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Characterization of Upper Air Way Tract in Snoring and Non-Snoring Patients: A CT Based Study

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Abstract

Snoring is part of the spectrum of sleep disordered breathing. The patients with snoring should be evaluated for nasal airway obstruction. In this study, the upper air way tract was characterized in snoring patients and compared with none snoring using a quantify method for the corresponding anatomic upper air way (UA) parameters examined by Computerized Tomography (CT). Two hundred Asian patients undergoing CT scanning for head and neck were included and were divided into two groups (snoring group [n = 127] and non-snoring group [n = 73]) (mean age: 44.8 ± 15.9 years and 26.2 ± 7.0). Total 8 parameters were measured on sagital reconstructed CT images for each subject. The differences in neck circumference (NC), linear distance between mandibular plane and hyoid bone (Mp-H), upper airway length (UAL), the maximum thickness of the soft palate (SP max), soft palate length (PNS-U), linear distance between anterior and posterior nasal spine (ANS-PNS), retroglosal width (RS), retroplatal width (RP) between the snoring and non-snoring groups were compared statistically using independent sample t-test. Results showed that the NC, UAL, and SP max were significantly higher in snoring group; however RP was found to be significantly lower. Inferior positioning of hyoid bone gives longer measurement for MP-H. In snoring group UAL was found to be significantly different at p ≤ 0.000 between the two genders. All the measured variables showed no significant differences in respect to age. UA CT quantitative features play an important role in the characterization of the anatomy and are compared between snoring patients and non-snoring subjects.

Keywords

Snoring, Upper Air Way Tract, Computerized Tomography

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1. Introduction

The upper airway (UA) is comprised of numerous cylindrical segments of different cross-sectional areas and of unequal length; and therefore, the UA acts as tubes of Venturi [1]. The passage of airflow through these airways should satisfy the equation of Bernoulli and the law of Poiseuille [1] but it moderately assures these laws, because of its particular anatomical and functional features. The UA has different segments characteristics which can be firm or collapsible depending on morphology and trophicity [2].

During normal sleep the tone of the pharyngeal airway dilator muscles, the genioglossus, levator palati, and palatopharyngeus is decreased with resultant partial upper airway collapse and narrowing of the lumen giving rise to turbulent flow [3]. The turbulence leads to vibration of the soft tissues in the collapsible part of the upper airway. This extends from the choanae to the epiglottis and involves the soft palate, the uvula, the tonsils, the tonsillar pillars, the tongue base and the muscles of the pharynx [4].

In normal individuals upper airway narrowing increases the resistance to airflow at sleep onset. The nose accounts half of the total airway resistance to airflow and a semi-blocked nose requires increased inspiratory effort; this lowers intrapharyngeal pressures and tends to suck the pharyngeal walls together causing increased snoring [5]. Many patients have a worsening of their snoring when they suffer from an upper respiratory tract infection or an increasing in nasal resistance which may aggravate snoring by increasing the negative intrapharyngeal pressure leading to inspiration flow limitation and trembling of the upper airway walls [6].

Patients with sleep apnea have narrowing in the oropharynx, usually at the level of the uvula-soft palate complex or the base of the tongue [7] [8]. Less frequently, tonsillar hypertrophy, pharyngeal tumors, or other disorders may cause obstructive sleep apnea (OSA) [9]-[14]. Several clinical symptoms such as snoring, apnea during sleep, and other disturbances may possibly present [15].

Different modalities, such as polysomnography, endoscopy, are used in the diagnosis and evaluation of OSA [16]-[18]. Diagnosis may be difficult and more complicated in choosing the best surgical procedure in each case. Computed tomography (CT) is a noninvasive technique that allows a detailed assessment of the entire upper airway [19]-[21]. CT scanning significantly improves soft tissue contrast, leads surgical interventions toward the abnormal anatomic sites and allows for precise measurements of cross-sectional areas at different levels [22]. Studies utilizing CT scanning have been able to show correlations between anatomic changes and step up of obstruction parameters, giving an accurate measurement of upper airway area [23].

Sleep-disordered breathing is a series of disorders ranging from primary snoring to severe OSA [24]. It is thought to be due to varying combinations of anatomical and neuromuscular factors resulting in airway obstruction. Different ethnic groups have significant differences in craniofacial and soft tissue features. These ethnic differences in craniofacial morphology greatly affect airway dimensions as Caucasians, Afro-Americans Asian populations [25] [26]. Since craniofacial features differ among ethnic populations, specific characteristics for each population might suggest the risk for snoring in concerned ethnic population and require further diagnostic evaluation. The patients with snoring should be evaluated for nasal airway obstruction. In this study, we characterize the UA that has been evaluated subjectively as nasal obstruction using a quantify method for the corresponding anatomic upper air way parameters in patients with snoring using CT so as to acquire better results in distinguishing healthy controls from snoring patients.

2. Materials and Methods

2.1. Sample and Technique

Two hundred patients undergoing CT scanning for head and neck were included in the study. 147 (73.5%) were males and 53 (26.5%) were females. The sample was divided into two groups (snoring group [n = 127] and non-snoring group [n = 73]) (mean age: 44.8 ± 15.9 years and 26.2 ± 7.0). The CT scans of patients without snoring or any sleep related symptoms or changes affected the upper air way tract were evaluated as controls and were used for comparison with snoring group. All participants were non traumatic. In the present study the Saudi population in the sample including 174 patients and the rest were from other Asian populations. Verbal consent was firstly obtained from all potential participants. The aims, benefits of the present study were explained to all participants in details. As the majority of individuals who snore are unaware of their snoring, questions about snoring were answered by the bed partner or relatives and not by the snorer themselves and those with conditions that may in any way, alter the findings of the current study were excluded. MDCT scanner was (Toshiba Aquilion (TSX-101A) 16 slice, (Jizan General Hospital, KSA)). The study span during the period from 2014-2015.

The examinations were performed with all patients in the supine position with their heads and neck in a neutral position, lateral scout view was taken first to determine the level of the scans, Scanning was done from the lower portion of the upper cervical spine to the upper facial orbit. The conditions of scanning were 120 kVp, 300 mA with slice thickness of 1, 1.5 and 2 mm. pixel size 512 × 512. Measurements were done on the lateral scout view and sagittal views, using special computer soft ware (RadiAnt DICOM viewer 32 BIT).

Neck circumference (NC) at the level of coric thyroid membrane, ages and seven standard bony and soft-tissue measurements to show changes in snoring patients were obtained.

2.1.1. Identifying Variables

a- Soft palate length (PNS-U) that is the distance between posterior nasal spine and the uvula,
b- Maximum thickness of soft palate (SP max),
c- Upper airway length (UAL) is vertical distance from the hard palate to the hyoid bone,
d- Retroplatal width (RP) behind the soft palate,
e- Retroglosal width (RS) behind the tongue,
f- MP-H is the distance between mandibular plane and hyoid bone,
g- ANS-PNS is the linear distance between anterior nasal spine (ANS), and posterior nasal spine (PNS).

2.1.2. Identifying Reference Points

h- Anterior Nasal Spine (ANS)—the most anterior point on the maxilla at the nasal base,
i- Posterior Nasal Spine (PNS)—the tip of the posterior nasal spine of the palatine bone, at the junction of the soft and hard palate.

2.2. Data Analyses

Data were analyzed using Statistical Package of Social Sciences (SPSS) (Inc., Chicago, Illinois version 16). The data obtained were analyzed statistically by computing descriptive statistics: Mean, ± SD values and percentages. Paired t-test was used for testing the differences between the formulae results. The difference at value of $P < 0.01$ will be considered significant.

3. Results

The following tables presented the data obtained from snoring and non snoring patients. Mean age of the snoring males was 42.6 ± 14.61 years and the females was 53.2 ± 18.25 years.

4. Discussion

The present study included both genders. The prevalence of snoring was found to be 127 patients including 100 males (78.7%), their ages were 42.6 ± 14.61 and 27 females (21.3%), and their ages were 53.2 ± 18.25 age ranged between 15 and >75 years (**Figure 1**). Comparing with previous studies done for snoring; men and

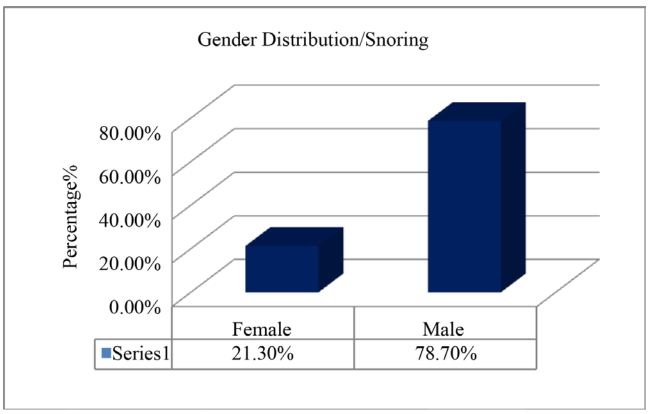

Figure 1. Classification of snoring group according to gender presented in percentages %.

women showed an increase of snoring in mid-life [27]-[29]. In other study of patients between 30 and 60 years of age, the highest prevalence were found among men between 50 and 60 years. Fifty three percent of men and 31% of women in this age group reported snoring [30]. Large population based studies have shown an increasing trend in prevalence of snoring up to the age group of 60 - 69 years in Finland [31] and up to 60 - 70 years in Spain [32]. Other studies have reported higher prevalence among middle-aged populations: 44% in men and 28% in women in the USA and 28% - 44% and 6% - 19% in Finland, respectively [27] [30] [31]. Men have 2- to 3-fold greater risk of snoring than women, but mechanisms underlying this difference are not clear. Results from a recent study suggest that increased collapsibility in the pharyngeal airway in men is based on anatomical differences [33].

Table 1 shows independent samples t-test for equality of means between the snoring and non snoring groups studied for age and different anatomical areas differences. Significant difference between the ages of snoring patients and non snoring group at $p \leq 0.000$ was detected. The difference between the neck circumference (NC) was found to be significantly differ and greater in snoring patients than non-snoring at $p \leq 0.000$. The importance of considering the measurement of NC because it is was established that having a neck circumference (NC) of 40 cm or more is one of the most significant risk factor for the development of Obstructive Sleep Apnea Syndrome (OSAS) and it is a cutoff point as a risk factor for OSAS [34]. Our sample have less measurement and not reach the cutoff point of obstruction diagnosis, but it differ from non-snoring; it means the measurements increased by 43 mm from 109.4 mm for patients measurements ranged from 84.5 - 126 mm, may consider as snoring complain but not broaden to be diagnosed as obstruction sleep apnea. We justify this findings is that to be anatomical variations between different studied ethnic groups [26] [33]. Despite the clear association between snoring underlying causes and obesity, the mechanisms behind this relationship is not yet fully understood. Particular patterns of fat distribution may be specifically relevant and underlie the pathophysiological

Table 1. Independent samples T-test for equality of means between the snoring and non snoring groups studied for age and different anatomical areas.

	Group	N	Mean ± SD	MAX	MIN	P-value
AGE	Snoring	127	44.8 ± 15.9	85	18	0.000**
	Non snoring	73	26.2 ± 7.0	47	15	
NC	Snoring	127	151.5 ± 97.1	1222	104	0.000**
	Non snoring	73	109.4 ± 10.6	126	84.5	
MP-H	Snoring	127	14.4 ± 13.3	153	0.0	0.059
	Non snoring	73	11.3 ± 5.1	31.8	4.10	
ANS-PNS	Snoring	127	54.2 ± 32.8	418	38	0.170
	Non snoring	73	48.9 ± 4.5	62.6	41.7	
Rs	Snoring	127	14.0 ± 3.7	25	4.3	1.00
	Non snoring	73	13.1 ± 3.2	22.3	7.5	
Rp	Snoring	127	6.0 ± 5.0	57	0.0	0.001**
	Non snoring	73	9.3 ± 8.2	58	3.10	
UAL	Snoring	127	60.7 ± 7.7	80	45	0.000**
	Non snoring	73	55.1 ± 6.8	72.4	39.9	
SP-MAX	Snoring	127	11.8 ± 1.8	18.2	5.8	0.000**
	Non snoring	73	8.6 ± 1.5	11.8	5.3	
PNS-U	Snoring	127	41.3 ± 31.9	39.4	29	0.084
	Non snoring	73	34.7 ± 5.2	49.7	23.7	

**Significance at level 0.01.

mechanisms. Neck fat deposition (neck circumference), have been specifically related to snoring [34] [35]. Obesity has also been clearly shown to be linked to sleep disturbance breathing. It seems that this is in part a proxy marker for neck circumference [36]. Therefore weight particularly is coincident with a presence of snoring.

The linear distance between mandibular plane and hyoid bone (Mp-H) was found to be greater and differ between the two groups. In snoring patients, the hyoid bone was found to be more inferiorly placed. The justification of the presence of snoring in such patients is that the lower position of the hyoid increase the mandibular consignment because of the requirement of extra energy to elevate the tongue; this, worsen apnea by resulting in the open-mouth posture during sleep concluded with snoring, this was similar to the finding mentioned in previous study [37], similarly Wong *et al*. found that the hyoid bone was located more posteriorly in Chinese snoring subjects when compared with Malays and Indians [38] and our study population were Saudi and other Asian populations. Retroplatal width (RP) was found to be smaller in snoring patients and differed significantly at $p \leq 0.001$. Upper airway length (UAL) which was measured as the vertical distance from hard palate to the hyoid bone differed significantly at $p \leq 0.000$. When compared to snoring group, length of soft palate (PNS-U) was found to be longer in snoring than in non-snoring group but the difference is not significant ($P < 0.084$). Adverse results were found in a study done by Abhishek Dubey [39].

The maximum thickness of the soft palate (SP max) differs significantly at $p \leq 0.000$ between the two groups. The snoring patients in another similar study in different population showed significantly longer soft palate, which occupied more space in the oropharyngeal area. Studies had indicated that continuous vibration of the soft palate during snoring leads to continuous trauma and causes mucosal edema, further reducing upper airway patency [40]. The increased muscular stiffness of the soft palate suggests that its tissues undergo morphological and functional changes, supported by the findings of the uvular and soft palate muscles in snoring [40]. The changes thought to be due to varying combinations of anatomical and neuromuscular factors resulting in airway changes [26]. In our sample, there is no pathological findings or underlying cause for obstruction were detected except the changing in the measurements. Predictive factors in upper airway anatomy or detected variation that explaining the progression of snoring were not found, another similarly study done by Pendlebury *et al*.,1997 mentioned similar findings [41].

However, this mechanism depends on the morphology orofacial musculature. Many other studies have also found that the interrelationship of craniofacial morphology and muscle function of the upper airway is important in the understanding pathogenesis behind snoring [42]. Different ethnic groups have significant differences in craniofacial and soft tissue features. These ethnic differences in craniofacial morphology greatly affect airway dimensions [39]. These differences were due to ethnicity changes. We suppose that the difference between the two groups is that they are of different ethnicity.

Mean and standard deviation, t-test for equality of means of the measured anatomical areas for snoring patients classified according to gender were studied and the measurements were presented in (**Table 2**). No significant difference was detected in the evaluated anatomical structures between genders except the UAL; the men have greater measurements than females in the studied population. Results from a recent study suggest that increased collapsibility in the pharyngeal airway in men is based on anatomical differences between genders as mentioned by Malhotra *et al*. (2002a) [33]. Age classes have no impact on the measured anatomical areas for snoring patients this was presented in (**Table 3**). Studies showed that the reasons for differences in prevalence of snoring with age are poorly understood as mentioned in previous studies [43].

Several imaging methods had evaluated and measured the upper air way tract [44]. Two-dimensional (2D) lateral cephalograms have traditionally served as the radiographic standard for airway assessment in patients with upper respiratory tract problems. Although lateral cephalometric measurements are useful for analyzing airway size in the sagittal plane, they do not accurately depict the 3-dimensional (3D) airway anatomy. In addition, the correlation of commonly used linear and angular measurements obtained from lateral cephalograms with the severity of disease, has not been documented in published studies [45]-[47]. Finally, although the most physiologically relevant information is obtained from axial images, perpendicular to the direction of airflow, the axial plane is not visualized on lateral cephalograms [48].

In contrast, an accurate 3D image of the airway can be obtained using computed tomographic (CT) data in the coronal, axial, and sagittal planes [49]. Although multiple reports have been published on the use of CT imaging for assessment of the upper airway, few data are available on the reliability of this technique [50] [51].

The advantage of our usage of the based technique and imaging methods in the current study is that with MDCT, thin-section images of the entire central airways was obtained in only a few seconds, creating an isotropic data set in which the resolution is excellent [52]. MDCT technique provides higher spatial resolution,

Table 2. Mean and standard deviation, T-test for equality of means of the measured anatomical areas for snoring patients classified according to gender.

	GENDER	N	Mean ± S.D	P-value
NC	Male	100	155.4 ± 108.99	0.390
	Female	27	137.2 ± 14.65	
MP-H	Male	100	13.5 ± 4.87	0.158
	Female	27	17.6 ± 27.52	
ANS-PNS	Male	100	51.8 ± 4.73	0.110
	Female	27	63.2 ± 71.03	
Rs	Male	100	14.0 ± 3.89	0.979
	Female	27	14.0 ± 3.32	
Rp	Male	100	6.2 ± 5.57	0.209
	Female	27	4.9 ± 1.77	
UAL	Male	100	62.3 ± 7.34	0.000**
	Female	27	54.8 ± 6.64	
SP-MAX	Male	100	11.9 ± 1.77	0.071
	Female	27	11.2 ± 2.25	
PNS-U	Male	100	42.6 ± 35.85	0.373
	Female	27	36.4 ± 4.39	

**Significance at level 0.01.

faster speed, greater anatomic coverage, and higher quality multiplanar reformation and 3-D reconstruction images. Multiplanar and 3-D reconstruction images help to overcome the limitations of axial images by providing a more anatomically meaningful display of complex structures of the airways [53] [54]. These images have been shown to enhance the detection of airway stenoses if present and to aid the assessment of the craniocaudal extent of the stenosis, and to clarify complex airway abnormalities [55]. They have also been shown to improve diagnostic confidence of interpretation, measurements and enhance pre-procedural planning for bronchoscopy and surgery [53].

Although multiplanar and 3-D reconstruction images do not actually create new data, they provide an alternative method of viewing CT data that is often more visually accessible and anatomically meaningful.

The progress in CT technology allowed us to obtain high resolution 1, 2-mm-thick sections. The setting of computer window and zoom factor ensured high accuracy in measurements. We believe that the measurements of the upper air way tract by modern CT technique can be used as a guide for the evaluation of norms, diseases and their severity before and after surgery. Sagittal reconstruction can demonstrate the narrowing at the level of the uvulopalatinal complex and at the base of the tongue. The CT reconstruction can be important when there are difficulties in deciding which the procedure of choice is. Uvulopalatopharyngoplasty should be the choice when there is only uvulopalatinal narrowing [44]. However the CT reconstruction is a nonaggressive technique for demonstrating the location of the pharyngeal narrowing if present.

5. Conclusions

Results showed that the NC, UAL, and SP max were significantly higher in snoring group; however RP was also found to be significantly lower. Inferior positioning of hyoid bone gives longer measurement for MP-H. In snoring group UAL was found to be significantly different at $p \leq 0.000$ between the two genders. All the measured variables showed no significant differences in respect to age. UA CT quantitative features play an important role in the characterization of the anatomy and are compared between snoring patients and non-snoring

Table 3. Mean and standard deviation, T-test for equality of means of the measured anatomical areas for snoring patients classified according to age classes.

		Descriptive				ANOVA
		N	Mean ± S.D	Minimum	Maximum	P-value
Rs	15 - 30	20	14.2 ± 4.27	7.60	23.40	0.072
	31 - 45	57	14.0 ± 3.63	6.50	21.40	
	46 - 60	30	12.8 ± 3.46	4.30	19.30	
	61 - 75	12	16.5 ± 4.21	12.00	25.00	
	>75	8	14.4 ± 2.39	10.80	17.90	
	Total	127	14.0 ± 3.77	4.30	25.00	
Rp	15 - 30	20	6.5 ± 2.45	2.20	11.40	0.627
	31 - 45	57	6.4 ± 7.02	1.50	57.00	
	46 - 60	30	5.2 ± 2.52	0.00	11.50	
	61 - 75	12	6.2 ± 2.41	2.30	10.00	
	>75	8	3.9 ± .66	3.00	4.90	
	Total	127	6.0 ± 5.03	0.00	57.00	
UAL	15 - 30	20	58.1 ± 6.64	46.30	67.70	0.075
	31 - 45	57	61.1 ± 8.24	45.00	80.80	
	46 - 60	30	63.2 ± 7.3	51.30	80.40	
	61 - 75	12	56.9 ± 7.91	47.20	71.20	
	>75	8	60.3 ± 6.12	46.30	66.90	
	Total	127	60.7 ± 7.79	45.00	80.80	
SP-MAX	15 - 30	20	11.1 ± 2.35	5.80	16.20	0.234
	31 - 45	57	12.1 ± 1.53	7.70	15.80	
	46 - 60	30	11.7 ± 2.04	7.40	15.70	
	61 - 75	12	11.3 ± 2.45	8.60	18.20	
	>75	8	12.2 ± 1.23	10.80	14.70	
	Total	127	11.8 ± 1.89	5.80	18.20	
PNS-U	15 - 30	20	38.0 ± 4.74	31.90	47.00	0.908
	31 - 45	57	44.4 ± 47.39	29.10	394.00	
	46 - 60	30	39.2 ± 4.84	31.50	50.00	
	61 - 75	12	38.0 ± 6.65	29.40	52.50	
	>75	8	39.7 ± 4.99	30.50	46.00	
	Total	127	41.3 ± 31.94	29.10	394.00	
NC	15 - 30	20	137.9 ± 15.54	112.00	177.40	0.916
	31 - 45	57	159.7 ± 143.87	118.70	1222.00	
	46 - 60	30	150.8 ± 18.49	117.70	184.60	
	61 - 75	12	140.5 ± 21.34	104.30	174.50	
	>75	8	146.7 ± 11.22	130.50	159.10	
	Total	127	151.5 ± 97.13	104.30	1222.00	

Continued

MP-H	15 - 30	20	12.5 ± 4.27	6.50	22.80	0.446
	31 - 45	57	13.0 ± 5.09	0.00	24.30	
	46 - 60	30	18.3 ± 25.97	5.70	153.00	
	61 - 75	12	13.4 ± 4.59	6.60	19.60	
	>75	8	15.3 ± 4.48	8.10	22.20	
	Total	127	14.4 ± 13.33	0.00	153.00	
ANS-PNS	15 - 30	20	52.5 ± 5.42	43.80	61.70	0.079
	31 - 45	57	51.2 ± 5.25	38.00	64.20	
	46 - 60	30	51.6 ± 3.93	42.60	61.60	
	61 - 75	12	80.2 ± 106.40	44.00	418.00	
	>75	8	51.1 ± 3.87	45.80	58.70	
	Total	127	54.2 ± 32.87	38.00	418.00	

subjects adding information about the ethnicity and gender related difference. Further investigation was required using large sample of snores and non-snores concerning only Saudi population in order to establish norms for their measurements so as to predict early changes in UA in cases of sleep-disordered breathing diagnosing series of disorders ranging from primary snoring to severe OSA.

From this point of view, however, the axial images provide a more comprehensive review of the entirety of the thoracic structures and also serve as an important point of reference for optimal interpretation of multiplanar and 3-D images. Thus, we recommended that the radiologist should review the traditional axial images in addition to the alternative display images (multiplanar and 3-D reconstruction images) when interpreting a CT study of the upper air way tract, in addition to evaluate the lower respiratory tract and related thoracic structures. Despite the study done on the selected anatomical structures with age and gender, additional studies, with larger numbers of patients, are required to document the benefits of this technology using axial and multiplanar 3D images to characterize the upper and lower air way tract.

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