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Review Article
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Prevalence of Sleep-Disordered Breathing in Patients Who Underwent Endoscopic Nasal Sinus Surgery: Investigation of Nasal Obstruction as a Risk Factor for Sleep-Disordered Breathing

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Abstract

Purpose: To investigate the prevalence of Sleep-Disordered Breathing (SDB) in patients with nasal diseases who underwent Endoscopic Nasal Sinus Surgery (ESS) compared with control patients without nasal disease who underwent tonsillectomy.

Methods: An observational retrospective case-control study was conducted of 155 adults with nasal diseases who underwent ESS (ESS group) as well as 94 adults with no nasal symptoms or diseases who underwent tonsillectomy due to infection of the tonsils (tonsillectomy group). Patients with obstructive sleep apnea, patients with a chief complaint of snoring or excessive daytime sleepiness, or patients having large tonsils were excluded from the study. Home sleep apnea testing was performed prior to admission for surgery.

Results: The prevalence in normal, mild, moderate, and severe SDB was respectively 29.0%, 38.7%, 23.2%, and 9.0% in the ESS group and 50.0%, 39.4%, 10.6%, and 0% in the tonsillectomy group. There were significant differences in the mean 3% oxygen desaturation index (3% ODI) score between the ESS and tonsillectomy groups in men but not in women. Obese men in the ESS group were much more susceptible to having moderate or severe SDB when they were aged ≥40 years. Regression analysis revealed that the preoperative 3% ODI score had two significant determinants in the ESS group-BMI and male sex-whereas age, nasal resistance, and CRS with nasal polyps were not significant predictors.

Conclusions: Among patients who underwent ESS, 32.3% had moderate to severe SDB, including 9.0% with severe SDB. Nasal obstruction could be a potential risk factor for SDB in male patients.

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Introduction

Nasal obstruction is a common complaint among patients with Chronic Rhinosinusitis (CRS), nasal allergies, or nasal septal deviation. In these patients, a significant increase in nasal resistance can influence the collapsibility and resistance in the pharynx located downstream from the nose during sleep, leading To Sleep-Disordered Breathing (SDB).

A previous study reported that Obstructive Sleep Apnea (OSA) was induced when the nose of a healthy individual was blocked [1]. In addition, the Wisconsin Sleep Cohort Study revealed that participants who reported nasal congestion due to allergy were 1.8 times more likely to have moderate to severe SDB than those without nasal congestion due to allergy [2]. In another study, stepwise multiple regression analysis showed that nasal resistance, body mass index (BMI), male sex, and cephalometric parameters were contributing factors to SDB severity [3]. Another study in an American population revealed that patients diagnosed as having CRS had a higher likelihood of having already received a diagnosis of SDB compared with a control population that did not have CRS [4]. A recent study reported that the prevalence of OSA was 4.39 times higher in the nasal septal deviation group compared with the control group, which was more pronounced with increasing BMI but decreased significantly after septoplasty [5].

Endoscopic Nasal and Sinus Surgery (ESS) is recommended for patients with nasal diseases when patients do not respond to conservative treatments. It is well known that some patients with

SDB require ESS. However, it is not well-known what percentage of patients who are undergoing ESS have SDB. Therefore, the purpose of this study was to investigate the prevalence of SDB in patients with nasal diseases who underwent ESS compared with control patients without nasal diseases or SDB symptoms who underwent tonsillectomy due to infection of tonsils.

Methods

This observational retrospective case-control study involved adult patients aged ≥20 years who were diagnosed as having CRS, CRS with nasal polyps (CRSwNP), nasal allergies, or septal deviation and underwent ESS under general anesthesia (ESS group) as well as patients who had no nasal symptoms or diseases and underwent tonsillectomy under general anesthesia due to a diagnosis of chronic tonsillitis or focal infection of tonsils such as IgA nephropathy, sternocostoclavicular hyperostosis, or palmoplantar pustulosis (tonsillectomy group). Patients with nasal diseases were excluded from the tonsillectomy group on the basis of nasal endoscopy and x-ray findings. Patients who had SDB, patients who visited an outpatient clinic with a chief complaint of snoring or excessive daytime sleepiness, and patients who had large tonsils (Brodsky classification grade 2, 3, and 4) were excluded from the study. Patients who were diagnosed as having uncontrolled or serious illness (i.e., neurological diseases, chronic heart failure, pulmonary disease, or any other comorbid sleep disorders) were also excluded. Patients who were diagnosed as having tumors or cysts in the nasal cavity or sinuses were excluded from the ESS group. Patients were recruited from April 2016 to March 2024 in our ENT department.

Patients were divided into three categories based on their BMI (<25, non-obese; ≥25 to <30, obese I; ≥30, obese II) according to the guidelines for the management of obesity disease [6].

Home Sleep Apnea Testing (HSAT) was performed at home prior to admission for surgery. For the HSAT examination, patients were instructed on the use of a type 3 device (PMP-300; Philips Respironics, Pittsburgh, PA) through one-on-one instruction with a sleep technologist. A pulse oximeter was attached to the patient's finger, using a flexible probe. The obtained data were fed into a personal computer, and the signals were digitized and recorded using the accompanying software. The graphic display shows oxygen saturation against time with 10 data points per minute, with each point representing the lowest saturation in a 6-sec interval. Baseline saturation was defined as the mean saturation in the previous minute. The algorithm sequentially scans each recorded oxygen saturation value, and if the lowest oxygen saturation value is 3% lower than the baseline oxygen saturation, the program assigns an event marker as a 3% desaturation event. We set 3% desaturation as the index criterion of the Oxygen Desaturation Index (ODI) for HSAT according to the guidelines of the AASM scoring manual [7]. The 3% ODI score was calculated by dividing the total number of 3% oxygen desaturation events by the total monitoring time. Records were manually reviewed for all patients by sleep specialists. Monitoring time was defined as the total recording time minus periods of artifact and the time during which the patient was awake. In most cases, type 3 HSAT was performed for 2 nights. For patients with multiple HSAT measurements, the higher ODI score was included in the analyses. Patients with a 3% ODI score of <5/h were classified as normal, ≥5/h to <15/h as having mild SDB, ≥15/h to <30/h as having moderate SDB, and ≥30/h as having severe SDB.

Nasal Resistance (NR) was measured with an anterior rhinomanometer (HI-801; Chest M.I., Inc., Tokyo, Japan) in the supine position. Left, right, and total inspiratory nasal resistance values at negative 100 Pa were also measured.

CRSwNP was diagnosed according to the European position paper on rhinosinusitis and nasal polyps 2020 based on the evidence of type 2 inflammation (the number of eosinophils in the mucosa tissue, peripheral blood, or total IgE of peripheral blood), the need for systemic corticosteroids, significantly impaired quality of life, significant loss of smell, and a diagnosis of comorbid asthma [8].

Statistics and Ethics

The Ethics Committee of Teikyo University approved this study (Approval No. Teirin 24-048). The descriptive statistics for all variables are presented as the mean ± standard deviation. Differences between unpaired subjects were evaluated by the Mann–Whitney U test. A p value less than 0.05 was considered statistically significant. All statistical analyses were performed using the IBM Statistical Package for Social Science (ver. 26; IBM Inc., Armonk, NY).

Results

We analyzed data from 155 adults (110 male and 45 female) for the ESS group (mean age, 49.7 ± 15.7 years [20 to 79]; mean BMI, 24.0 ± 4.2 kg/m^2 [15.6–39.3]; mean 3% ODI, 12.3 ± 11.5/h [0 to 61.8]; mean Respiratory Event Index [REI], 11.5 ± 11.4/h [0 to 60.9]; mean bilateral NR, 0.51 ± 0.40 Pa/cm3/sec [0.07 to 2.56]), and 94 adults (50 male and 44 female) for the tonsillectomy group (mean age, 38.6 ± 14.3 years [20 to 75]; mean BMI, 24.9 ± 4.9 kg/m^2 [17.1 to 35.7]; mean 3% ODI, 5.7 ± 4.9/h [0 to 20.6]; mean REI, 4.9 ± 4.7/h [0 to 25.4]).

Among patients in the ESS group, the prevalence of normal, mild, moderate, and severe SDB was respectively 29.0% (n=45), 38.7% (60), 23.2% (36), and 9.0% (14), while among patients in the tonsillectomy group, it was 50.0% (47), 39.4% (37), 10.6% (10), and 0% (0) (Figure 1).

There were significant differences in the mean 3%ODI score between the ESS and tonsillectomy groups in both non-obese (p=0.01) and obese (p=0.04) men, whereas there were no significant differences in non-obese (p=0.35) and obese (p=0.71) women (Figure 2).

The mean 3% ODI scores according to BMI and age categories in the ESS group in men are shown in Figure 3. Increased BMI was related to a greater 3% ODI score. Male patients categorized as obese I and II were much more susceptible to having moderate or severe SDB

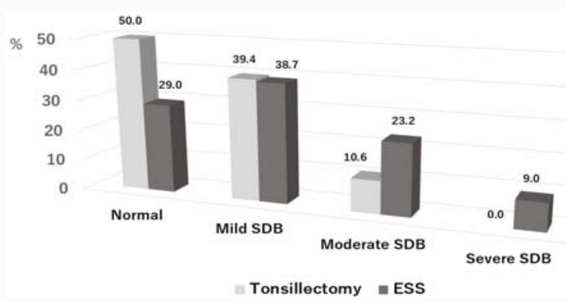

Figure 1: Prevalence of normal, mild, moderate, and severe SDB in patients who underwent tonsillectomy compared with those who underwent ESS. Severity of SDB is defined as 3% Oxygen Saturation Index (ODI) modified by home sleep apnea testing. SDB-Sleep-Disordered Breathing; ESS-Endoscopic Nasal and Sinus Surgery Group.

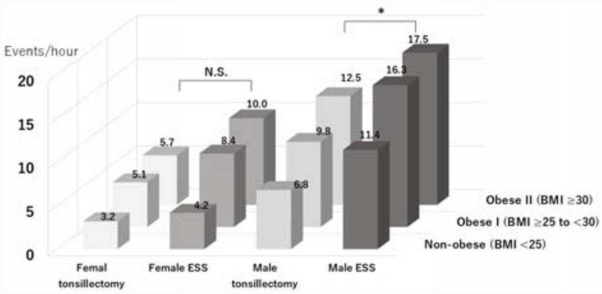

Figure 2: Mean 3% ODI according to sex and Body Mass Index (BMI) groupings in patients who underwent tonsillectomy compared with those who underwent ESS. The number above each bar represents the mean 3% ODI score. N.S., not significant, *:p< 0.05.

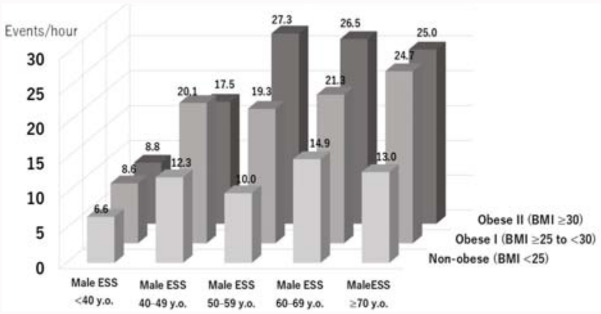

Figure 3: Mean 3% ODI according to age and Body Mass Index (BMI) groupings in male patients who underwent ESS. The number above each bar represents the mean 3% ODI score. BMI is categorized from <25 kg/m^2 in units of 5.0 and age is categorized from <40 years to ≥70 years in units of 10.

when they were aged ≥40 years compared with non-obese patients in the ESS group (Figure 3).

In the ESS group, 49 patients (31.6%) were diagnosed as having CRSwNP. The 3% ODI scores of patients with and without non-CRSwNP were 13.7 ± 12.5/h and 11.6 ± 9.3, respectively, but the difference between the two groups was not significant.

We included age, BMI, sex, NR, and CRSwNP as independent variables in multivariate stepwise regression analysis of the preoperative 3%ODI score in the ESS group. Regression analysis showed that the preoperative 3% ODI score had two significant determinants. BMI (t=3.31, beta=0.34, p=0.01) and male sex (t=3.21, beta=0.33, p=0.02) significantly predicted the relative preoperative 3% ODI score, whereas age, NR, and CRSwNP were not significant predictors.

Discussion

To our knowledge, this is the first study to investigate the prevalence of SDB in patients who underwent ESS. There were two novel findings in this study. First, we had more patients with SDB than we expected: 9.0% of patients had a 3% ODI score of 30/h or higher, while 32.3% had a 3% ODI score of 15/h or higher among patients who underwent ESS. BMI and male sex significantly predicted the risk of SDB in the ESS group, and obese male patients (BMI ≥ 25) were much more susceptible to having moderate to severe SDB when they were aged ≥40 years in the ESS group. Second, the mean 3%ODI score in the ESS group was significantly higher than that in the tonsillectomy group in men but not in women, indicating that nasal obstruction is a potential risk factors for SDB in male patients. However, there were no significant differences in the severity of SDB between the CRSwNP and non-CRSwNP groups. The prevalence of SDB with an Apnea Hypopnea Index (AHI) of 15/h or higher in Japan is reported to be 14.0%, indicating that the prevalence is more than twice as high in patients who underwent ESS [9].

Nasal obstruction, mouth breathing and SDB

A significant increase in nasal resistance can influence the collapsibility and resistance of the pharynx, which is located downstream from the nose, and the development of respiratory events during sleep can be explained by the Starling resistor model based on Bernoulli's principle. Another reason why nasal obstruction can be a risk factor for the onset of SDB is mouth breathing. Airflow in a tube is basically explained by the Starling resistor model; however, when breathing through the mouth, pharyngeal collapse cannot be explained by this model alone. In nasal diseases, nasal obstruction can be bypassed by opening the mouth and allowing a greater volume of air to be inspired and expired. Upper airway collapsibility and resistance during sleep have been reported to be significantly higher in people who breathe through the mouth compared with those who breathe through the nose [10,11].

We performed computational fluid dynamics analyses of the nose and pharynx during nasal breathing with the mouth closed, nasal breathing with the mouth open, and oral breathing [12]. The results showed that airflow velocity and static pressure peaked during oral breathing, suggesting that of the three conditions, oral breathing is the primary condition that leads to pharyngeal collapse. We also demonstrated that the airflow during nasal breathing with the mouth closed was smooth throughout the whole breathing route-without spreading, perturbations, or instability-whereas that during nasal breathing with the mouth open showed spreading and a disturbed, unsteady stream [12]. In a previous study, we divided Oral Flow (OF) during sleep into three main patterns: OF after a respiratory event, OF during a respiratory event, and spontaneous arousal-related OF [13]. Multivariate stepwise regression analysis revealed that spontaneous arousal-related OF was associated with nasal obstruction, typically seen in patients with moderate and mild OSA, suggesting that nasal obstruction is also a potential risk factor for respiratory events during sleep in patients with moderate and mild OSA [13]. These results might explain why nasal obstruction is a potential risk factor for SDB. The physiology of the upper and lower airways and respiratory control during sleep are more conducive to nasal breathing than to oral breathing.

Risk of postoperative ESS

ESS may increase the upper airway collapsibility that is induced by nasal packing or postoperative edema. Nasal packing is usually inserted into the nasal cavities after ESS, and thus the respiratory condition can worsen during sleep in these patients after ESS is performed. In addition, general anesthesia for patients with OSA is itself a risk. We previously reported that there were significant changes in intrathoracic pressure among the pre-operative, postoperative day 1 (POD1), and POD5 time points in patients with moderate to severe OSA who underwent ESS under general anesthesia, with intrathoracic pressure decreasing the most at night on POD1, indicating a risk of postoperative management [14]. The present study provides valuable information suggesting that preoperative detection of the presence of SDB in patients undergoing ESS under general anesthesia is desirable for safe perioperative management.

Can CRSwNP be a new phenotype of SDB?

CRSwNP and SDB are highly comorbid. As mentioned above, there is plenty of physiological and clinical evidence that nasal disease and mouth breathing are more likely to be linked to respiratory events. However, can CRSwNP be considered an independent risk factor for the onset of SDB?

European Rhinologic Society Guidelines propose a classification method based on localization (unilateral or bilateral) and the type of associated inflammation (type 2 inflammation or other inflammation). Such cases are characterized by nasal polyp formation and profound eosinophilic infiltration of the nasal mucosa [8]. Currently, CRSwNP is categorized as a type 2 inflammatory disease because of its similarity in the pathogenesis of other type 2 diseases such as bronchial asthma and atopic dermatitis and has often been associated with them. Basic research on the immune profile of patients with CRSwNP according to OSA severity revealed that OSA severity influences the immune profile in patients with CRSwNP, and that interleukin-6 and chemokineligand (CXCL)-1 in nasal polyp tissues were upregulated with moderate-to-severe OSA, whereas there were no significant effects in non-CRSwNP according to OSA severity [15]. In contrast, clinical age- and sex-matched comparative study found that the median AHI score, Epworth sleep scale score, and STOP Bang questionnaire score were significantly higher in patients with OSA alone than in those having both OSA and CRSwNP [16]. In the present study, there was no significant difference in the severity of SDB between the CRSwNP and non-CRSwNP groups, which does not support CRSwNP as an independent risk factor for the onset of SDB.

At present, it may be premature to conclude that CRSwNP is an independent risk factor for the onset of SDB. The clinical and pathological profile of CRSwNP should be considered differently from that of typical SDB, and each condition should be treated separately. Further evidence is needed to define patients with CRSwNP as a new SDB phenotype.

Study limitations

This study has two limitations. First, it is not a prospective trial, but rather a retrospective case-control study. Second, we used a type 3 monitor to detect sleep apnea. Although HSAT is not sufficiently reliable for exclusive diagnosis of AHI <5/h, it is reliable enough for definitive diagnosis of AHI ≥5/h and the exclusive diagnosis of AHI <20/h in adult patients [17].

Conclusions

Among patients who underwent ESS, 32.3% had moderate to severe SDB, including 9.0% with severe SDB. Preoperative evaluation of SDB is recommended for perioperative management, especially in obese male patients aged ≥40 years. The mean 3%ODI score in the ESS group was significantly higher than that in the tonsillectomy group in men but not in women, indicating that nasal obstruction is a potential risk factor for SDB in male patients. Further evidence is needed to define patients with CRSwNP as a new SDB phenotype.

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