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# Measurement of pharyngeal segments in Obstructive Sleep Apnea

Mensuração dos segmentos faríngeos na Apneia Obstrutiva do Sono

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## ABSTRACT

**Objective:** Obstructive Sleep Apnea (OSA) occurs by recurrent collapse of the upper airway during sleep. It results in complete (apnea) or partial (hypopnea) reduction of airflow and has intimate relation with the upper airway anatomy. Cephalometric analysis has been used to quantify airway dimensions. The aim of this study is evaluate the correlation between the anteroposterior dimension of the upper airway and the severity of obstructive sleep apnea. **Material and Methods:** A retrospective analysis was performed reviewing polysomnographic data (AHI) and anteroposterior cephalometric measurements of pharynx subregions: nasopharynx, oropharynx, hypopharynx. **Results:** The sample consisted of 30 patients. The mean body mass index was 29.60 kg/m$^2$ and the average age was 46.8 years. Nine patients presented severe OSA, seven had moderate OSA, seven had mild OSA, and seven were healthy. The Pearson's correlation index between the anteroposterior dimension of the nasopharynx, oropharynx and hypopharynx and AHI was respectively -0.128 (p=0.517), -0.272 (p=0.162) and -0.129 (p=0.513). **Conclusion:** The correlation between anteroposterior linear dimension of the airway and OSA severity, assessed by AHI, was not positive. As an isolated parameter it did not correlate to the severity of the obstrucive sleep apnea syndrome and should be evaluated in conjunction with other factors.

## KEYWORDS

Upper Airway; Obstructive sleep apnea; Cone beam CT.

## RESUMO

**Objetivo:** A Apneia Obstrutiva do Sono (SAHOS) ocorre por um colapso recorrente da via aérea superior durante o sono. Isto resulta na redução completa (apneia) ou parcial (hipopneia) do fluxo de ar, e apresenta relação íntima com a anatomia das vias aéreas superiores. A análise cefalométrica tem sido utilizada para quantificar as dimensões das vias aéreas. O objetivo deste estudo foi avaliar a correlação entre a dimensão anteroposterior da via aérea superior e a gravidade da SAHOS. **Material e Métodos:** Foi realizada a análise retrospectiva dos dados polissonográficos (IAH) e medidas cefalométricas anteroposteriores das sub-regiões da faríngе: nasofaringe, orofaringe e hipofaringe. **Resultados:** A amostra foi composta por 30 pacientes. O índice médio de massa corporal foi de 29,60 kg/m2 e a média de idade foi de 46,8 anos. Nove pacientes apresentaram SAHOS grave, 7 SAHOS moderada, 7 SAHOS leve e 7 eram saudáveis. O índice de correlação de Pearson entre a dimensão anteroposterior da nasofaringe, orofaringe e hipofaringe com IAH foi -0,128 (p=0,517), -0,272 (p=0,162) e -0,1229 (p=0,513), respectivamente. **Conclusão:** A correlação entre a dimensão linear anteroposterior da via áerea e a gravidade da SAHOS, avaliada por meio da IAH, não foi positiva. Como parâmetro isolado, a análise cefalométrica não foi correlacionada com a severidade da SAHOS e portanto, deve ser avaliada em conjunto com outros fatores.

## PALAVRAS-CHAVE

Vias aéreas superiores; Apneia obstrutiva do sono; Tomografia computadorizada de feixe cônico.

## INTRODUCTION

Sleep respiratory disorders have a high prevalence in the world population. Due to clinical, economic, and social repercussions they are a public health issue. The Obstructive Sleep Apnea (OSA) is the main sleep respiratory disorder [1]. The American Academy of Sleep Medicine (AASM) defines OSA as a recurrent collapse of upper airway during sleep, resulting in a complete (apnea) or partial (hypopnea) reduction of airflow [2].

Researchers have shown diversity in OSA prevalence because it reaches all ages and is associated with different risk factors, such as anatomical variations, comorbidities and habits. The estimated prevalence of OSA is 9% in women and 24% in men [3]. An epidemiologic study held at Sao Paulo, Brazil, has shown OSA prevalence to be 32.8% in the adult population. The associated risk factors were: males, body mass index (BMI) > 25 kg/m2, low socioeconomic status, advanced age and menopause [4].

Clinical findings include increased neck circumference, nasal obstruction, turbinate hypertrophy, septum abnormalities, flaccid palate, pharyngeal tonsils hypertrophy, macroglossia, oropharyngeal obstruction, and dentofacial deformities, including mandibular retrognathia5. Among the main signs and symptoms are snoring, witnessed apneas, choking during sleep, excessive daytime sleepiness, insufficient quality of night time sleep, fragmented sleep, nocturia, headaches in the morning, cognitive decline, memory loss, decreased libido, and irritability [5].

The AASM recommends diagnostic investigation of OSA, by polysomnography, in professional drivers and in every patient with cardiovascular or metabolic disease, such as: obesity with BMI > 35 kg/m$^2$, congestive heart failure, atrial fibrillation, arterial hypertension refractory to treatment, type 2 diabetes, nocturnal arrhythmias, stroke, pulmonary hypertension, and previous bariatric surgery [5]. The airway patency is a determinant factor of the disease. Several collapse points contribute to its onset. Obesity, edema and genetic factors may promote variations in the airway [5].

Cephalometric radiographs are commonly used to evaluate airway space regions in patients submmited to orthognathic surgery and orthodontic treatment. They are often employed to assess airway improvement in OSA patients who receveid orthognatic surgery. The Arnett-Gunson FAB Surgery allows to measure the pharyngeal airway space at the nasopharynx, oropharynx and hypopharynx [6]. The aim of this study was to verify the correlation between the severity of OSA, and the anteroposterior dimension of the pharyngeal airway space.

## METHODS AND MATERIALS

This retrospective study was approved by an Institutional Research Ethics Committee for Human Beings (registration 13185113.9.0000). It reviewed medical records of patients from the Oral and Maxillofacial Surgery Division of the Dental School at Araraquara - Unesp and from the Otorhinolaryngology Clinics of the Medical School of the University of Araraquara - Uniara. The inclusion criteria were minimum age of 18 years; individuals who had clinical evaluation for sleep respiratory disorders, associated to sygns and symptoms, such as snoring, daytime sleepiness, witnessed apneas and choking during sleep. The exclusion criteria were morbid obesity (BMI>40), craniofacial abnormalities such as craniosysostosis, craniostenosis, meningomyelocele and craniofacial clefts, nasal obstruction by polyposis, existence of any craniofacial or airway tumor; larynx or pharynx paralysis and previous maxillofacial or upper airway surgery. The study was limited to patients with sufficient data on demographics, BMI, basal polysomnography, and volumetric tomography of the face to build the cephalometric radiograph.

All patients had performed the computed tomography with the same protocol. To obtain the images, the patients were seated and placed in natural head position. They were instructed to not swallow during the exam. The images were obtained in a dental tomograph (I-Cat, KaVo, Brazil), set up at 120kVp, 36mA, 0.25mm voxel, and FOV of 16x22 cm, from the vertex of the cranium to C3 level. All images were extracted from DVD for specific software analysis. The DICOM files were imported and reconstructed using the Dolphin software (Dolphin Imaging Management Solutions, Chatsworth, California, USA). A cephalometric radiographic was generated and the cephalometric points of the Arnett-Gunson FAB Surgery were digitized for all patients by the same calibrated examiner. To determine the measurement error and intraexaminer calibration, the cephalometric analysis was performed in duplicate with an interval of 30 days.

The upper airway was evaluated at three levels:

- *Nasopharynx:* Linear distance between Arnett-Gunson (A/G) anterior PAS and A/G posterior PAS, at the level of the deepest point of the jaw (A)
- *Oropharynx:* Linear distance between Arnett-Gunson (A/G) anterior PAS and A/G posterior PAS, at the level of the maxillary central incisor (Mx1)
- *Hypopharynx:* Linear distance between Arnett-Gunson (A/G) anterior PAS and A/G posterior PAS, at the level of the most concave point in the anterior region of symphysis (B)

Also, all polysomnographies were performed at the Araraquara Sleep Clinic – SP, Brazil, after obtaining the tomograph. The sleep was evaluated during an average period of six hours. The electrophysiological variables evaluated during sleep were: electroencephalogram (EEG), electrooculogram (EOG), electromyogram (EMG), electrocardiogram (EKG), airway flow (oral and nasal), respiratory effort (thoracic and abdominal), other corporal movements (measured by EMG), blood gases (oxygen saturation) and body temperature. The exams were evaluated using the criteria of the 2012 AASM Manual [7]. A sleep disorders specialized physician obtained the apnea/hypopnea index by summing the apnea and hypopnea events divided by hours of sleep. According to the results, OSA was classified as absent (AHI<5 events/h), mild (5 ≤ AHI < 15 events/h), moderate (15 ≤ AHI < 30 events/h) or severe (AHI ≥ 30 events/h).

Data were analyzed by statistical descriptive tests and frequency of results. For groups equality evaluation the ANOVA test was chosen. The Kolgomorov-Smirnov test was chosen to analyze the normality of variables. For correlation of anteroposterior dimension of the pharynx subregions and AHI, the Pearson rank correlation coefficient was applyed. The SAS System for Windows (Statistical Analisis System), version 9.3 software (SAS Institute Inc, 2002-2008, Cary, NY, USA) was used for the analysis.

## RESULTS

Thirty-four patients were initially included, however, four patients were excluded. Three of them presented inadequate tomographic exams and one had incomplete records. Therefore, 30 patients were included in the study, 15 female (50.0%) and 15 male (50.0%).

The descriptive data is detailed in Tables 1 and 2. In Table 1 Kolgomorov-Smirnov test was used to determine the normality of the sample. All variables presented normal distribution, thus a parametric test was chosen. Table 2 shows ANOVA results to determine equality between OSA severity groups. There was a significant relationship for BMI (p=0.021). Figure 1 displays the Tukey test showing significant

difference in BMI only between the Normal and Severe Group (p=0.022).

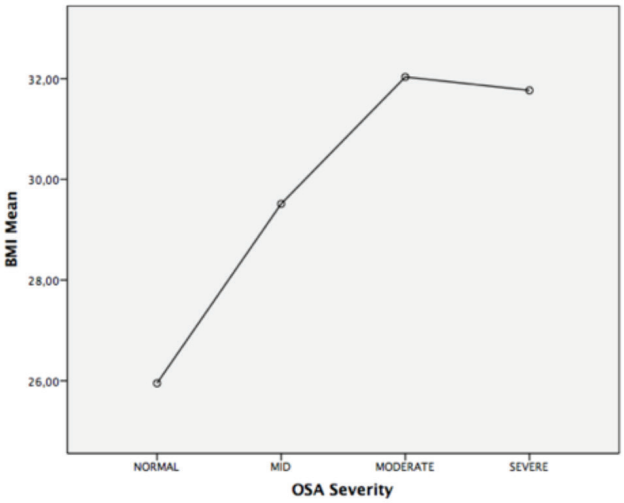



**Figure 1 -** Mean comparison of BMI between OSA severity groups. Tukey test for BMI was significant only between normal and sever group (p=0.022).

To evaluate reproductibility of the upper airway measurement a paired Student's t test was used (Table 3). The measurements were similar and did not show any statistical significant difference. The anteroposterior linear dimension used is a mean of the two measurements. The Apnea/Hypopnea Index (AHI) was statistically evaluated as a continuous variable, the Pearson's rank correlation coefficient was chosen (Table 4). Also, in Table 5 the Pearson's rank was controled by BMI, age and gender. There was a weak correlation between AIH and nasopharynx and hypopharynx measurements, which was not statistically significant. The correlation between the AIH and the oropharynx measurement was moderate and was not statistically significant. Gender, BMI and age did not influence the relationship between AIH and anteroposterior dimension of pharynx subregions.

**Table 1 -** Description and Normality Test of Continuous Variables

| Variable | Minimun | Maximun | Mean | Standard deviation | Kolgomorov-Smirnov test |
|---|---|---|---|---|---|
| Age (years) | 24.00 | 76.00 | 46.81 | 12.66 | 0.959 |
| BMI (kg/m²) | 24.70 | 38.40 | 29.60 | 3.89 | 0.558 |
| AIH (ev/hour) | 1.00 | 89.00 | 26.33 | 26.08 | 0.233 |
| Nasopharynx | 10.55 | 37.00 | 21.18 | 7.37 | 0.950 |
| Oropharynx | 3.20 | 13.35 | 6.95 | 2.21 | 0.833 |
| Hypopharynx | 3.25 | 19.30 | 8.97 | 3.31 | 0.924 |

**Table 2 -** Description of OSA severity according to AHI

| OSA Severity | Frequency (n) | Percent (%) | BMI mean (kg/m²) | Age mean (years) | Male percent (%) |
|---|---|---|---|---|---|
| Normal | 7 | 23.3 | 25.9 | 49.7 | 42.9 |
| Mid | 7 | 23.3 | 29.5 | 46.0 | 14.3 |
| Moderate | 7 | 23.3 | 32.0 | 50.0 | 57.1 |
| Severe | 9 | 30.0 | 31.8 | 42.8 | 77.8 |
| ANOVA Test | - | - | 0.021* | 0.711 | 0.085 |

* Statistical significance (p≤0.05).

**Table 3 -** Paired Student's T test between the two measurement determinations in mm², (p≤0.05)

| Area | Mean | n | Standard deviation | p |
|---|---|---|---|---|
| Nasopharynx T1 | 21.06 | 30 | 7.45 | 0.170 |
| Nasopharynx T2 | 21.28 | 30 | 7.32 | |
| Oropharynx T1 | 6.98 | 30 | 2.21 | 0.477 |
| Oropharynx T2 | 6.92 | 30 | 2.22 | |
| Hypopharynx T1 | 8.97 | 30 | 3.36 | 1.000 |
| Hypopharynx T2 | 8.87 | 30 | 3.28 | |

**Table 4 -** Pearson's Rank Correlation Coefficient

| | Nasopharynx | Oropharynx | Hypopharynx | AIH |
|---|---|---|---|---|
| Nasopharynx | 1 | -0.050 | -0.059 | -0.128 |
| | . | 0.792 | 0.758 | 0.517 |
| Oropharynx | -0.050 | 1 | 0.428 | -0.272 |
| | 0.792 | . | 0.018 | 0.162 |
| Hypopharynx | -0.059 | 0.428 | 1 | -0.129 |
| | 0.758 | 0.018 | . | 0.513 |
| AIH | -0.128 | -0.272 | -0.129 | 1 |
| | 0.517 | 0.162 | 0.513 | . |

**Table 5 -** Person's Rank Correlation Coefficient between Measurement and AHI, controlling BMI, gender and age

| | Nasopharynx | Oropharynx | Hypopharynx | AIH |
|---|---|---|---|---|
| Nasopharynx | 1 | 0.579 | 0.186 | -0.434 |
| | . | 0.015 | 0.474 | 0.082 |
| Oropharynx | 0.579 | 1 | 0.386 | -0.270 |
| | 0.015 | . | 0.125 | 0.294 |
| Hypopharynx | 0.186 | 0.386 | 1 | 0.145 |
| | 0.474 | 0.125 | . | 0.579 |
| AIH | -0.434 | -0.270 | 0.145 | 1 |
| | 0.082 | 0.294 | 0.579 | . |

## DISCUSSION

OSA is a dynamic disease which develops under upper airway total or partial obstruction during sleep, in one or more levels. Patients can show one or more obstructive sites located on the nasal cavity, oropharynx, base of tongue or hypopharynx [8]. The whole airway evaluation is fundamental on diagnosing OSA. Surgical treatment efficacy relies on determining and handling all multiple obstructive sites [8]. Several methods are useful on this analysis; most of them are performed with the patient sitting and conscious.

Cefalometric radiographs are widely available and used for evaluation of sleep disorders and facial deformities. This method allows bidimensional analysis of the upper airway. The advantages of this technique include low cost, simplicity and possibility of comparision with other studies. Correlation between CT scan and cephalometric radiograph measurements of the airway are described in the literature [6].

All OSA severity patient groups were included in this study, according to Table 1. The higher incidence of severe patients was considered normal, since they came from an OSA reference center. The anthropometric data showed that OSA predominated on obese middle aged individuals [4]. Seven non-OSA patients performed polysonography and tomography to investigate OSA due to cardiovascular or metabolic disease.

The anteroposterior dimension of pharynx subregions, a key variable for the study, was determined twice in different occasions by an examiner blind to any other study variable. This was necessary, considering that the Dolphin software needs a demarcation of the palatal and airway limiting planes in order to calculate the measurements. There was no significant difference between the measurements taken in two different occasions.

The correlation between the pharynx anteroposterior dimension and OSA (Table 4), was not positive. There was no correlation between the dimension of pharynx subregions and the AHI. Age, BMI and gender did not influence that relationship either. This data goes against common sense, since it is believed that surgical enlargement of the pharynx is the primary intervention in the treatment of airway in patients with OSA [8].

Tang et al. [9] have shown that the pharynx CT is useful to determine the upper airway obstruction plane. They evaluated only subjects with OSA and compared CT images obtained with the patient awake and asleep. The main obstructive plane is the oropharynx region. The oropharynx dimension was the variable that most correlated with AIH, but this correlation was not statistically significant.

Niu et al. [10] studied the dimension of the pharynx subregions in patients with and without OSA. They have shown that the most common planes of obstruction were at the oropharynx and hypopharynx areas in subjects with OSA. In our study none of the subregions of pharynx presented a significant relationship with OSA severity.

In this sample an individual with severe OSA may have an airway dimension similar

to that of a patient without OSA. The static measurement of the pharynx does not predict the severity of OSA. The disease is multifactorial and evaluation of a localized sector of the airway leads to misinterpretation because that variable alone fails to consider all levels of the airway and extrinsic compression of the pharynx.

Surgical procedures aimed at increasing the dimensions of the pharynx through the resection of endopharyngeal structures (tonsils, soft palate and lateral muscles) have lower rates of long-term success [11-12]. Those isolated methods to increase airway volume may fail in OSA treatment, since there is no linear relationship between the upper airway volume and OSA. Goh et al. [11] evaluated quality of life 18 years after isolated uvulopalatopharyngoplasty. They showed that 85.8% of patients still snored, daytime sleepiness was present in 79.5% of them, and 89.3% had fragmented sleep.

The AASM published in 2010 a meta-analysis on surgical procedures of the upper airway. The study concluded that procedures in an isolated region of airway showed no consistency in the reduction of AIH, with residual OSA after the procedure. The best results were obtained with multilevel surgery approach [12]. It is inferred that one of the causes of such findings is the lack of correlation between the dimension of the airway with AIH.

There was no correlation between the pharynx subregion dimension and OSA severity. Thus, the search for a single plane of airway obstruction in OSA patients seems a mistaken treatment strategy. This disease does not correlate with a single pharynx subregion. It's an airway multilevel disorder[8] and requires a multilevel treatment [12].

The cephalometric analysis is a fast and low risk method for patient examination. However, it is a static test and done with the patient seated. This may have influenced this study and others which applied this technique. The determination of AHI and severity of OSA is obtained with the patient lying down in natural sleep. The difference of position and static analysis of the pharynx can lead to different results between AHI and airway dimension.

This study demonstrates that the anteroposterior distance measurements of the pharynx subregions have no linear relationship with the severity of obstructive sleep apnea, as measured by the Apnea-Hypopnea Index. However, due to limitations of the sample size, a study with more subjects should be done to confirm the results.

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