Reduction of postural nasal resistance following oropharyngeal surgery in patients with moderate-severe obstructive sleep apnea*

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Abstract

Background: Patients with obstructive sleep apnea (OSA) have elevated nasopharyngeal resistances due to increased turbulent airflow. The study aims to investigate the effect of oropharyngeal surgery on nasal resistance in patients with various severity levels of OSA.

Methodology: Patients with greater or equal to 5 events hourly on the apnea-hypopnea index (AHI) were enrolled. Patients with retropalatal obstruction underwent uvulopalatopharyngoplasty, while patients with concurrent retrolingual obstruction underwent uvulopalatopharyngoplasty (UPPP) plus tongue base suspension. Before surgery and after surgery, subjective outcomes were assessed using a visual analog scale (VAS), and objective outcomes were assessed using overnight polysomnography and rhinomanometry. The limitation of the study was that UPPP instead of expansion sphincter pharyngoplasty was performed in this study.

Results: Sixty-two patients were enrolled, while 30 patients were diagnosed as mild OSA (group Mild) and 32 patients were moderate-severe OSA (group MS). The preoperative VAS of nasal obstruction in recumbency during sleep was significantly reduced after surgery in group MS. However, no significant differences between preoperative and postoperative VAS were found in group Mild. The postoperative anterior and posterior total nasal resistances (TNR) in sitting and supine positions were not significantly different from those before surgery in group. In contrast, the postoperative posterior TNR in supine position was 0.292±0.301(Pa/cm^3/s), compared with 0.425±0.343(Pa/cm^3/s) preoperatively.

Conclusions: Oropharyngeal surgery improves nasal obstruction during sleep and lowers the supine TNR measured in posterior rhinomanometry in patients with moderate-severe OSA. Oropharyngeal surgery is a possible treatment for postural nasal obstruction in patients with moderate-severe OSA.

Key words: obstructive sleep apnea, nasal obstruction, rhinomanometry, nasal resistance, uvulopalatopharyngoplasty, tongue base suspension

Introduction

Snoring and obstructive sleep apnea (OSA) affects at least 2% to 4% of the adult population [(1)], and is mostly caused by narrowed upper airway and abnormal collapsibility during sleep [(2)]. Dynamic magnetic resonance imaging, acoustic analysis, sedation endoscopy and pharyngeal luminal pressure recordings have established that both snoring and OSA are multilevel phenomena whereby turbulent airflow is linked with obstruction in the naso-, oro- and hypopharynx in differing proportions in individual patients [(3-7)]. The narrowed and collapsible upper airway facilitates high resistance in the upstream segment of upper airway. Over 90% of apneic patients have single obstruction in the retropalatal level, whereas 40–50% of those have obstruction in multiple sites, including retropalatal space, retrolingual space, and hypopharynx [8, 9]. Successful surgical management of OSA requires various procedures to address these multiple levels of airway obstruction [10-13]. Numerous observational studies have revealed a positive link between nasal obstruction and OSA [14-15]. Relief from severe nasal obstruction during sleep is related to significant normalization of mouth breathing, enhancement of sleep-stage architecture, and a modest reduction in the severity of OSA [16]. However, the response to surgical correction of nasal obstruction is frequently limited and unpredictable [17, 18]. Patients with OSA have been reported to have elevated nasopharyngeal resistances owing to increased turbulent airflow, particularly on assumption of recumbency during sleep [19, 20]. Increased nasal resistance in OSA patients results in symptoms of nasal obstruction, causing them to switch to oral breathing automatically during sleep, which worsens the severity of OSA in a vicious cycle. Although the association between nasal surgery and the severity of OSA is well studied, the effect of oropharyngeal surgery alone on nasal resistance in OSA patients has not been explored thoroughly. Therefore, this study aims to investigate the effect of oropharyngeal surgery on nasal resistance in patients with various severity levels of OSA.

Materials and methods

Inclusion criteria

A clinical study of case series with planned data collection was undertaken in patients who complained of snoring and experienced sleepiness during daytime. Each patient had a complete workup, including a thorough medical history review, physical examination, fiberoptic nasopharyngoscopy with Müller maneuver, rhinoscopic examination, rhinomanometry and overnight polysomnography. Palate position and tonsil size were graded according to the Friedman classification [10]. This work enrolled patients with more than or an equivalent of 5 events hourly on the apnea-hypopnea index (AHI). Patients with retropalatal obstruction underwent uvulopalatopharyngoplasty (UPPP), while patients with concurrent retrolingual obstruction and a Friedman palate position of grade 3 or 4 [21] underwent UPPP plus tongue base suspension (TBS) [13]. Patients with allergic rhinitis, chronic rhinitis, nasal septal deviation, sinonasal disease or tonsil sizes of grade 3 or 4 were excluded. This study was approved by an institutional review board of Far Eastern Memorial Hospital (108134-E).

Subjective evaluation

A visual analog scale (VAS) was used to quantify the subjective feeling of nasal obstruction during sleep [22]. The degree of nasal obstruction before surgery and 6 months after surgery was estimated based on a scale ranging from 0 (no obstruction) to 10 (complete obstruction). Patients were asked to mark a cross on a line corresponding to their own perception of nasal obstruction.

Polysomnography

Overnight polysomnography was performed in each patient before surgery and at 6 months after surgery. The sleep study variables were the AHI score and minimal oxygen saturation (MOS). The AHI score refers to the total number of obstructive apnea and hypopnea episodes per hour of sleep. Apnea refers to cessation of airflow for at least 10 seconds. Hypopnea refers to a 50% or greater reduction in the baseline ventilatory value for more than 10 seconds associated with a more than 4% decrement in oxygen saturation.

Rhinomanometry

Rhinomanometry (Rhinomanometer NR6, GM instruments, Glasgow, UK) was performed in each patient before surgery and at 6 months after surgery. The anterior rhinometry procedure was performed following a rest period in a seated position and after lying down for 5 min in a supine position. A pressure sensor was placed in one nostril and detected the flow of air in the other nostril. Hence, the resistance of each nasal cavity and total nasal resistance could be computed separately. Total nasal resistance (TNR) was determined from the unilateral recordings. Posterior rhinomanometry procedure was performed with a peroral air-filled cannula pushed posteriorly over the tongue and maintained through closed lips. The transnasal pressure was obtained by measuring the difference between the pressure in the pharynx and the pressure in the nasal mask with a differential pressure transducer. Special care was taken to prevent the mask from compressing the compliant portion of the nose and compromising nasal airflow.

Statistical analysis

Statistical analysis was performed using SPSS software (SPSS Inc, Chicago, IL, USA). A comparative analysis of the results was performed by Student's t test and chi-square analysis as appropriate, where $P<0.05$ indicated a statistically significant difference.

Results

Total 62 patients (49 men and 13 women; age range, 21-69 years [mean age, 47.6 years]) were enrolled. Among them, 30 patients with AHI more than or an equivalent of 5 events hourly but less than 15 hourly (group Mild), and 32 patients with AHI greater than or equal to 15 events hourly (group MS). Table 1 shows demographic and baseline characteristics of subjects. Table 2 lists the data concerning sleep before and after surgery. Before surgery, the AHI was 8.9±3.3 (/h) in group Mild, compared with 6.4±1.8 (/h) after surgery ($p<0.05$, paired t-test). The preoperative AHI was 48.8±19.3 (/h) in group MS, in contrast to 24.1±15.3 (/h) postoperatively, exhibiting a significant difference ($p<0.05$, paired t-test). The preoperative VAS of nasal obstruction in recumbency during sleep (6.5±2.3) was significantly reduced after surgery in group MS (2.7±1.5, $p<0.05$, paired t-test). However, no

Table 1. Summary of demographic and baseline data.

	mild OSA	moderate-severe OSA	p value
n	30	32	
Gender (male/female)	22/8	27/5	>0.05[a]
Age (years)	46.7±13.0	47.9±8.3	>0.05[b]
BMI (kg/m2)	24.8±3.0	28.2±4.0	<0.05[b]
FPP I-II/III-IV	28/2	3/29	<0.05[a]
UPPP/UPPP+TBS	30/0	3/29	<0.05[a]

OSA = obstructive sleep apnea; BMI = body mass index; FPP = Friedman palate position; UPPP = uvulopalatopharyngoplasty; TBS = tongue base suspension; Data were expressed as mean ± SD; [a] Chi-square analysis; [b] t-test.

Table 2. Data concerning sleep before and after surgery.

	Preoperative	Postoperative	p value
mild OSA (n=30)			
AHI (/h)	8.9±3.3	6.4±1.8	<0.05
MOS (%)	84.9±7.1	88.1±6.5	>0.05
BMI (kg/m2)	24.8±3.0	25.2±3.6	>0.05
VAS of NO*	2.8±1.5	3.0±1.7	>0.05
moderate-severe OSA (n=32)			
AHI (/h)	48.8±19.3	24.1±15.3	<0.05
MOS (%)	71.0±9.1	79.2±10.1	<0.05
BMI (kg/m2)	28.2±4.0	28.3±4.5	>0.05
VAS of NO*	6.5±2.3	2.7±1.5	<0.05

OSA = obstructive sleep apnea; AHI = apnea-hypopnea index; MOS = minimal oxygen saturation; BMI = body mass index; VAS = visual analog scale; NO = nasal obstruction; Data were expressed as mean ± SD.
*Nasal obstruction was evaluated in recumbency during sleep.

Table 3. Preoperative and postoperative rhinomanometric findings in patients with mild OSA and moderate-severe OSA.

	Preoperative ($Pa/cm^3/s$ for TNR)	Postoperative ($Pa/cm^3/s$ for TNR)	p value
mild OSA (n=30)			
Ant. sitting TNR	0.192±0.066[a]	0.227±0.090	>0.05
Ant. supine TNR	0.257±0.211[a]	0.265±0.188	>0.05
Post. sitting TNR	0.244±0.194[b]	0.237±0.152	>0.05
Post. supine TNR	0.287±0.150[be]	0.269±0.188	>0.05
moderate-severe OSA (n=32)			
Ant. sitting TNR	0.201±0.148[c]	0.205±0.115	>0.05
Ant. supine TNR	0.296±0.303[c]	0.219±0.122	>0.05
Post. sitting TNR	0.320±0.259[d]	0.274±0.169	>0.05
Post. supine TNR	0.425±0.343[de]	0.292±0.301	<0.05

OSA= obstructive sleep apnea; TNR=total nasal resistance; Data were expressed as mean ± SD; The same letter indicates significant differences (p<0.05).

significant differences were found between postoperative and preoperative VAS of nasal obstruction in recumbency during sleep in group Mild (p>0.05).
Table 3 presents the rhinomanometric results. Before surgery, the TNR in supine position was significantly raised compared with that in sitting positions in both groups (p<0.05, paired t-test). Additionally, the anterior sitting and supine TNR as well as the posterior sitting TNR had no significant differences between group Mild and group MS (p>0.05). However, group MS had a higher preoperative posterior supine TNR than group Mild (p<0.05).
After surgery, in group Mild, the postoperative anterior and posterior TNR in sitting and supine positions were not significantly different from those before surgery (p>0.05, paired t-test). In group MS, the postoperative anterior and posterior TNR in sitting position were not significantly different from those before surgery (p>0.05, paired t-test). The postoperative posterior TNR in sitting position also did not differ significantly from those before surgery (p>0.05, paired t-test). In contrast, the postoperative posterior TNR in supine position was 0.292±0.301($Pa/cm^3/s$), compared with 0.425±0.343($Pa/cm^3/s$) preoperatively, which exhibited significant differences (p<0.05, paired t-test). Figure 1 showed the individual patient response for the AHI and posterior TNR in supine position after surgery in patients with moderate-severe OSA.

Discussion

Nasal resistance is affected by multiple factors, including the length of the nose nasal mucosal change, structural abnormality and adenoidal swelling. The air flow passing through the nose and nasopharynx is restricted by its shape and diameter [23, 24]. Since this study aims to investigate the direct effect of oropharyngeal surgery on the postural nasal resistance in patients with OSA, it excluded patients with allergic rhinitis, chronic rhinitis, nasal septal deviation and sinonasal disease. Analytical results show that an increase in resistance is observed with anterior and posterior rhinomanometry when patients move from the seated to the supine posture in both groups. The finding is attributed to the postural effect on nasal resistance, which is mostly related to an increase in nasal mucosal and submucosal thickness because of vascular dilation. This is consistent with previous data obtained with acoustic rhinomanometry [25].
Before surgery, the anterior sitting and supine TNR as well as the posterior sitting TNR had no significant differences between group Mild and group MS. However, group MS had a higher pre-

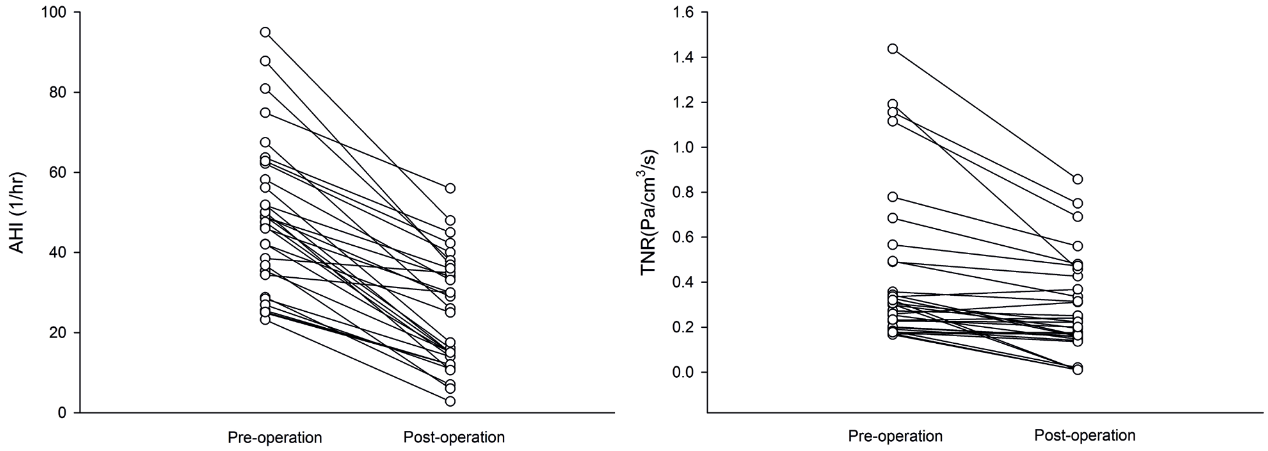

Figure 1. The individual patient response for the apnea-hypopnea index (AHI) and posterior total nasal resistance (TNR) in supine position after surgery in patients with moderate-severe obstructive sleep apnea. Open circles and solid lines=individual patients.

operative posterior supine TNR than group Mild. These results are possibly due to the severity of OSA and the measurement of posterior rhinomanometry, which is measured from the air pressure in the pharynx over the posterior portion of the tongue. The gravity affects the soft palate and tongue base, which moves posteriorly as the subject shifts from an upright to a supine posture. Tongue drop and enlargement of the soft palate and the uvula is a frequent finding in OSA. A large, posteriorly-positioned tongue base contributes to the narrowing of the posterior oropharynx. Therefore, patients with moderate-severe OSA may have more marker relative changes in pharyngeal resistance with posture, with an already decreased pharyngeal cross-sectional area, than patients with mild OSA. Previous studies have reported a fall in nasal resistance in response to mandibular advancement and tongue protrusion, which is thought to reflect a reduction in transpalatal resistance [26, 27]. Lofaso et al. [28] reported a weak relationship between bilateral nasal resistance and AHI using posterior rhinomanometry in an upright position. Virkkula et al. showed that TNR increased more on lying down in patients with OSA compared with non-apneic snorers. These findings are compatible with our results but they did not analyze the TNR with posterior rhinomanometry in the supine position [29].

Collapse of the upper airway is usually multilevel, including at the level of the velopharynx, tongue base, and the lateral pharyngeal walls. Many patients with moderate-severe OSA have bulky thick lateral pharyngeal walls that lead to collapse of the upper airway. Expansion sphincter pharyngoplasty has been reported to a surgical technique to reduce lateral pharyngeal collapse in patients with moderate-severe OSA [30]. In this investigation, 90% (29/32) patients with moderate-severe OSA were treated with UPPP plus TBS. Notably, lateral pharyngoplasty was also performed in patients with bulky soft tissue around the lateral pharyngeal wall noted during operation. Our previous report demonstrated that TBS prevents the tongue from dropping back in a supine position. In severe OSA patients after failed UPPP, the mean reduction in AHI was 56 % [13]. After surgery, the anterior sitting and supine TNR, as well as posterior sitting TNR, were not significantly different from the preoperative TNR in both groups. However, the postoperatvie posterior TNR in supine position was significantly reduced compared to the preoperative TNR in group MS. This finding is attributed to the anatomical abnormality in group MS. Correction of retropalatal obstruction and suspension of tongue base lowered the transpalatal pressure, leading to reduced TNR in supine position in posterior rhinomanometry. However, since anterior rhinomanometry mainly measures the resistance in the bony portion of the nose, the groups show no significant differences of the posture TNR measured with anterior rhinomanometry after oropharyngeal surgery. Nakata et al. [19] reported that simple tonsillectomy reduces erect nasal resistance measured in anterior rhinomanometry in OSA patients with hypertrophic tonsils of grade 3 or grade 4. Tonsillectomy enlarges nasopharyngeal space, and diminishes turbulent airflow in the upright position. In these patients, the nasal resistance in the upright position is affected by the hypertrophic tonsils regardless of the severity of OSA. Since this study aims to investigate the effect of posture and oropharyngral surgery on nasal resistance in patients with various severity levels of OSA, patients with hypertrophic tonsils of grade 3 or grade 4 are excluded. Therefore, the discrepancy between the two studies may be because subjects in this work had tonsil sizes of grade 1 or 2, and OSA was mainly caused by retropalatal obstruction and tongue drop. The effect of gravity on soft palate and tongue drop was stronger in recumbency than in upright position in the MS group.

Notably, the subjective outcome of VAS of nasal obstruction during sleep was improved after surgery in the MS group, but not in the Mild group. Clinically, failure of relieving nasal obstruction after septomestoplasty is generally attributed to incomplete surgery, atrophic rhinitis, and empty nose syndrome [31]. However, the finding indicates the oropharyngeal surgery should be considered in treating postural nasal obstruction in patients with moderate-severe OSA, because oropharyngeal surgery alone may improve nasal obstruction in these patients.

The study still has some limitations. First, drug-induced sleep endoscopy (DISE) is able to offer the possibility of dynamic upper airway evaluation during artificial sleep as a technique for selecting surgical treatment for OSA [32-34]. However, DISE is not performed routinely in patients with OSA in this study. Second, expansion sphincter pharyngoplasty is considered superior to UPPP, especially in avoiding the concentric scar typical of the latter. Nevertheless, UPPP instead of expansion sphincter pharyngoplasty was performed in this study. Third, all the data were collected in woken patients. However, the collapsibility of airway and nasal obstruction is greater in recumbency during sleep than during wakefulness. Therefore, the difference of TNR in supine position measured in posterior rhinomanometry is anticipated to be more significant in sleep than in wakefulness.

Conclusion

The results of this study show that oropharyngeal surgery improves the symptom of nasal obstruction during sleep, and reduces the supine nasal resistance measured in posterior rhinomanometry in patients with moderate-severe OSA. Oropharyngeal surgery is a possible treatment for postural nasal obstruction in patients with moderate-severe OSA.

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Authorship contribution

CCH: study design, acquisition and interpretation of data, drafting of the manuscript, final approval of the version, and accountability for all aspects of the work. PWC, LJJ: study design, acquisition and interpretation of data, final approval of the version, and accountability for all aspects of the work. TWH: study design, acquisition and interpretation of data, drafting and revision of the manuscript, final approval of the version, and accountability for all aspects of the work.

Conflict of interest

None.

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