



Cone Beam Computed Tomography Analysis of Upper Airway Measurements in Patients With Obstructive Sleep Apnea

Suleiman M. Momany, Ghaida' AlJamal, BDS, MS,
Bassam Shugaa-Addin, BDS, MSc and
Yousef S. Khader, BDS, MSc, MSPH

ABSTRACT

Purpose: To explore the validity of cone beam computed tomography (CBCT) as one of many predictive tools that can be used (alone or in conjunction) to help in identifying high-risk cases of obstructive sleep apnea (OSA) that should get the earliest possible referral to a sleep specialist for standard diagnostic polysomnography, and to identify imaging airway parameters that may be predictive of OSA severity.

Methods: Using a case-control design, 45 subjects matched by age and sex (22 OSA cases and 23 controls) were included in this study. Subjects were assigned as cases depending on a sleep study with apnea-hypopnea index (AHI) > 5 and as controls depending on a Berlin questionnaire score identifying low risk or no risk of OSA. All subjects had CBCT scans. Airway and craniofacial parameters as assessed by CBCT were compared between the 2 groups. Significant CBCT variables were entered into a logistic regression model to identify risk factors of OSA and the correlations of variables with AHI were evaluated using multiple linear regression. For all tests $P \leq 0.05$ was considered statistically significant.

Results: OSA cases had larger body mass index and neck circumference than controls. OSA cases showed significantly smaller airway narrowest cross-sectional areas (CSAs) ($P < 0.05$) and larger posterior nasal spine and the second cervical vertebrae distances ($P < 0.001$) than those in controls. Airway narrowest CSA showed a significant negative correlation with AHI ($r = -0.653$, $P = 0.001$) and was a significant variable for predicting the AHI of OSA cases in multiple regression analysis.

Conclusions: The importance of narrowest CSA and posterior nasal spine and the second cervical vertebrae distance in the pathogenesis of OSA has been highlighted in the present study. We can conclude that CBCT can provide findings that entail earlier referral of suspected patients with OSA for further assessment.

Key Indexing Terms: Obstructive sleep apnea; Cone beam computed tomography; Airway cross-sectional area; Airway length, Total airway volume. [Am J Med Sci 2016;1(0):111-111.]

INTRODUCTION

Obstructive sleep apnea (OSA) is a common sleep disorder affected mainly by upper airway morphology; it results from cessation or reduction of airflow during sleep because of repetitive total or partial collapse of the pharyngeal airway for at least 10 seconds with persistent respiratory effort.¹ Disruptions to breathing during sleep lead to many adverse health consequences.^{2,3}

OSA is a significant contributor to motor vehicle accidents, a cardiovascular risk factor and likely contributes to metabolic syndrome.⁴⁻⁶ Prevalence of OSA was estimated to be approximately 3-7% for adult men and 2-5% for adult women in the general population.⁷ Most patients who have OSA remain undiagnosed.^{8,9}

Awareness of the prevalence and health consequences of OSA is increasing which mandates a high level of suspicion for this disorder in daily practice.¹⁰ OSA is still underdiagnosed because diagnostic procedures are expensive and usually delayed, and predictive criteria

are still unsatisfactory.¹¹ Polysomnography remains the gold standard for OSA diagnosis and it can evaluate cardiopulmonary consequences of OSA. The severity of OSA is indexed using the apnea-hypopnea index (AHI).

Evaluation of OSA using polysomnography is time consuming and expensive, and different methods used in determining AHI may give different results.¹² Attempts were made to search for a methodology that has the potential to determine the risk of OSA using different imaging modalities that directly reflects the status of the upper airway.^{13,14} Over the years, lateral X-ray cephalometry had become one of the diagnostic tools in patients with OSA, and is especially useful for evaluation of craniofacial morphology.¹⁵ Although 2-dimensional imaging is of great value, the complex shape of the airway is not evaluated except with 3-dimensional (3D) imaging techniques.¹⁶ The axial plane which cannot be visualized on lateral cephalogram is very important for airway evaluation because it is perpendicular to the

airflow.¹⁷ Although computerized tomography (CT) and magnetic resonance imaging are powerful 3D imaging tools, the radiation issue of CT and the limitations of magnetic resonance imaging dictate the search for more suitable alternatives.

Cone beam computed tomography (CBCT) is advantageous in short scanning time (10-70 seconds) and there is a relatively low dose of radiation compared with conventional CT.¹⁸

Despite low soft tissue resolution, CBCT shows high contrast between bone, empty spaces and soft tissues in general so the airway can be visualized ideally in relation to the hard tissue structures of the skull.^{19,20} Reliability of the CBCT imaging has been evaluated in comparison to multidetector CT and the measurements of the upper airway space using CBCT were fairly accurate.²¹⁻²⁴

The aim of this study was to compare the CBCT scan measurements between patients with OSA and controls to find out whether any differences could be clearly delineated (in imaging airway parameters) that may be predictive of the presence of this disease and its severity, and thus, explore the possibility of using CBCT as a tool facilitating but not replacing polysomnography that may help to predict high-risk cases of OSA that may be candidates for earlier assessment for standard diagnostic polysomnography. Furthermore, use of CBCT in conjunction with other predictive tools (such as clinical evaluation including neck circumference, waist circumference and body mass index [BMI] as well as Berlin and similar questionnaires) may augment the prediction accuracy.

MATERIALS AND METHODS

Subjects

This study was approved by the Institutional Review Board at Jordan University of Science and Technology.

The study included 22 OSA cases (19 males and 3 females) and 23 controls (21 males and 2 females). The cases were patients diagnosed with OSA at the sleep clinic in King Abdullah University Hospital, Irbid, Jordan, whereas the controls were patients without OSA presenting to the Dental Teaching Center at Jordan University of Science and Technology, Irbid, Jordan, for implant placement, restorative purposes and temporomandibular joint-related problems and who required CBCT study as part of their treatment plan. Patients who had anatomical maxillo-mandibular issues were excluded. All the cases were adults who had a polysomnography-proven OSA and had not performed any craniofacial surgery related to OSA, whereas the controls were patients with no symptoms of sleep apnea and were low risk on the Berlin questionnaire, which is a highly validated screening tool to rule out OSA in low-risk groups and was used considering the financial limitations as well as the difficulties to recruit low-risk patients to undergo polysomnography, although polysomnography would have been preferred for more definitive evaluation.

The sample size of almost 22 persons in each group is sufficient to detect a moderate effect size between the 2 groups at a level of significance of 0.05 and power of 65%.

After signing an informed consent, demographic data were recorded for all subjects. Neck circumference was measured at the level of the cricothyroid cartilage using a nondistensible tape measure.

CBCT scans were taken in the radiology clinic of the Dental Teaching Center, Jordan University of Science and Technology using Kodak 9500 cone beam 3D system (Kodak Dental Systems, Carestream Health, Rochester, NY). Subjects were sitting upright with Frankfurt plane (a plane that passes through orbitals and porions) parallel to the floor, they were asked to sit very still, put teeth into occlusion and not to swallow. It was ensured that all subjects kept their heads in natural head position by asking them to place the chin on the chinrest and by adjusting the central positioning of their head using a midsagittal positioning laser beam. Additionally, they were instructed to inhale and hold their breath for 10-12 seconds during the effective exposure time to standardize the respiratory phase for all subjects. Radiographic exposure parameters of 90 Kv and 10 mA were used. Each 10.8-second scan acquired 598 primary images making a CBCT volume with a voxel size of $300 \times 300 \times 300 \mu\text{m}$ (isotropic). In this study, the large field-of-view mode ($18 \times 20 \text{ cm}$) was used. To visualize CBCT scans, we used InVivoDental software (version 5.2, Anatomage, San Jose, CA), a DICOM viewer that allows complete analysis of a CBCT scan including viewing, measuring and segmentation.

The volume rendering tab in the InVivoDental software was used to calculate the airway volume. The field of interest was defined by the best sagittal view of the airway, which allowed clear visualization of the posterior nasal spine (PNS) and the second cervical vertebrae (C2). Software manual instructions for airway volume calculation were followed. Using the left click of the mouse, 2 points were picked by clicking along the airway path, this produced 2 lines that are parallel to Frankfurt plane, one of them was adjusted to pass through the most anterior inferior border of C2, whereas the other was adjusted to pass through PNS (Figure 1A).

By right clicking on the airway path, the software generated a color-coded airway volume reconstruction pattern in which the narrowest cross-sectional area (CSA) was indicated by a red circle (Figure 1B). A total of 2 values were given with this pattern, the airway volume in cm^3 and the minimum CSA in mm^2 .

Linear and Angular Measurements

The section tab in the software was used for the linear and angular measurement. Using the midsagittal section, the distance from PNS to the most anterior inferior border of C2 was measured. Cephalometric angles (SNA and SNB angles) were also measured to

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