Major Factors Affecting Severity of Obstructive Sleep Apnea

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Received: 17 August 2014 / Accepted: 3 November 2014 / Published online: 7 December 2014
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Abstract Computed tomography (CT) has become a common method for evaluating obstructive sleep apnea (OSA). The aim of this study was to analyze the relationships between CT parameters and clinical parameters in OSA patients to determine major factors affecting the severity of OSA. The records of 128 consecutive snoring patients (98 males, 30 females) diagnosed with OSA were retrospectively reviewed. Polysomnography was performed for each patient. On CT scans, airway areas were measured at the level of the hard palate, the soft palate, and the base of the tongue. Polysomnographic parameters were compared by gender and age using the Mann–Whitney *U* test. Pearson's correlation coefficient was used to analyze relationships between variables and the AHI in each age group. The women were significantly older than the men ($p < 0.01$). The AHI and apnea index were significantly higher in men than in women. Stage 1 sleep and rapid eye movement sleep were more frequent in men than in women. The area at the base of the tongue was significantly smaller in women than in men ($p = 0.027$). In the 50–60 age group, the AHI was significantly higher in men (41.47 ± 19.67) than in women (17.14 ± 15.63) ($p =$

0.001). OSA severity varies with age, gender, and upper airway area. The OSA prognosis could be improved by evaluating the major factors and treating OSA patients according to epidemiological characteristics and anatomical structures.

Keywords Obstructive sleep apnea · Polysomnography · Computed tomography · Gender · Age · Upper airway

Introduction

Obstructive sleep apnea (OSA) is a common disease, with an estimated prevalence of 4 % in men and 2 % in women [1]. It has been shown previously that the prevalence of OSA differs according to gender and age [2–4], but this has not yet been adequately explained. OSA develops as the result of various physiological characteristics. Anatomical differences in the upper airway, differences in upper airway mechanics, hormonal influences, and breathing control have all been hypothesized to be involved in the gender and age differences in the severity and prevalence of sleep apnea [2, 3]. However, there has been limited research on these aspects of OSA, and some reports are unreliable as they assessed only one or two factors [4, 5].

The purpose of this study was to evaluate the association between OSA and patient characteristics, including anatomical factors assessed by quantitative analyses of computed tomography (CT) images.

Materials and Methods

We retrospectively analyzed the records of all patients who had been diagnosed with OSA by polysomnography (PSG;

Poster presented at the meeting of the World Congress on Sleep Apnea (WCSA), Rome, August 27, 2012 and at the 7th Asian Sleep Research Society Congress, Taipei, November 30, 2012.

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Apnea-hypopnea index, $AHI > 5$) and had undergone CT between November 1, 2008 and Jun 7, 2012 at Seoul St. Mary's Hospital. We excluded subjects with a sleep efficiency $<40\%$ or an apnea-hypopnea index (AHI) $<5\%$. The study population consisted of 128 patients (98 males, 30 females), who were divided by age into three groups: <50 , 50–60, and >60 years. The body-mass index (BMI) was calculated as $\text{body weight/height}^2$ (kg/m^2).

Overnight PSG was performed using a Grass Telefactor computerized PSG system. Standard surface electrodes were used to record electroencephalographic, electrooculographic, electromyographic (submental and anterior tibialis), and electrocardiographic activities. Blood oxygen saturation was monitored using pulse oximetry, with the sensor placed on the earlobe or finger. Nasal and oral thermocouples were used to monitor airflow. Respiratory effort was monitored using thoracic and abdominal movement electrodes. Recording and scoring techniques were in accordance with current guidelines (AASM Manual for the Scoring of Sleep and Associated Events, published in 2007).

For the CT scans, the patients were placed in the supine position on the scanner bed, and paranasal sinus (PNS) CT images were acquired at 120 kV and 180 mA with a 7-s scan time. Serial 0.6-mm axial images were obtained. All images were examined by the same physician using a bone shadow (window, 2000 HU; level, 400 HU). We selected three consecutive axial PNS CT images for each of the following locations: the hard palate (HP) level, the end of the hard palate bone, the soft palate (SP), the end of the uvula, the base of tongue (BOT), and up to the epiglottis. Upper airway cross-sectional areas were measured in square millimeters using Infinity software (ver. 6.0.0; Lumenera Corp.). To allow accurate measurements, all images were magnified. We retrospectively collected patient information, including age, gender and underlying disease, from the medical records.

Statistical Analysis

Student's *t* test was used to compare the variables between men and women, with SPSS software (ver. 12.0 for Windows; SPSS, Chicago, IL). Polysomnographic parameters were compared by gender and age using the Mann–Whitney *U* test. Pearson's correlation coefficient was used to analyze the relationship between variables and AHI in each age group. To identify factors affecting the severity of OSA, step-wise multiple regression analysis was performed. In all analyses, *p* values <0.05 were considered to indicate statistical significance. This study was approved by the institutional review board of Seoul St. Mary's Hospital.

Results

In total, 128 patients (98 men and 30 women) were included in our study. The distributions of sleep stages, PSG data, and demographic characteristics are shown in Table 1. Consistent differences in sleep quality were apparent between men and women and among different age groups.

Gender and Age

The women were significantly older than the men (54.7 ± 8.47 vs. 43.9 ± 11.18 years, respectively; $p < 0.01$). The AHI and apnea index (AI) of the men were significantly higher than those of the women (AHI , $p = 0.019$ and AI, $p = 0.013$).

Upper Airway Area

The area at the bottom of the tongue was significantly larger in men than in women ($p = 0.027$; Fig. 1). Regression analysis showed that the BOT area was inversely proportional to age ($r = -0.201$, $p = 0.05$; Table 2); that is, the BOT area was smaller in older patients. However, within each age group (<50 , 50–60, and >60), the area at each level (HP, SP, and BOT) of the upper airway did not differ significantly between men and women.

PSG data

Sleep stage 1 ($p = 0.038$) and REM sleep ($p = 0.047$) were significantly more prevalent in men than in women. Sleep stage 2 occurred significantly more often in women than in men ($p = 0.001$; Fig. 2). In the 50–60 age group, the AHI was significantly higher in men (41.47 ± 19.67) than in women (17.14 ± 15.63 ; $p = 0.001$) (Fig. 3). Multivariate logistic regression analysis revealed that the AHI was significantly correlated with the frequency of sleep stage 1 ($r = 0.754$, $p < 0.001$), the BMI ($r = 0.294$, $p = 0.03$), and the lowest O_2 saturation ($r = -0.527$, $p < 0.001$) (Table 3).

Discussion

With the current obesity epidemic, the prevalence of OSA is almost certain to rise [6]. Sleep features and sleep disorders appear to play important roles in determining end-organ dysfunction [7, 8], chronic health conditions, and mortality [9, 10]. Currently, OSA can be evaluated using a

Table 1 Gender differences in polysomnographic and anthropometric variables

Parameter	Male	Female	<i>p</i> value
Age (years)	43.9 ± 11.18	54.7 ± 8.47	<0.01*
BMI (kg/m ²)	25.8 ± 3.1	26.86 ± 4.11	0.183
AHI	36.35 ± 23.42	24.37 ± 21.24	0.019*
AI	20.50 ± 20.48	9.25 ± 14.79	0.013*
SS1 (% of group)	22.38 ± 15.32	15.37 ± 10.15	0.038*
SS2 (% of group)	57.85 ± 15.03	68.4 ± 10.39	0.001*
SWS (% of group)	0.16 ± 0.91	0.10 ± 0.56	0.665
REM (% of group)	18.13 ± 6.67	15.0 ± 7.19	0.047*
Number of snores/h	255 ± 210.5	198.57 ± 164.33	0.276
Lowest O ₂ saturation (%)	78.1 ± 8.34	79.8 ± 6.98	0.380

Values shown are mean ± SD

BMI body mass index, *AHI* apnea-hypopnea index, *AI* apnea index, *SS1* sleep stage 1, *SS2* sleep stage 2, *SWS* slow-wave sleep, *REM* rapid eye movement

* Significantly different between males and females

Fig. 1 Differences in upper airway areas on CT scans between men and women. The area at the BOT level was significantly greater in men than in women at all ages ($p = 0.027$)

Fig. 2 Differences in polysomnography results between men and women. Sleep stage 1 ($p = 0.038$) and REM sleep ($p = 0.047$) were significantly more frequent in men than in women. Sleep stage 2 was significantly more common in women than in men ($p = 0.001$)

Table 2 Correlations between upper airway areas on CT scans and age

Parameter	Pearson's correlation coefficient	<i>p</i> value
HP and age	0.038	0.70
SP and age	0.163	0.10
BOT and age	−0.201	0.05*

HP hard palate, *SP* soft palate, *BOT* base of tongue

* Significantly correlated

variety of technical methods such as CT, fibroscopy, cytometry, and PSG. However, many doctors may not make optimal use of the data. The present study identified factors that affect OSA and that can be used in designing treatment plans for OSA.

According to epidemiological studies, there are both gender- and age-related differences in OSA manifestations [3, 11, 12]. OSA is reported to be more prevalent in males

Fig. 3 Differences in the AHI between men and women in each age group (<50, 50–60, and >60). The AHI was significantly higher in men (41.47 ± 19.67) than in women (17.14 ± 15.63 ; $p = 0.001$) in the 50–60 age group

than in females [6]. The reason for the reduced susceptibility of females to OSA is unclear, although number of factors have been suggested, including body fat distribution

Table 3 Correlations of BMI, age, and lowest O₂ saturation with AHI

Parameter	Pearson's correlation coefficient	<i>p</i> value
BMI and AHI	0.294	0.003*
Age and AHI	−0.045	0.648
Lowest O ₂ saturation and AHI	−0.527	<0.001*

BMI body mass index, AHI apnea-hypopnea index

* Significantly correlation

[13], upper airway shape [14], craniofacial morphology [15], and hormonal influences [16–18]. It has also been reported that females exhibited less severe AHI scores [19]. Females more frequently failed to report snoring or apnea on questionnaires, perceived themselves to be less sleepy on the Epworth sleepiness scale (ESS), and considered themselves to be more depressed [19]. In another study, women with OSA were older, more obese, and had larger waists and hips, compared with men with OSA [20].

In the present study, AHI and AI were significantly higher in men than in women with OSA. Furthermore, stage 1 sleep and REM sleep were more prevalent in men. These findings suggest greater severity of OSA and poorer quality of sleep in men than in women. Older age was associated with impaired sleep in women, especially in those older than 50 years of age, with a less consistent association in men. Among the women older than 50 years in the present study, almost all had experienced menopause, suggesting that reduced estrogen levels may influence OSA in older women [16, 18].

OSA is characterized by the episodic collapse or narrowing of the upper airway during sleep, resulting in apnea or hypopnea, gas exchange abnormalities, and sleep fragmentation [21]. In the present study, to explore the issue of anatomical obstruction, the upper airway was assessed by PNS CT [22, 23]. This is the first report to quantitatively evaluate the relationship between clinical characteristics and anatomical measurements in OSA.

We measured the area of the upper airway at three different levels. First, at the level of the hard palate, the airway consisted mostly of bony structures and was not affected by the floppy muscle. Second, at the level of the soft palate, the airway consisted of a small amount of soft tissue and muscle, and there was little variation in airway size at this level. Third, the area at the base of the tongue is a closed space, surrounded by the mandible. Compared with males in the present study, females had a significantly smaller area at the base of the tongue. The size of the mandible is also anatomically smaller in females than in males. Furthermore, the tongue, a large muscle organ, loses muscle tone with age and with the altered hormone levels

during menopause. We hypothesize that deflection of the tongue, especially in older women, further narrows the small upper airway area at the base of the tongue in women and that this airway obstruction increases the incidence of OSA in women. Thus, we suggest that the use of a tongue retractor or mouth device may be a more effective treatment for OSA in older women than in men.

This study has a limitation stemming from its small sample size. However, to improve the reliability of our data and to overcome some of the bias in previous studies, we chose to analyze data collected from subjects who had been assessed with the same PSG equipment and the same CT scanner in one hospital.

Conclusions

OSA severity varies with age, gender, and upper airway area. The prognosis for OSA could be improved by evaluating the major factors affecting OSA and treating OSA patients according to epidemiological characteristics and anatomical structures. The development of new techniques can provide additional data, but it is important to carefully analyze and apply the data to make an accurate diagnosis and plan the most effective treatment of a disease.

Conflict of interest The authors have no financial disclosures.

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