KOREA J. ORTHOD. 1997. 27(6) : 865-870

A size analysis in obstructive sleep apnea patients

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The submental region in patients with Obstructive Sleep Apnea (OSA) is perceived to be larger than normal. Therefore, neck thickness has become a variable routinely measured during clinical screening of OSA subjects. In general, OSA patients are believed to have a large tongue and a narrow airway. To test if OSA patients have a larger face and tongue than non-apneics, eighty pairs of upright and supine cephalograms were obtained from four groups of subjects subclassified in accordance with severity. The sum of distances between pairs of landmarks was calculated for each subjects and employed as a pure size variable for the face and tongue. Only tongue size becomes larger in accordance with apnea severity in both body positions ($P<.01$). Tongue size reflects apnea severity, yet it provides only a small fraction of the explanation with regard to apnea severity. We conclude that size may be one factor of many which are significantly related to OSA severity.

Key words: Obstructive Sleep Apnea, cephalometry, tongue, landmark, supine position

Although an anatomically large tongue in combination with a narrow pharyngeal airway has been speculated on as a primary causal factor for OSA, obesity also appears to play a significant role in the pathophysiology of the disease. Several studies have reported that a thick neck may be a variable can be used for screening of OSA patients[1]. Clinicians have observed that most OSA patients are obese and therefore, supposedly have a large face and neck. It has been shown that a loss of even a few kgs of body weight can markedly improve OSA severity[2]. Many previous studies have quantified the size of the tongue and airway, and tried to associate the size of the structure with obesity[3]. Size of anatomical structures is traditionally evaluated by area[4,5,6] and volme[7] measurements. However, these measurements include a mixed sence of size and shape. For instance, a narrow airway can have a large volume when it is long. Therefore, a volume measurement does not necessarily express size of the structure. Few studies have attempted to evaluate a geometical size of the face and tongue in OSA patients.

Lateral cephalometry has become a routine adjunctive diagnostic tool for OSA due to its speed, accessibility, and low cost. In contrast to other major imaging techniques, such as computed tomography (CT) or magnetic resonance imaging (MRI), conventional cephalograms are obtained in the upright body position in awake subjects. In order to correlate the cephalogram with information from these techniques, supine cephalometry has been developed[8]. A few recent cephalometric studies have examined the effect of posture on upper airway size and related structure

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changes. However, the precise changes that occur in the upper airway during body position changes still remain unclear.

A precisely weight-matched investigation by Horner et al.[9] reported that there are no systemic differences in fat deposit distribution between OSA patients and normal subjects, and they could not establish a significant association between the degree of obesity and the size of fat deposits[10]. Moreover, if obesity is over-emphasized as an etiologic factor, it may be hard to explain the existence of non-obese OSA patients in terms of size. Size has been believed to play an important role in the pathophysiology of OSA. However, it might obscure an important underlying functional process as well. The current project attempts to measure pure geometrical size of the face and tongue in patients with OSA by eliminating shape from a mixture of size and shape, and tries to answer the following questions; How much does the size of the face and tongue influence OSA severity ? What is the relationship between tongue size and obesity? What is the effect of a posture change on face and tongue size.

MATERIALS AND METHODS

To diagnose OSA, overnight hospital polysomnogram monitoring was performed on each patient at the Respiratory Sleep Disorder Clinic. Sleep and its stages was documented by electroencephalogram (EEG), electrooculogram (EOG) and electromyogram (EMG) activity was recorded from the submental muscles[11]. Apneas were defined as cessation of airflow at the nose and mouth for longer than 10 seconds and were documented by an infrared CO_2 analyzer (Model LB-2; Beckman Instruments, Inc., Schiller Park, IL). A single electrocardiogram (ECG) lead (modified V2) was recorded to detect cardiac arrhythmias. SaO_2 was monitored continuously with a pulse oximeter (Model N-100; Nellcor, Inc., Hayward, CA). Chest wall movement was monitored by a respiratory inductive plethymograph (Respitrace@; Ambulatory Monitoring zEquipment, Ardsley, NY). The data were recorded 15-channel polygraph (Model 78; Grass Instruments Co., Quincy, MA) at a paper speed of 10 mm/s. A

Table 1 Anthropometric variables and apnea indices

	mean	s.d.	min.	max.
AGE(yrs)	45.86	12.47	18	71
BMI	29.39	6.21	21.08	53.04
Weight (kg)	88.75	16.89	56	148.50
AI	11.20	13.74	0	67.71
RDI	26.63	23.88	0	98.75

s.d. indicates standard deviation
min. indicates minimum value
max. indicates maximum value
BMI (Body Mass Index) = Weight (kg) / Height^2 cm^2)
AI (Apnea Index)
RDI (Respiratory Disturbance Index)

microcomputer continuously monitored and stored arterial oxygen saturation, chest wall movement, and heart rate data on a mass storage medium. Subjects with ongoing respiratory infections, subjects on medication known to affect muscle activity, those who required orthognatic surgery, or edentulous subjects were excluded from the study.

A total of 80 subjects were selected from patients referred to the clinic (Table 1). The subjects were classified into four subgroups according to OSA severity: non-apneic, mild, moderate and severe. The severity of sleep apnea was evaluated by a combination of Apnea Index (AI), defined as the total number of apneas divided by the total sleep time in minutes, and Respiratory Disturbance Index (RDI), defined as the total number of apneas and hypopnoeas divided by the total sleep time in minutes. The non-apneic group included subjects whose AI ranged from 0-4 or whose RDI ranged from 0-9. The mild group included OSA subjects who presented an AI of 5-15 or 10-30 for RDI. The moderate subjects demonstrated 16-25 for AI or 31-50 for RDI. The severe group included subjects who had values higher than 25 for AI or 50 for RDI. The non-apneic group consisted of 20 subjects was included to provide a standard. The mild, moderate and severe group included 26, 17 and 17 subjects respectively.

A pair of cephalograms were obtained for each subject in upright and supine positions. Details regarding the cephalographic technique are provided in a previous paper[8]. Seven landmarks considered to best

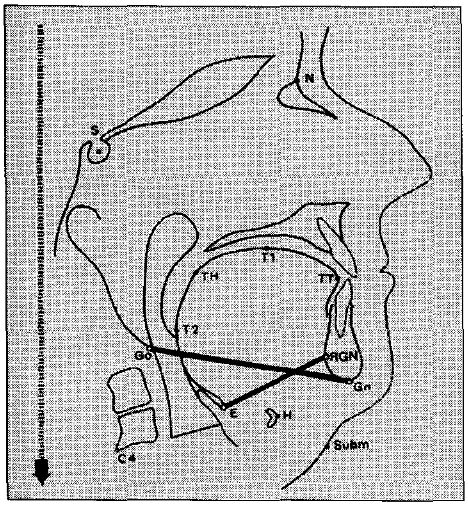

Figure 1. Landmarks on the face and tongue. **S** (Sella), **N** (Nasion), **Gn** (Gnathion), **Go** (Gonion), **H** (Hyoidale), **C4** (4th Vertebra), and **Subm** (Submentale) are landmarks for the face. **TT** (Tongue Tip), **T1**, **TH** (Tongue Height), **T2**, **E** (Epiglottis), **H** (Hyoidale) and **RGN** (Retrognathion) are landmarks for the tongue. An arrow on the left indicates the true vertical chain.

depict the facial configuration were determined on the cephalograms; Sella, Nasion, Gnathion, Gonion, Hyoidale, 4th vertebra, and Submentale. Submentale was defined as the intersect point of the inferior chin profile in the submental area and a line through RGN. All landmarks were coordinated with X and Y axis values (Fig. 1).

The simplest size variable may be the distance between any pair of K landmarks[12]. A constructed

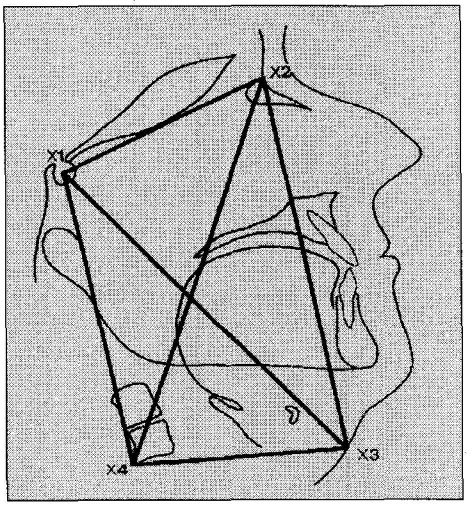

Figure 2. This figure demonstrates how the size variable is constructed. The sum of all the interlandmark distances, $\Sigma\{X_i - X_j\}$ is employed as the size variable.

landmark variable, which is the root-summed-squared set of interlandmark distances, was employed as the size variable for the face, SIZFACE and for the tongue, SIZTONGUE (Fig. 2). Two dimensional structures of the face and tongue were traced on acetate paper with a 0.5 mm pencil for each of the landmarks and outlines. Boundaries were outlined in the middle of tissue transition zones to take into account averaging.The landmarks and outlines were digitized and stored in a computer. The statistical programs SYSTAT (SYSTAT, Inc., Evanston, IL) was utilized to analyze the data. Pearson's product moment correlation was employed to examine the correlation between the

A total of seven landmarks were utilized for the tongue analysis.

TT Tongue Tip:	The center of the lead disc attached on the transition border from ventral to dorsal surface of the tongue tip.
T1:	A tangential point on the dorsal surface with the true horizontal line.
TH Tongue Height:	The highest point of the tongue curvature relative to a line from E to TT.
T2:	A tangential point on the dorsal surface with the true vertical line.
E Epiglottis:	The deepest point of the epiglottis.
H Hyoidale:	The most anterior and superior point of the hyoid bone.
RGN Retrognathion:	The most posterior point of the mandibular symphysis along a line perpendicular to the FH (Frankfort Horizontal) plane.

Table 2. Pearson's product moment correlation coefficient.

	SIZFACE		SIZTONGUE		RDI
	upright	supine	upright	supine	
Weight	0.632 ***	0.667 ***	0.564 ***	0.511 ***	0.453 ***
BMI	0.481 ***	0.517 ***	0.481 ***	0.391 ***	0.439 ***
RDI	0.185	0.270 *	0.346 **	0.219	1.000

* indicates $P < 0.05$
** indicates $P < 0.01$
*** indicates $P < 0.001$

Table 3. ANOVA analysis on group differences in different body position.

		upright				supine			
		SIZEFACE		SIZTONGUE		SIZFACE		SIZTONGUE	
GROUP	N	mean	s.d.	meanx	s.d.	mean	s.d.	mean	s.d.
NON-APNEIC	20	287.51	26.65	210.35	24.48	287.09	27.24	207.79	23.67
MILDx	26	288.34	24.96	212.52	22.93	287.90	25.51	212.03	22.17
MODERATE	17	291.71	27.76	216.20	25.50	292.08	28.36	214.94	24.65
SEVERE	17	289.61	27.76	217.16	25.50	290.38	28.36	212.91	24.65
P		0.112		0.004		0.035		0.873	

variables. An one-way ANOVA (Analysis of Variance) was used to examine the group effect.

RESULTS

Tables 1 summarizes the anthropometric data and sleep index variables. Body Mass Index is a height standardized weight variable calculated by the formula of BMI = Weight (Kg) / $Height^2$ cm^2). A simple correlation is examined to find which is better correlated to RDI between weight and BMI (Table 2). Weight appears to be more associated with RDI than BMI, yet the difference was nominal. Correlation between the size variables and weight, BMI, and RDI was also investigated. In both positions, SIZFACE shows higher correlation to weight variables than SIZTONGUE, however SIZTONGUE in the upright position is found to best associate with RDI. Correlation coefficients of SIZFACE to Weight, BMI, and RDI are higher in the supine position, whereas those of SIZTONGUE to the same variables are higher in the upright position.

Mean value changes of the structure size in accordance with apnea severity are tabulated in Table 3. The ANOVA test evidenced that there is a tongue size difference among the subgroups in both body positions at a P level of 0.004. The face size appears not to be different from subgroup to subgroup, however the tongue size evidently becomes larger in accordance with apnea severity in both body positions.

DISCUSSION

Obesity has been recognized as the strongest predisposing factor for OSA[13]. The mechanical load of breathing is increased with obesity and is significantly exaggerated in the supine position[14]. Tables 2 demonstrates that BMI and Weight are significantly associated with apnea severity. In agreement with an earlier study[15], the results of the current study reveal that BMI does not surpass the variable Weight in its predictability of RDI. Another interesting observation in this study was that the face size is better associated with weight than is tongue size (see Table 2). Therefore, we suppose that an obese person may have a larger face in clinical terms. However, tongue size in the upright position showed a higher correlation with RDI than did face size. An individual with a large face may tend to be heavy, but this person does not necessarily have a large tongue.

The ANOVA table summarizes the results. The more severe symptoms the OSA patient shows, the larger the tongue size in the upright position (see Table 3). When comparing tongue size between upright and supine positions, it becomes smaller in the supine position in each group. This might explain the corresponding higher genioglossus (GG) EMG activity reported in awake OSA subjects[16]. Theoretically, an OSA patient with a large tongue would be expected to have a smaller pharynx in the supine position than in the upright when one considers the response of the tongue to gravitational pull. However, these results report a higher correlation coefficient between tongue size and severity in the upright position than in the supine. This finding suggests that the tongue size does not change significantly as the body posture changes from upright to supine in an awake state. In awake subjects, the GG muscle activity may increase to keep the airway open in the supine position and the tongue size as measured in the midplane may become smaller in the supine position.

Standardization of size by any variable explicitly measured, regardless of its unit, confounds the variation of that unit[12]. The geometric size variable employed here is uncorrelated to shape coordinates, and it explains nothing but size. As long as the selected landmarks describe the entire form of a biological object faithfully, the sum of all squared distances between the pairs of landmarks express size without any confounding factor. This size variable may be superior to other size variables such as area or perimeter which are often used clinically. In summary, tongue size is found to be a variable which reflects apnea severity significantly, yet still provides only a small fraction (Adj R^2 = 0.108 to RDI) of the explanation with regard to OSA symptoms. The size used in this paper is not the same size which has been measured in the previous studies. Nevertheless, it may be speculated that size may not be a main risk factor for apnea severity. Based on this interpretation, we conclude that the size imbalance of anatomical structures of the face and tongue may have been over-emphasized as a possible cause of OSA.

ACKNOWLEDGEMENTS

The authors wish to thank to Ms. M. Wong for her computer expertise.

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국문초록

폐쇄성 수면무호흡 환자의 안면 및 혀의 크기에 대한 연구

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폐쇄성 수면무호흡(이하 OSA)환자의 일반적 특징의 하나로 다소 비대한 Submental부위를 든다. 따라서 근간에는 경부주위의 측정을 임상적 진단의 한 보조방법으로 채택하는 경우도 있다.

본 연구는 80명의 환자로 부터 직접위와 앙와위의 두 자세에서 각각 두 장의 측모두부방서선사진을 채득하여 OSA환자의 안면과 혀의 크기를 일반인의 그것과 비교 하였다. 채득된 실험자료는 각각 증상의 심한 정도에 따라 무증상군, 경미군 中증군 그리고 重증근으로 나누었다. 크기 측정의 방법으로는 각각의 두 계측점간의 거리를 측정하여 모든 계측치의 합으로 해부학적 크기를 대신하였다. 결과로서, 안면의 크기가 혀의 크기보다 체중과 더 높은 상관관계를 보였으나, 증상의 심한 정도와는 혀의 크기가 더 중요한 측정치 임을 알 수 있었다. 혀의 크기가 증상의 정도에 비례함에 있어서 1%의 유의차를 보였다.

주요 단어 : 폐쇄성 수면무호흡, 측모두부방사선사진, 혀, 앙와위
* 본 연구의 일부는 연세치대 교정학교실 연구비로 이루어졌음.