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Soft palate length and upper airway relationship in OSA and non-OSA subjects

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Abstract

Background—The narrowest area of the airway between the posterior nasal opening and the epiglottis is usually located in the retro palatal area. Many consider this the most likely site of airway obstruction during an obstructive sleep apnea (OSA) event. The aim of this study was to investigate the differences in soft palate and airway length between OSA and non-OSA patients.

Methods—In this study, we analyzed the ratio of the soft palate and the upper airway length in 45 consecutive patients. Twenty-five had an Apnea–Hypopnea Index of more than five events per hour and were classified in the OSA group (male, 19; female, 6). These patients were compared with 20 normal controls (male, 12; female, 8). Controls who complained of snoring did have sleep studies ($n=5$). The other fifteen controls were clinically asymptomatic and did not have sleep studies. Medical computed tomography scans were taken to determine the length of the upper airway and the soft palate length measured in the midsagittal image.

Results—Soft palate length was significantly larger in OSA patients compared to controls ($p=0.009$), and in men compared to women ($p=0.002$). However, there were no differences in airway length. The soft palate length, as a percent of oropharyngeal airway length, was significantly larger in OSA patients compared to controls ($p<0.0001$) and in men compared to women ($p=0.02$). Soft palate length increases significantly with age by 0.3 mm per year in males (after adjustment for body mass index (BMI) and OSA). Soft palate length as a percent of airway

length is larger in OSA patients and increases significantly with BMI in males only after adjusting for age.

Conclusion—In this study, OSA patients had a longer soft palate in proportion to their oropharyngeal airway compared to controls as well as men compared to women. This proportion could be used for identifying patients at risk for OSA in combination with age.

Keywords

Soft palate length; Oropharyngeal airway; Obstructive sleep apnea; Computerized tomography

Introduction

One local airway factor proposed as causative agent of obstructive sleep apnea (OSA) is a long soft palate. One interesting study performed a longitudinal cephalometric imaging analysis of the morphological changes occurring in the pharynx between early and middle adult life [1]. The study involved 16 young adults (mean age=20.2 years) who had cephalometric films taken and repeated across an interval of 32 years. Changes in soft palate and airway dimensions were examined and the results showed (1) the vertical oropharynx length increased by 4.7 mm after 20 years of age, (2) the anteroposterior dimension (AP) retropalatal airway size decreased with age, but (3) the retroglossal AP airway size stayed unchanged. Interestingly, they reported that the soft palate became longer and thicker over time in these subjects. Mallampati, an anesthesiologist, proposed a clinical scoring system to assess the length of the soft palate. The Mallampati score was correlated to OSA severity in two studies [2,3]. Several additional studies report increased length of the soft palate in apnea patients versus nonapnea subjects and in obese OSA patients compared with snorers and nonobese patients [4–8]. Johal et al. found in female OSA subjects, the soft palate was longer (4.02 mm; $p<0.05$) than in female controls, whereas, in male subjects, the difference between OSA and non-OSA males was not statistically significant [9]. We note that the female OSA patients had a much higher BMI than controls (OSA; 38 kg/m²; controls 26.5 kg/m²). Namyslowski et al. found excessive flaccidity and muscular atrophy in the soft palate and uvula in patients with snoring and OSA, and this suggests that the soft palate can change shape with time and disease [10]. Malhotra et al. reported that the soft palate length also increased progressively with aging ($R=0.48$; $p=0.003$), with the increase with age in women being significant ($p=0.004$) [11]. Finally, an Italian study examined the value of MR imaging of the oropharynx during wakefulness [12]. They found an inverse correlation between the soft palate length and arterial oxygen partial pressure (an indicator of apnea).

The finding that the soft palate of OSA patients is larger or longer than non-OSA controls is not a universal finding. Battagel et al., using cephalometric images, showed that the mean soft palate length of control subjects was 2 mm longer than the OSA group and the snorer's group [13]. They did not find the length difference to be statistically significant between snorers and OSA, however, there were significant differences between the three groups (analysis of variance, $p<0.05$).

The aim of this paper was to investigate the differences in soft palate length between OSA and non-OSA patients, in particular, the relationship between the soft palate length and the airway length and the influence of BMI, gender, and aging in soft palate and airway length.

Research methods

Subjects

Forty-five consecutive Japanese patients had spiral CTs taken to further examine their maxillofacial and cervical structures as part of their diagnostic assessment. These patients were seeking treatment for one of several clinical problems. Thirty of these subjects had OSA/snoring symptoms and also had a polysomnogram. Of the 30 patients, 25 patients had more than five events per hour (Apnea–Hypoapnea Index, AHI) and were classified as OSA. Five patients had less than five events per hour and were diagnosed as simple snorers. These five patients were included in the control group. The 20 control subjects were seeking treatment at the Tsurumi University Dental Hospital for one of several clinical problems including simple snorer ($n=5$; M=2, F=3), malocclusion (anterior open bite; $n=5$; M=4, F=1), temporomandibular disorders ($n=4$; M=2, F=2), osteoarthritis ($n=1$; F=1), minor jaw deformity ($n=2$; F=1, M=1), enlarged torus ($n=1$; M=1), enlarged coronoid process ($n=1$; M=1), and mandibular fracture ($n=1$; M=1). The age, BMI, gender, and height for the OSA and controls is presented in Table 1. The patients gave written consent to participate in this study approved by the Ethics Committee at Tsurumi University Dental Hospital.

Sleep studies

The sleep studies consisted of one night full polysomnography at the hospital. Apnea was defined as the cessation of airflow >10 s documented on polysomnogram, and a hypopnea was defined as a reduction in airflow >10 s associated with a fall in oxygen saturation of at least 3% and an arousal from sleep documented on polysomnogram. Cases had a mean AHI of 24.7 ± 16.55 events per hour with a median of 19 and a range of [6.0–60.0]. The control subjects, except the five snorers (patients with AHI of more than five events per hour), did not have polysomnograms; but based on clinical interview, they did not exhibit hypersomnolence or loud snoring symptoms.

Device and software

The imaging of the airway was performed using spiral CT (Radix Prima, Hitachi Medical Co., Tokyo, Japan). The parameters used for the imaging were tube voltage=120 kV; tube current=75 mA; irradiation time=1 s; slice thickness=1 mm; table speed=1 mm/s. From the resulting data, the airway was extracted using image analysis software (Amira 3.1, Mercury Computer Systems/3D Viz group, San Diego, CA, USA) to reconstruct three-dimensional images and to measure the airway and soft palate length.

Measurement of the airway and soft palate

The operator (YS) chose the midsagittal image of the soft palate. All measurements were performed in this slice (Fig. 1). We defined the upper airway length (AWL) between the posterior nasal spine and the top of epiglottis. The soft palate length (SP) was determined by a point to point measurement from the posterior nasal spine and the tip of the soft palate. The soft palate vertical length (SVL) was defined between the PNS and the tip of the soft palate. Lastly, to see what percent of the oropharynx airway was occupied by the soft palate, we also divided the soft palate vertical length by the upper airway length (SVL/AWL).

Statistical analysis

We investigated the differences in mean age and BMI between groups with the two-sample t test and the differences in gender and OSA status with the Chi-square test. The anatomical variables (SP, SVL, SVL/AWL) did not pass the formal normality test (Kolmogorov–Smirnov), so we used nonparametric Wilcoxon rank sum (or Mann–Whitney) test. We investigated the linear relationships between the variables with linear regression. The linear

regression assumptions of linearity, homoscedasticity, and normality of the residuals were successfully evaluated. Stepwise logistic regression analyses were performed with OSA status as the dependent variable. Explanatory variables included age and BMI (common confounders for OSA) and the variables in Table 2 (SP, SVL, SVL/AWL, AWL). Statistical analysis was carried out with SAS 9.1 (SAS Institute Inc. Cary, NC, USA) with significance level of 0.05.

Repeatability of the measurements

To test the reliability of the measurements, 20 patients (ten OSA cases and ten controls) were randomly selected and their images remeasured by the same examiner after a 60-day interval. Statistical analysis of the difference between the duplicate measurements was conducted by computing the intraclass correlation coefficient (ICCC). The ICC was 0.998 for the airway length, 0.997 for the soft palate vertical length SVL, and 0.999 for the soft palate SP, which represents highly reliable measurements.

Power calculations

Based on preliminary results with $n=13$ OSA cases and $n=13$ controls, we found a mean SVL/AWL of 74.7 ± 5.30 for cases and 67.8 ± 8.61 for controls. To achieve an 80% power with $\alpha=0.05$ and two-sided comparison, we calculated; we need $n=17$ patients in each group. The final size of $n=25$ cases and $n=20$ controls provided a statistical power of 0.999.

Results

Differences by OSA group

The statistical analysis of the sample data shows that our controls were younger by 9 years and thinner (2.5 kg/m^2) than the OSA patients; however, there were no significant differences at baseline in gender distribution or patient's height (Table 1). Though the median airway length from PNS till tip of the epiglottis was not statistically significantly different, the other anatomical parameters (soft palate length, vertical length, and SVL/AWL) were significantly larger in the OSA group (Table 2). The median SVL/AWL score was 9.2% larger in OSA patients, and this difference was statistically significant ($p<0.0001$) with 99.9% power.

Differences by gender

The secondary statistical analysis of the sample data stratified by gender shows that women were 14 years older, shorter (14.2 cm), and thinner (1.8 kg/m^2) than men; however, there were no significant differences at baseline in OSA distribution or BMI (Table 3). Though the airway length was not statistically significantly different between genders, the other anatomical parameters (soft palate length, vertical length, and SVL/AWL) were larger in men (Table 4). The median SVL/AWL score was 7.6% larger in men, and this difference was statistically significant ($p=0.018$) with 73.4% power.

Changes with age and BMI

Multivariate linear regression analyses are presented in Table 5 for men and Table 6 for women. Soft palate length and vertical length increase significantly with age in men but not in women. BMI and OSA status are significant predictors of SVL/AWL in men ($p=0.011$). However, only OSA status is predictive of SVL/AWL in women ($p=0.0085$).

Stepwise multiple logistic regression models using $\text{AHI} < 5 / \geq 5$ as the dependent variable, controlled for age and BMI identified the following factors as determinants of the presence

of OSA: age and SVL/AWL. Of the variance of OSA, 45% was explained by this model ($R=44.9\%$; $p<0.0001$).

Discussion

The velopharynx is the most collapsible part of the oropharyngeal region, and it has been repeatedly reported to be smaller in OSA subjects [8,14]. In this sample we confirmed a large difference in soft palate length from PNS to tip of soft palate of 3.6 mm between OSA and non-OSA subjects (OSA, 42.2 mm; controls, 38.6), which compares well with the results by Sakakibara in a Japanese population with mean soft palate length of 39.0 mm for controls, 41.7 mm for nonobese OSA, and 42.9 mm for obese OSA [8]. A similar difference of 3.3 mm is observed in soft palate vertical length between OSA and control groups. In a different study with ninety-two subjects, Lam et al. found that after controlling for common confounders such as body mass index and age, subjects with severe OSA had longer soft palate (OR 1.16, $p<0.01$) [14].

In this study, a significant gender difference was also seen with men having a 6.1-mm longer soft palate length (and 5.3-mm longer soft palate vertical length) than women. This finding confirms the results of Malhotra who compared the soft palate length between ten older men and ten older women (around 65 years old) and found the soft palate is 7.1 mm longer in the males [11]. Moreover, soft palate length increases significantly with age in men but not in women after adjusting for BMI and OSA status. Our data agrees with the longitudinal study performed by Johnston and Richardson [1] who showed that soft palate length increased with age. Due to the limited number of subjects, the 11 male and five female results were pooled. The authors conclude that there may have been a sex difference in the findings. Malhotra also reported that the soft palate length increased progressively with aging ($R=0.48$; $p=0.003$), with the increase with age in women being significant ($p=0.004$), but interestingly, not in men ($p=0.08$), which is somewhat paradoxical since apnea prevalence is clearly higher in men [11]. The disparity of findings between our study and Malhotra's could be due to small sample size and differences in age and BMI between the two populations.

In this study, the airway length from PNS to tip of epiglottis was not significantly different in controls compared to OSA patients. If we compare only the males as in Lowe's study, we found a nonsignificant difference of 3.95 mm between OSA and controls (results not shown), which is similar to their findings of an airway length 3.99 mm longer in male OSA subjects ($p=0.020$) compared to normal controls [15]. In our sample, the airway length was 3.3 mm longer in males than females, though this difference was not significant. This is consistent with Segal's results who found that men had longer airways compared to women, 67.07 ± 6.72 versus 54.24 ± 3.70 mm ($p=0.00003$) [16]. The discrepancy in magnitude between our study and Segal's can be partly explained by the difference in age between our subjects. The oropharyngeal airway gets 4.7 mm longer after 20 years according to a prospective study [1], and the women in our group were 14 years older than the men.

We created a percent score for the amount of oropharyngeal length occupied by the soft palate (SVL/AWL). In this sample, SVL/AWL score was significantly larger in male OSA subjects by 8.3% and in women OSA subjects by 11.8% after controlling for age and BMI. SVL/AWL increases significantly with BMI only in men in this sample. These results agree with the literature, simple snorers, or controls have smaller soft palate than OSA [4–6]; however, prior studies were not adjusted for airway length. According to this data, males have also larger SVL/AWL score compared to women, which agrees with prior reports that women have smaller soft palate than men [11].

This is a cross-sectional study based on enrollment of patients attending one hospital clinic. As expected, the patients in this study only represent at best the patients attending this clinic, all of Japanese descent. Further research is necessary to generalize the results to the general population and other ethnicities. Women and men were represented in both groups with no statistical difference between OSA and control groups; however, groups were not matched by age, gender, or BMI to include all consecutive patients. This is a limitation of the study; however, linear regression analyses were statistically adjusted for age and BMI, and men and women analyzed separately. Another limitation is that not all controls had a polysomnogram; unfortunately, this is usually the case with studies including hospital controls who do not exhibit any symptoms of obstructive sleep apnea.

Conclusion

In this group of 45 Japanese, OSA patients had significantly longer soft palate length than controls. Soft palate length increases with age in males and is smaller in females after adjusting for BMI and OSA status. In this study, OSA patients had a longer soft palate in proportion to their oropharyngeal airway compared to controls as well as men compared to women. This proportion could be used for identifying patients at risk for OSA in combination with age.

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Fig. 1.

Linear measurements used in this study. *SP* distance between posterior nasal spine and tip of soft palate, *AWL* vertical height between posterior nasal spine and top of epiglottis, *SVL* vertical height between posterior nasal spine and tip of soft palate

Table 1

Descriptive statistics by OSA group

Variable	OSA group (mean $\pm$ SD; $n=25$)	Control group (mean $\pm$ SD; $n=20$)	p value t test
Age (years)	56.0 $\pm$ 12.38	46.7 $\pm$ 15.36	0.030
BMI (m/kg ²)	24.5 $\pm$ 2.94	22.0 $\pm$ 3.94	0.018
Gender	19 M, 6 F	12 M, 8 F	0.249 ^a
Patient's height (cm)	165.6 $\pm$ 10.20	165.6 $\pm$ 7.56	0.918 ^b

M male, *F* female^aChi-square test^bWilcoxon rank sum test for nonparametric variables

Table 2

Comparison of OSA and control patients

Variable	OSA group (mean $\pm$ SD; $n=25$)	Control Group (mean $\pm$ SD; $n=20$)	p value ^a (power)
Airway length (AWL, mm; from PNS to tip of epiglottis)	45.1 $\pm$ 6.61; median=45	47.5 $\pm$ 8.26; median=44	0.559
Soft palate length (SP, mm; from PNS to tip soft palate)	42.2 $\pm$ 5.19; median=41.9	38.6 $\pm$ 6.57; median=37.9	0.009
Soft palate vertical length (SVL, mm)	35.4 $\pm$ 4.56; median=34.0	32.1 $\pm$ 7.46; median=30.0	0.005
Soft palate vertical length as a percent of airway length (SVL/AWL, %)	78.9 $\pm$ 6.92; median=77.4	67.5 $\pm$ 8.06; median=68.2	<0.0001 (power=99.9%)

^a Wilcoxon rank sum test for nonparametric independent groups

Table 3

Descriptive statistics by gender

Variable	Men (mean $\pm$ SD; $n=31$)	Women (mean $\pm$ SD; $n=14$)	p value t test
Age (years)	47.5 $\pm$ 13.45	61.5 $\pm$ 11.7	0.002
BMI (m/kg ²)	23.9 $\pm$ 3.08	22.1 $\pm$ 4.44	0.113
OSA	19 (61.3%)	6 (42.9%)	0.249 ^a
Patient's height (cm)	170.0 $\pm$ 5.09	155.8 $\pm$ 8.15	<0.0001

^a Chi-square test

Table 4

Comparison by gender (secondary analysis)

Variable	Men (mean $\pm$ SD; $n=31$)	Women (mean $\pm$ SD; $n=14$)	<i>p</i> value ^a (power)
Airway length (AWL, mm; from PNS to tip of epiglottis)	47.2 $\pm$ 8.08; median=45.0	43.9 $\pm$ 5.15; median=44.0	0.274
Soft palate length (SP, mm; from PNS to tip soft palate)	42.5 $\pm$ 5.76; median=41.7	36.4 $\pm$ 4.42; median=35.5	0.002
Soft palate vertical length (SVL, mm)	35.6 $\pm$ 6.31; median=34.0	30.3 $\pm$ 4.01; median=29.5	0.006
Soft palate vertical length as a percent of airway length (SVL/AWL, %)	75.9 $\pm$ 9.49; median=77.1	69.2 $\pm$ 7.30; median=69.5	0.0180 (power=73.4%)

^aWilcoxon rank sum test

Table 5

Multivariate linear regression analyses for men; change in dependent variable per unit of BMI, age, and OSA status

Dependent variable	Change per increase of one unit of BMI (<i>p</i> value)	Change per 1year of age increase (<i>p</i> value)	OSA=1 (<i>p</i> value)	Adjusted <i>R</i> ²	F-ANOVA test <i>p</i> value
SP (mm)	-0.101 (0.695)	0.342 (<.0001)	-1.482 (0.383)	0.496	<0.0001
SVL (mm)	0.304 (0.306)	0.336 (<.0001)	-2.381 (0.222)	0.457	0.0002
SVL/AWL (%)	0.929 (0.004)	0.016 (0.858)	8.344 (.0009)	0.501	0.011

Table 6

Multivariate linear regression analyses for women. Change in dependent variable per unit of BMI, age, and OSA status

Dependent variable	Change per increase of one unit of BMI (<i>p</i> value)	Change per 1year of age increase (<i>p</i> value)	OSA=1 (<i>p</i> value)	<i>R</i> ² (Adj. <i>R</i> ²)	F-ANOVA test <i>p</i> value
SP (mm)	-0.204 (0.536)	0.141 (0.266)	2.551 (0.435)	0.280 (0.063)	0.330
SVL (mm)	0.107 (0.710)	0.108 (.327)	2.042 (0.475)	0.327 (0.125)	0.246
SVL/AWL (%)	0.337 (0.363)	-0.265 (0.074)	11.831 (.007)	0.674 (0.577)	0.0085