Magnetic Resonance Imaging of Upper Airway Soft Tissue Structures in Obstructive Sleep Apnea

Obstrüktif Uyku Apnesinde Üst Hava Yolu Yumuşak Doku Yapılarının Manyetik Rezonans Görüntülemesi

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ABSTRACT

Background/Aim: We aimed to compare the size of upper airway soft tissue structures between obstructive sleep apnea (OSA) patients and normal controls by using magnetic resonance imaging (MRI).
Methods: Sixty-eight subjects available with neck MRI and polysomnography (PSG) were retrospectively included in the study. The subjects were divided into two groups according to apnea hypopnea indexes (AHI). The subjects with AHI more than 5 were considered to be OSA and the subjects with AHI less than 5 were considered to be controls. In all cases volume of the tongue, cross-sectional area of the uvula and upper airway volume were measured with MRI.
Results: No significant difference revealed between controls and OSA patients regarding demographic data, BMI, tongue volume, soft palate volume, upper airway volume, arousal index and basal oxygen saturation (P > 0.05). Tongue volume was found to be significantly greater in males compared to females in both study and control group (P < 0.05).
Conclusions: In this study there was no significant difference between OSA patients and controls regarding volume of upper airway and soft tissue structures. However significant difference revealed in comparison of upper airway sizes in opposite genders. Thus, gender may play an important role in determining upper airway soft tissue sizes.

Key Words: Obstructive Sleep Apnea, Magnetic Resonance Imaging, Upper Airway Volume

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ÖZET

Amaç: Obstrüktif uyku apnesi (OUA) hastaları ile normal kontroller arasında üst hava yolu yumuşak doku yapılarının boyutunu manyetik rezonans görüntüleme (MRI) kullanarak karşılaştırmayı amaçladık.
Yöntem: Boyun MRG ve polisomnografi (PSG) kayıtları bulunan 68 hasta geriye dönük olarak çalışmaya dahil edildi. Vakalar apne hipopne indekslerine (AHİ) göre iki gruba ayrıldı. AHİ' si 5'ten fazla olanlar OUA tanısı ile çalışma, AHİ' si 5'ten az olanlar kontrol grubu olarak kabul edildi. Tüm vakalarda dil hacmi, uvulanın kesit alanı ve üst hava yolu hacmi MRG ile ölçüldü.
Bulgular: Demografik veriler, VKİ, dil hacmi, yumuşak damak hacmi, üst hava yolu hacmi, uyanma indeksi ve bazal oksijen satürasyonu açısından kontroller ve OUA hastaları arasında anlamlı bir fark görülmedi (P> 0.05). Hem çalışma hem de kontrol grubunda dil hacmi kadınlara göre erkeklerde anlamlı olarak daha yüksek bulundu (P <0.05).
Sonuç: Bu çalışmada OUA hastaları ve kontroller arasında üst hava yolu hacmi ve yumuşak doku yapıları açısından anlamlı bir fark bulunmadı. Bununla birlikte, cinsiyetler arası üst hava yolu boyutlarının karşılaştırılmasında anlamlı farklılık ortaya çıktı. Bu nedenle cinsiyet, üst hava yolu yumuşak doku boyutlarının belirlenmesinde önemli bir rol oynayabilir.

Anahtar Sözcükler: Obstrüktif Uyku Apnesi, Manyetik Rezonans Görüntüleme, Üst Hava Yolu Hacmi

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INTRODUCTION

Obstructive sleep apnea (OSA) is a fairly common condition characterized by recurrent pharyngeal collapse during sleep and affects 2 to 4 % of middle age adults (1). Although exact pathogenesis of the OSA is unknown, differences in the soft tissue and bony structures of upper airway are the most likely explanations. Clinical features of this disease include chronic sleep loss with wide-ranging consequences including cardiovascular diseases such as hypertension and myocardial infarction, stroke and neurocognitive sequel (1,2).

OSA is a complex disease with many contributing factors. The contributing factors include anatomy, age, sex, family history of sleep apnea, nasal pathology, alcohol use and gastroesophageal reflux. Upper airway anatomy is without doubt the most important factor in a patient with OSA. Abnormalities of airway length cross-sectional area, shape and collapsibility contribute to obstruction (3). Bony structures and soft tissue structures such as the tongue, soft palate, lateral pharyngeal walls, and lateral pharyngeal fat pads are known to be important factors in the pathogenesis of OSA (1,2).

Upper airway evaluation is an important component of the diagnostic workup for the OSA. Several techniques are available for assessing the upper airway including thorough clinical head and neck examination, flexible nasopharyngoscopy and imaging modalities. Various imaging modalities have been used to understand the biomechanics of the upper airway and the interactions between the soft tissue and craniofacial structures. These modalities include acoustic reflectance, fluoroscopy, cephalogram, magnetic resonance imaging (MRI) and computed tomography (CT) (2,3).

Although an ideal imaging modality for the evaluation of upper airway does not yet exist MRI is probably the best method for this purpose that it provides excellent resolution of upper airway and soft tissue, accurately measures cross-sectional airway area and volume, allows imaging in the axial, coronal, sagittal planes and provides data suitable for three-dimensional reconstructions of upper airway soft tissue and craniofacial structures without radiation exposure.

The aim of this study was to investigate the soft tissue and airway abnormalities of patients with OSA by MRI.

MATERIALS and METHODS

The database of Gazi University Faculty of Medicine was examined between 2001 and 2013 retrospectively. Sixty-eight subjects whom had been performed polysomnography and neck MRI previously were included in the study. All subjects underwent history taking, thorough otorhinolarygologic examination and polysomnography (PSG). Subjects were divided into two groups according to apnea hypopnea index (AHI) obtained by polysomnographic evaluation. Patients with AHI more than 5 per hour were considered to be OSA (group 1) and patients with AHI less than 5 per hour were considered to be controls (group 2). All subjects were asked to answer VAS (visual analog scale) for the loudness of their snoring that “zero” for there is no any snoring and “ten” for the loudest snoring they have ever heard. Exclusion criteria included any contraindication for MRI such as cardiac pacemaker, any history of neck surgery such as congenital neck mass surgery, thyroid surgery, velopharyngeal surgery, neck dissection or continuous positive airway pressure (CPAP) use. Also the patients with a time gap more than three months between two studies (MRI and PSG) were excluded from the study.

MRI

All MRI examinations were performed with a 1.5 - T system (Signa Excite, GE Medical Systems, and Milwaukee, USA) with neurovascular coil. The imaging protocol consisted of a fast spin-echo axial and sagittal T1 - weighted sequence. Imaging parameters were as follows: TR/TE, 350/10; section thickness, 5 mm; intersection spacing, 0.0; field of view (FOV), 20 cm for sagittal and axial images; and matrix size, 320 x 192. Scanning time per patient was 6 - 7 minutes. MR images were transferred to Advantage Workstation 4.1 (GE Medical Systems). In all cases, volume of the tongue, cross-sectional area of the uvula in midsagittal plane and the volume of the airway between the posterior nasal spine and vocal cord were measured by using image processing software (3D or Volume Rendering). A semi-automatic calculation of the borders permitted virtual reconstruction of these structures. The tongue was defined according to the anatomical definition with all of its intrinsic muscles and the entire genioglossus and hyoglossus muscles as posteroinferiorly a line from the hyoid bone to the vallecula. The pharyngeal airway was defined radiologically as being bordered anteriorly by the soft palate or tongue, laterally by the tonsils, and posteriorly by the pharyngeal wall. This process took about half an hour per patient.

Polysomnography (PSG)

PSG was performed in an accredited sleep laboratory associated with a tertiary university hospital. PSG was performed with continuous monitoring of electroencephalography, electrooculography, chin electromyography, respiratory effort (thoracoabdominal impedance plethmysthography), and airflow via nasal thermistor, electrocardiography, oximetry and anterior tibialis electromyography. Staging was performed according to the Rechtschaffen and Kales (4) scoring. Manual apneas were defined as the complete cessation of airflow for a minimum of 10 seconds. Hypopneas were defined using the following criteria: (a) a 50 % decrease in airflow during sleep, (b) a 20 % decrease in airflow associated with a 3 % drop in oxygen saturation, and/or terminated by an arousal, and (c) the event lasts 10 seconds or longer.

Statistical Analysis

Independent sample t test was used to compare the groups and Pearson’s correlation was used for correlations. P-value lower than 0.05 was required for statistical significance.

RESULTS

There were 43 patients in OSA group that was consisted of 31 males and 12 females with a mean age of 51 ± 11 years (range 23 - 67) and 25 patients in control group that was consisted of 13 males and 12 females with a mean age of 43 ± 11 (range 21 - 68). The mean time gap between MRI study and PSG evaluation was 3.4 ± 2.2 weeks (range 0.5 - 9.3).

Multiple statistical comparisons including gender specific comparisons were made between patients and controls and following results were obtained. The data are also summarized in Table 1. Correlations between different parameters in control group, study group and gender specific comparisons were summarized in table 2, table 3 and table 4 respectively.

There was no significant difference between controls and OSA patients regarding genders, tongue volume, upper airway volume, soft palate volume, arousal index, basal oxygen saturation, age, BMI, body weight and height ($P > 0.05$). There was significant difference between their minimal and mean oxygen saturations ($P = 0.001$, $P = 0.045$).

Female patients versus female controls

There was no significant difference between both groups regarding age, body weight, height, body mass index and visual analog scale (VAS) scores ($P > 0.05$). Statistical comparison of measurements obtained by MRI for both groups revealed no difference in the volumes of tongue, upper airway and soft palate ($P > 0.05$). Results of polysomnographic evaluation were similar for both groups except for minimal oxygen saturation which was significantly lower in female patients than female controls ($P = 0.001$) and for mean oxygen concentration, which was higher in female controls than female patients ($P = 0.001$).

Male patients versus male controls

There was no significant difference between both groups regarding age, body weight, height, body mass index and VAS scores ($P > 0.05$). Statistical comparison of measurements obtained by MRI for both groups revealed no difference in the volumes of tongue, upper airway and soft palate ($P > 0.05$). Results of polysomnographic evaluation were similar for both groups except for mean oxygen saturation, which was significantly lower in male patients than male controls ($P = 0.006$).

Male controls versus female controls

There was no significant difference between both groups regarding age, body weight, height, body mass index and VAS scores ($P > 0.05$). Statistical comparison of measurements obtained by MRI for both groups revealed no difference in the upper airway volumes whereas volumes of the tongue and soft palate were significantly greater in male controls than female controls ($P = 0.002$ and $P = 0.002$ respectively). Results of polysomnographic evaluation were not significantly different for both groups ($P > 0.05$).

Male patients versus female patients
There was no significant difference between both groups regarding age, body weight, height, body mass index and VAS scores (P > 0.05). Statistical comparison of measurements of both groups obtained by MRI revealed that the tongue volumes were significantly larger in male patients than female patients (P = 0.002). Results of polysomnographic evaluation were not significantly different for both groups (P > 0.05).

Table 1. Overall and gender-specific comparison of different parameters (Min: Minimum)

Parameters	Overall (n=68)			Females (n=24)			Males (n=44)		
	Patients (n=43)	Controls (n=25)	p Value	Patients (n=12)	Controls (n=12)	p Value	Patients (n=31)	Controls (n=13)	p Value
	Mean±SD	Mean±SD		Mean±SD	Mean±SD		Mean±SD	Mean±SD	
Age	52±11	47±12	>0.05	53±8	47±11	>0.05	51±9	47±9	>0.05
Body weight	84±12	80±17	>0.05	78±18	73±16	>0.05	90±11	86±15	>0.05
Height	168±9	165±8	>0.05	156±7	160±5	>0.05	173±6	170±8	>0.05
BMI	30±4	29±6	>0.05	32±7	29±7	>0.05	30±4	29±6	>0.05
Min. Oxygen saturation	70±10	89±6	**<0.05**	68±12	89±3	**<0.05**	69±9	87±5	**<0.05**
Mean oxygen saturation	83±5	92±4	**<0.05**	86±9	94±3	**<0.05**	85±7	91±4	**<0.05**
Basal oxygen saturation	95±2	95±3	>0.05	94±2	96±2	>0.05	94±2	94±3	>0.05
Arousal index	14±10	18±23	**<0.05**	14±8	31±34	**<0.05**	16±11	16±8	>0.05
AHI	41±31	1.1±1.2	**<0.05**	44±53	0.9±0.9	**<0.05**	35±25	1.5±1.6	**<0.05**
Tongue volume	95±20	89±23	>0.05	82±16	80±16	>0.05	111±21	101±23	>0.05
Upper airway volume	15±4	14±4	>0.05	12±3	12±4	>0.05	17±5	14±3	>0.05
Soft palate volume	380±81	326±82	>0.05	324±53	306±25	>0.05	394±101	398±68	>0.05

Table 2. Correlation between different parameters in control group (Sat: Saturation, Vol: Volume, BMI: Body mass index, Min: Minimum)

Parameters compared		Correlation coefficient (r)	Statistical significance (P)
Gender	Soft palate vol.	0.630	**0.002**
Tongue vol.	Soft palate vol.	0.638	**0.002**
Soft palate vol.	Min.oxygen sat.	-0.658	**0.002**
Soft palate vol.	Mean oxygen sat.	-0.781	**0.003**
Soft palate vol.	Weight	0.625	**0.04**
Age	Min.oxygen sat.	-0.575	**<0.001**
Weight	Min.oxygen sat.	-0.776	**0.005**
Age	Mean oxygen sat.	-0.595	**0.03**
Weight	Mean oxygen sat.	-0.626	**0.04**

Table 3. Correlation between different parameters in patient group (Sat: Saturation, Vol: Volume, BMI: Body mass index, Min: Minimum)

Parameters compared		Correlation coefficient (r)	Statistical significance (P)
Gender	Tongue volume	0.568	**0.002**
Tongue volume	Upper airway volume	0.441	**0.002**
Tongue volume	Soft palate volume	0.402	**0.004**
Tongue volume	Height	0.614	**0.004**
Upper airway vol	Weight	0.453	**0.045**
Upper airway vol	Height	0.681	**0.001**
AHI	Min.oxygen sat.	-0.730	**<0.001**
AHI	Mean oxygen sat.	-0.868	**<0.001**
AHI	Weight	0.536	**0.01**
AHI	BMI	0.624	**0.003**
Weight	Basal oxgen sat.	-0.601	**0.004**
Min.oxygen sat	Age	-0.446	**0.003**
Min.oxygen sat	Weight	-0.469	**0.02**
Mean oxygen sat	Weight	-0.533	**0.01**
Age	Arousal	-0.446	**0.03**

Table 4. Correlation between different parameters in male and female patients (Sat: Saturation, Vol: Volume, BMI: Body mass index, Min: Minimum)

Parameters compared		Male Patients Correlation coefficient (r)	Statistical significance (P)	Female Patients Correlation coefficient (r)	Statistical significance (P)
Upper airway vol.	Weight	0.657	**0.015**		>0.05
AHI	Min oxygen sat.	-0.5	**0.048**	-0.941	**0.001**
AHI	Mean oxygen sat.	-0.657	**0.006**	-0.970	**0.001**
AHI	Age	0.491	**0.03**		>0.05
AHI	Weight	0.54	**0.046**	0.760	**0.044**
AHI	BMI	0.684	**0.01**	0.743	**0.005**
BMI	Basal oxygen sat.	-0.647	**0.02**	-0.540	**0.04**
Min oxygen sat.	Weight	-0.699	**0.005**	-0.809	**0.03**
Min oxygen sat.	BMI	-0.667	**0.01**	-0.724	**0.005**
Mean oxygen sat.	Weight	-0.699	**0.006**	-0.802	**0.03**
Mean oxygen sat.	BMI	-0.667	**0.001**	-0.540	**0.002**

DISCUSSION

In this study we have used MRI in order to measure the size of upper airway and soft tissue structures in patients with OSA and controls. The size of upper airway and surrounding soft tissue structures of both groups were compared. We have found no significant difference between controls and OSA patients regarding tongue volume, upper airway volume and soft palate volume. Results of polysomnographic evaluation except minimal and mean oxygen saturations, age, BMI, body weight and height for both groups were also not significantly different.

The pathogenesis of OSA has an anatomic component. The smaller size of the upper airway predisposes collapsing during sleep. The upper airway may be narrowed anatomically secondary to increases in the size of upper airway soft tissue structures such as tongue and soft palate (1-3). Although we did not demonstrate a statistical difference in the volumes of tongue and soft palate, there are large amounts of data supporting that patient with OSA to have tongue and soft palate greater in size (1-6).

The pathogenesis of the increase in size of upper airway soft tissues is still not clear but several causes have been proposed including edema secondary to negative pressure during sleep, obesity and genetic factors (5). Gender may also play an important role in determining upper airway soft tissue sizes. Women have smaller upper airway soft tissue structures than men (6). Whittle et al (7) reported that total neck soft tissue volume and upper airway soft tissue structures including tongue and soft palate were significantly larger in men than in women, which included age- and weight-matched normal men and women. We have also found that gender is an important factor for the size of the upper airway soft tissue structures. There was no statistically significant difference in volumes of tongue, upper airway and soft palate when measurements of patients and controls (female patients-female controls, male patients-male controls) in same gender were compared. However the comparisons between female controls and male controls and between female and male patients suggested significant differences in volumes of upper airway structures. Volumes of the tongue and the soft palate were significantly greater in male controls when compared with female controls. Tongue volumes were significantly greater in male patients when compared with female patients.

Numerous imaging modalities have been used to assess the upper airway and surrounding soft tissue and bony structures. These modalities include acoustic reflection, fluoroscopy, nasopharyngoscopy, cephalometry, CT and MRI (3,5,8,9). Although an ideal imaging modality for the evaluation of upper airway does not yet exist MRI is probably the best method for this purpose. Because MRI provides excellent upper airway and soft tissue resolution, accurately demonstrates the cross-sectional area and volume, allows imaging in multiple planes and does not expose the patient to any ionizing radiation. The majority of upper imaging studies indicate that the upper airway of OSA patients is narrower than normal population. CT and MRI studies have shown soft palate and tongue volumes are greater in patients with OSA (5,8,9).

In a study evaluating morphological features of the volume of the upper airway soft tissues in male patients with OSA, tongue, soft palate and lateral pharyngeal wall volumes were not significantly different between OSA and control groups, although lateral pharyngeal wall volume correlated with AHI (10). Schotland et al (11) evaluated upper airway musculature in patients with OSA by MRI and found difference in suprahyoid muscles. Comparison of OSA patients and control groups showed increased soft tissue content of the tongue muscles in patients with OSA. Schwab and Goldberg (12) showed that the volume of the upper airway soft tissue structures is enlarged in patients who have OSA by using volumetric analysis and MRI. In a study evaluating the upper airway, excess fat deposition in the soft palate and tongue was shown in patients with OSA compared with weight-matched control subjects (13). Ciscar et al. (14) found no significant difference in maximum area of velopharynx between healthy subjects and patients with OSA. There are also studies demonstrating longer and thicker soft palate in patients with OSA by using cephalometry (15,16). In a cephalometric and dynamic CT study Yucel et al. (17) found that patients with severe OSA had significantly thicker soft palate than did the mild/moderate OSA patients and control groups. Bradley et al. (18) measured pharyngeal size in snorers by using acoustic reflection and concluded that snorers with and without sleep apnea have smaller pharyngeal cross-sectional areas than non-snorers. In the current study comparing upper airway and soft tissues between OSA patients and control subjects by using MRI, no significant difference was found between control subjects and OSA patients regarding tongue volume, upper airway volume and soft palate volume.

There are some limitations of this study due to retrospective study design. The time gap (3.4 ± 2.2 weeks) between two studies (MRI and PSG) may affect the results. We compared simple snorers and OSA patients as two groups and there were not any statistically significance between these two groups regarding tongue volume, upper airway volume and soft palate volume. The severity of the disease was ruled out in our study. These parameters could be related with the severity of OSA. And the other limitation of this study was that the MRI was performed while the patients were awake and this situation probably does not reflect the anatomical abnormality during sleep.

CONCLUSIONS

Although numerous studies have shown significant difference between normal subjects and patients with obstructive sleep apnea in size of upper airway and soft tissue structures, in this study we have found no difference between both groups. When we compared the opposite genders we have found significant difference in upper airway sizes. Thus, gender may play an important role in determining upper airway soft tissue sizes.

Conflict of interest
No conflict of interest was declared by the authors.

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