that several components of the nasal anatomic worksheet correlated with the NOSE score strongly suggests appropriate validity. The nasal anatomic worksheet represents a simple organization of all the pertinent aspects of the physical examination of the nasal cavity; therefore, we did not feel a formal assessment of reliability was critical for the study. Regardless, a separate reliability study is being considered.

Nasal anatomy should be evaluated in a standardized fashion in patients undergoing evaluation for OSAS as a part of a comprehensive evaluation. On the basis of the results of this study, the authors would not recommend turbinoplasty, septrhapy, or nasal valve correction as a primary treatment of OSAS even in patients with obvious TH, severe SD, and/or nasal valve compromise. Patients undergoing surgery to correct symptoms of nasal obstruction should have a clear understanding that these procedures are not intended to cure their sleep apnea. However, anatomic nasal defects that are associated with nasal obstruction may adversely affect a patient’s ability to tolerate CPAP. Nasal valve compromise, TH, and SD should be identified in patients with OSAS and corrected in patients with poor CPAP compliance. Furthermore, knowledge of the nasal anatomy may prove to have utility in mask selection. Future research will be needed to evaluate the impact of nasal surgery on CPAP compliance.

While correcting an obstructed nasal airway and restoring nasal patency have been thought of as important to improve CPAP effectiveness and usage compliance, surgical intervention to correct nasal occlusion alone has shown limited efficacy for the primary treatment of OSAS. Our data support this view. Extensive efforts were used to account for possible confounders from known associations with OSAS severity, including age, sex, BMI, and so on. The study was designed to have 90% power to detect an association if one existed. After careful, detailed anatomical measurements and extensive data analysis, we found no significant association between nasal anatomical abnormalities and OSAS severity in the largest group of patients heretofore systematically analyzed.

**Conclusion**

Abnormal nasal anatomy was not found to be significantly associated with objective OSAS severity. Specific measurements of abnormal nasal anatomy using a standardized examination were correlated to subjective measures of nasal obstruction.

**Author Contributions**

Keith P. Leitzen, conception and design, acquisition of data, analysis and interpretation of data, drafting and revising manuscript, final approval of manuscript; Scott E. Brietzke, analysis and interpretation of data, drafting and revising manuscript, final approval of manuscript, supervision; Robin W. Lindsay, conception and design, acquisition of data, analysis and interpretation of data, drafting and revising manuscript, final approval of manuscript, supervision.

**Disclosures**

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