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# Upper Airway and its Association with Neck Circumference and Hyoid Position in OSA Subjects – A Cephalometric Study

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## ABSTRACT

**Introduction:** Obstructive sleep apnea (OSA) is a common disorder characterized by recurrent pharyngeal obstruction during sleep. Upper airway anatomy plays a major role in pathogenesis of OSA. Neck obesity as measured by neck circumference and position of hyoid are independently associated with OSA severity, but their relation with anatomical variables and pharyngeal collapsibility is less well known.

**Objective:** To determine the association of upper airway collapsibility with hyoid position and neck circumference among OSA patients.

**Methods:** Records of polysomnography diagnosed 40 OSA patients satisfying the inclusion criteria were selected. Lateral cephalograms were recorded at natural head position. Upper airway variables measured are superior pharyngeal airway space (SPAS), middle pharyngeal airway space (MPAS), inferior pharyngeal airway space (IPAS) and length of soft palate. Hyoid position was assessed by the distance from hyoid to mandibular plane and hyoid to C3 vertebrae. Neck circumference (cm) was measured for all subjects at the level of cricothyroid membrane.

**Results:** Inferiorly positioned hyoid bone, increased length of soft palate and larger neck circumference showed statistically significant correlation with increased upper airway collapsibility among OSA patients ($P<0.05$).

**Conclusion:** As the study shows the association of upper airway collapsibility with neck obesity and hyoid position, during routine clinical and radiographic examination larger neck circumference, inferiorly displaced hyoid and increased length of soft palate helps in identifying high risk candidates for OSA.

**Key Words:** Airway space, Apnea hypopnea index, Body mass index, Cephalometry, Neck circumference, Obstructive sleep apnea

## INTRODUCTION

Obstructive sleep apnea (OSA) occurs as a result of intermittent reduction or complete pause in breathing due to constriction of upper airway during sleep leading to excessive daytime sleepiness (ESS).[1] It is often associated with obesity, hypertension, type II diabetes mellitus, cardiovascular diseases resulting in reduced quality of life and increased risk for road traffic and workstation accidents.[2,3] Both anatomical and functional abnormalities of the upper airway contributes to compromised airway space and thus increases upper airway collapsibility during sleep. Although changes in ventilatory and neuromuscular control mechanisms can result in the reduced airway patency, anatomical factors play an essential role in the development of OSA.[4]

Polysomnography (PSG) is regarded as the gold standard in diagnosing OSA,[5] but it does not explain the structural flaws in an individual. Upper airway imaging techniques like Computed tomography, Magnetic resonance imaging, lateral cephalograms have provided significant insights regarding the pathogenesis of OSA. Lateral cephalometric radiographs which is more economical method can be used as a primary screening tool for studying the upper airway obstruction, tongue and hyoid positioning caused by skeletal and soft tissue abnormalities.[6]

Obesity is regarded as one of the major risk factor for the occurrence and progression of OSA and a number of parameters such as altered body mass index (BMI), neck as well as waist circumference, and waist to hip ratio (WHR) are

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all considered as risk factors for OSA[7].Neck circumference (NC) is a strong predictor of OSA,[8] and the differences in the severity of OSA explained by central obesity also depends on the variation in the NC. Obesity and craniofacial abnormalities have shown to account for more than two-thirds of the variations in the Apnea-Hypopnea (AHI) score.[9] In the majority of the diagnosed patients, the association with anatomic factors together with other symptoms are the main contributing factors for the development of OSA. Although Neck circumference and hyoid bone position are known to be related to the severity of OSA, the correlation between this pharyngeal collapsibility and anatomical variables is less studied. Thus this study aimed to establish any correlation between neck circumference and hyoid position on upper airway collapsibility among OSA patients.

## MATERIALS AND METHODS

Records of 40 PSG diagnosed OSA patients (males=30 & females=10) aged above 20 years satisfying the inclusion criteria were selected from the Department of Orthodontics, Amrita School of Dentistry, Kochi, Kerala. The study protocol was evaluated and accepted by the institutional review board (IRB-AIMS-2020-113) at Amrita Institute of Medical Sciences, Kochi, Kerala. All the included subjects had undergone Overnight PSG using a home sleep test using Philips Respironics AliceNight machine. An experienced laboratory technician recorded the sleep data according to the standard criteria. Apnea and hypopnea were described according to the Chicago criteria as proposed by the American Academy of Sleep Medicine.[6] Inclusion criteria were patients with AHI >15 indicating moderate to severe OSA (Apnea-Hypopnea Index, AHI) and exclusion criteria were those with severe periodontal disease, edentulous arch, pathologic airway obstruction, TMJ disorders.

Neck circumference (cm) were measured for all subjects at the level of cricothyroid membrane (Figure 1).[7] In obesity, NC will be >34cm for females and >37cm for males. Lateral cephalograms were recorded at the natural head position with voluntary relaxed lip position and with teeth in maximum intercuspation. All radiographs were recorded with the same machine, Cranes D X-ray digital unit, version 3 (Soredex Co., Tuusula, Finland) and hand traced on matte acetate by one investigator to eliminate any inter-examiner variability The airway was analysed as described by Battagel et al.[10] Upper airway and hyoid position variables shown in Figure 2.

Superior pharyngeal airway space (SPAS) - measured from the point midway between posterior nasal spine to tip of the soft palate (PNS-P) parallel to the line that intersects the gonion and B point and it represents the distance between the dorsal surface of the soft palate and the posterior pharyngeal wall.

Middle pharyngeal airway space (MPAS)- measured through the posterior tip of the soft palate (P), parallel to the line that intersects B point and gonion and it represents the distance between the dorsal surface of the base of the tongue and the posterior pharyngeal wall.

Inferior pharyngeal airway space (IPAS) - measured on the line that intersects gonion and B point and represents the distance between the dorsal surface of the base of the tongue and the posterior pharyngeal wall.

Length of the soft palate (P-PNS) - measured by the length of the line that connects the tip of the soft palate with the posterior nasal spine.

1) H-C3- Distance of hyoid to C3 vertebrae
2) H- MP- Distance of hyoid perpendicular to mandibular plane

### Statistical analysis

This was performed using IBM SPSS 20 (SPSS Inc, Chicago, USA). To determine the relationship between neck circumference and hyoid position variables Pearson correlation coefficient test was used. p-value < 0.05 was considered statistically significant. Ethical Clearance Number: IRB-AIMS-2020-113.

Figure 1: Neck circumference.

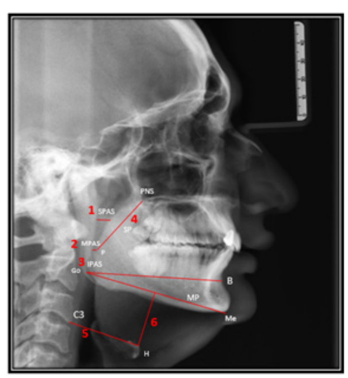


Figure 2: Cephalometric variables evaluated.

## RESULTS

40 PSG diagnosed OSA patients were included in the study.

Correlation between neck circumference with upper airway and hyoid variables. Neck circumference shows a negative moderate degree of correlation correlated with superior airway space (r= -0.62), middle airway space (r= -0.69), inferior airway space (r= -0.63) and was statistically highly significant (p<0.001). Neck circumference was positively correlated with length of the soft palate (r= 0.69), distance from hyoid to the mandibular plane (r=0.64) and distance from hyoid to c3 vertebrae (r=0.38) and was statistically significant (p<0.05, Table 1 & Figure 3).

Correlation between upper airway and hyoid position. Distance from hyoid to the mandibular plane was negatively correlated with superior airway(r= -0.45), middle airway (r= -0.66), inferior airway space (r= -0.61) and was statistically significant (p<0.001). Distance from hyoid to C3 was negatively correlated with superior airway (r= -0.48), middle airway (r= -0.14) and inferior way space (r= -0.08) but was statistically not significant with middle and inferior airway space (Tables 2 and 3).

Correlation between length of the soft palate and upper airway. The length of the soft palate showed a negative correlation with superior airway (r= -0.34), middle airway space (r= -0.51) and inferior airway (r=-0.29) but was statistically significant only with upper and middle pharyngeal airway space (Table 4).

**Table 1: Correlation of neck circumference with upper airway and hyoid variables**

| Variables | N | NC (cm)<br>Pearson Correlation coefficient (r) | p-value |
|---|---|---|---|
| SPAS | 40 | -0.626 | **0.000**** |
| MPAS | 40 | -0.695 | **0.000**** |
| IPAS | 40 | -0.632 | **0.000**** |
| H-MP | 40 | 0.648 | **0.000**** |
| H-C3 | 40 | 0.382 | **0.015*** |
| SP | 40 | 0.693 | **0.000**** |

**p<0.001 is statistically highly significant, *p<0.05 is statistically significant

**Table 2: Correlation of hyoid position with upper airway variables**

| Variables | n | H-MP<br>Pearson Correlation coefficient (r) | p value |
|---|---|---|---|
| SPAS | 40 | -0.457 | **0.003*** |
| MPAS | 40 | -0.662 | **0.000*** |
| IPAS | 40 | -0.616 | **0.000*** |

* p<0.001 is statistically highly significant

**Table 3: Correlation of hyoid to C3 with upper airway variables**

| Variables | n | H-C3<br>Pearson Correlation coefficient (r) | p-value |
|---|---|---|---|
| SPAS | 40 | -0.488 | **0.001*** |
| MPAS | 40 | -0.145 | 0.371 |
| IPAS | 40 | -0.083 | 0.610 |

* p<0.001 is statistically highly significant

**Table 4: Correlation of Soft palate with upper airway variables**

| Variables | N | SP<br>Pearson Correlation coefficient (r) | p-value |
|---|---|---|---|
| SPAS | 40 | -0.343 | **0.030*** |
| MPAS | 40 | -0.512 | **0.001**** |
| IPAS | 40 | -0.294 | 0.065 |

**p<0.001 is statistically highly significant, *p<0.05 is statistically significant

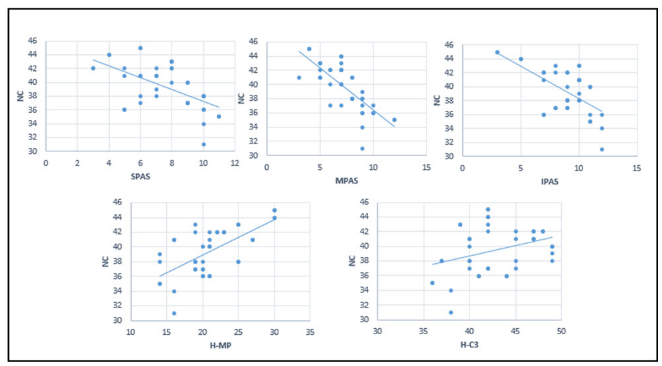


**Figure 3:** Scatter plot graphs showing the correlation of neck circumference with upper airway and hyoid variables.

## DISCUSSION

Undiagnosed OSA remains a major public health concern. Globally, the different population studies have estimated the prevalence of OSA to be 0.3-5.1%.[11] More than 80% of moderate to severe OSA remain undiagnosed despite having adequate health care access. Limited availability of in-lab PSG's, high cost, time and labour-consuming procedures are its main drawbacks. Therefore, more attention should be directed towards identifying high-risk subjects for OSA through routine clinical and radiographic examination.

The different risk factors for developing OSA include altered BMI, increased neck circumference, waist circumference and waist-hip ratio. Craniofacial morphology is also increasingly accepted as a critical component for OSA pathogenesis.[12]

As cephalometric analysis allows quantitative assessment of craniofacial morphology several variables are allied with the development and progression of OSA. These include inferiorly positioned hyoid bone, an enlarged tongue and soft palate, a smaller cross-sectional of the velopharyngeal area and a more posteriorly placed maxilla and mandible.[13,14] Even though advanced technologies like Computed tomography, Magnetic resonance imaging are available, lateral cephalometry is more preferred as it is less expensive, minimal radiation exposure, easy to access, and non-invasive nature but the main disadvantage being it produces a two-dimensional image of the three-dimensional space.

In this study upper airway dimensions like superior pharyngeal, middle pharyngeal and inferior pharyngeal airway showed a negative correlation with neck circumference, length of the soft palate and hyoid position. That is with increasing neck circumference, the upper airway narrowed resulting in severe forms of OSA. Also, when the length of the soft palate and distance of the hyoid to the mandibular plane increased resulted in the narrowing of the upper airway dimension. The associations between neck circumference and hyoid position with pharyngeal collapse have been controversial.[15] Hyoid bone position is significantly important. According to the American Thoracic Society,[16] in healthy individuals, the hyoid bone position is found at the C3-C4 cervical vertebrae, while in OSA patients it is usually at the C4-C6 level. Riha et al,[17] Chang et al[18] also reported inferior positioning of the hyoid bone in OSA subjects. As tongue muscles are attached to the hyoid bone, it causes an inferior displacement of the hyoid due to the increased fat accumulation in the neck region (increased NC) or can be due to macroglossia resulting in posterior displacement of the tongue reducing upper airway patency. This intensifies the risk of developing more severe grades of OSA. Ono et al[19] also found a significant positive correlation between NC and hyoid to C3 vertebrae in OSA subjects, which was similar to this study.

The OSA subjects in this study had considerably longer soft palates, which occupied the majority of the space in the oropharyngeal area leading to airway constriction. This was in agreement with Malhotra et al,[20] who first described that pharyngeal length will increase upper airway collapsibility using a finite element airway model. NC is a more effective factor in determining OSA. Obesity in the upper pharyngeal region is reflected by neck circumference, which modifies the dimension of the upper airway due to fat deposition around the neck region.[8] Ferguson et al[21] stated that subjects who were diagnosed with OSA had a larger neck compared with non-OSA subjects. Onat et al[22] found that NC was a marker of central obesity and found that NC (Neck circumference) is greater among men than women. OSA is manifested during sleep as the repetitive collapse of the upper airway that occurs due to reduced tone of the airway dilator muscle. Increased NC may alter the normal upper airway mechanism and in different ways influence the pathophysiology of OSA. Fat deposition around the parapharyngeal area could result in reduced competence and change the shape of the upper airway leading to its increased collapsibility.[23] Obesity is also coupled with the reduction in lung volumes, especially it affects the functional residual capacity, leading to reduced tracheal tug, constriction of upper airway size and causing increased airflow resistance. Thus, cephalometric analysis together with clinical parameters is highly recommended as one of the most important screening tools in diagnosing and treatment planning for OSA patients.[24]

## CONCLUSION

In this study, upper airway collapsibility was strongly associated with increased neck circumference, increased length of the soft palate and inferior displacement of the hyoid bone. Thus patients should be screened carefully before referring them for expensive investigations such as overnight polysomnography. Despite the limitation of evaluating the airway which is a three-dimensional space using two-dimensional lateral cephalometric technique, it adequately reveals the anatomy of the head and neck region as well as the morphology of the upper airway which can be accurately interpreted by an experienced professional as a primary screening tool. Therefore, routine clinical and radiographic examinations can help in identifying high-risk subjects for OSA.

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**Author Contributions**

1. Dr Parvathy Ghosh- Concept, design, Definition of intellectual content, literature search, data collection, data analysis, manuscript preparation, Manuscript editing, Guarantor.

2. Dr N.K Sapna Varma- Concept, Definition of intellectual content, design, data analysis, manuscript review, Guarantor.

3. Dr V.V Ajith- Concept, design, Definition of intellectual content, manuscript review.

4. Anand Suresh- Literature search, data collection, manuscript editing.

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