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# Radiographic Imaging of Obstructive Sleep Apnea: A Narrative Article

**Marco Isaac[1], Dina Mohamed ElBeshlawy[2,3], Ahmed ElSobki[4], Dina Fahim Ahmed[2], Sarah Mohammed Kenawy[2]**

[1]*Department of Oral and Maxillofacial Radiology, Faculty of Oral and Dental Medicine, Delta University for Science and Technology, Gamasa, Egypt.*
[2]*Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Cairo University, Cairo, Egypt*.
[3]*Department of Oral and Maxillofacial Radiology, Galala University, Al Galala, Egypt.*
[4]*Department of Otorhinolaryngology, Faculty of Medicine, Mansoura University, Mansoura, Egypt*.

Correspondence: Marco Emad Shawky Isaac; International Coastal Rd, Al Hafir WA Al Amal, Al Satamoni, Dakahlia Governorate 7730103; Tel: +201223775262; Email: marco.isaac@deltauniv.edu.eg

**ABSTRACT**

Obstructive sleep apnea is a sleep disorder characterized by repeated bouts of apnea or hypopnea, resulting in the airway's collapse. This condition is concerning since it can lead to many health issues, such as cardiovascular disease and memory loss. Two-dimensional imaging is inadequate for a comprehensive diagnosis because of the intricate structure of the airway. Three-dimensional imaging is preferable since it accurately portrays the patient's airway architecture. Although Computed Tomography and Magnetic Resonance Imaging can accurately depict the true three-dimensional structure of the airway, their use is limited due to variables such as high radiation dosage and noisy scans. Cone beam computed tomography can generate accurate three-dimensional anatomical scans of the entire head with minimal radiation exposure.

***Keywords:*** *Obstructive Sleep Apnea; Cone-Beam Computed Tomography; Polysomnography; Airway Obstruction*

## 1. Introduction

Obstructive sleep apnea (OSA) is a mutual sleep disorder that causes significant physiological abnormalities with therapeutic consequences. The Apnea Hypoapnea Index (AHI), which quantifies sleep physiological anomalies and determines illness severity, has changed OSA's classification. Then, "five or more bouts of apnea or hypopnea during an hour of sleep with accompanying symptoms or 15 or more episodes per hour of sleep independent of related symptoms" were used to define OSA. Sleep apneas and hypopneas are counted every hour to calculate the AHI. The AHI score classifies OSA as mild (5-14/hour), moderate (15-30/hour), or severe (30/hour). (Mannarino 2012, Maspero 2015, Park 2011)

OSA severity is affected by upper airway dilator muscle function, respiratory control, and respiratory arousal threshold. Human pharyngeal airways lack bone. Therefore, nearby muscles must empty the upper airway. These muscles bend the upper airway for speech, swallowing, and breathing. Pharyngeal muscles may cause OSA due to neural modulation, muscular response, and effectiveness. (Eckert 2018)

Intermittent upper airway collapse and low oxygen saturation cause insomnia. Chronic fatigue, one of the most prevalent OSA symptoms, is typically underestimated, so patients cannot distinguish between OSA symptoms and regular exhaustion in the early stages. Sleepiness worsens with illness and impairs daily living. In average-aged men and women, OSA has climbed to 2-4% and 1-2%, respectively, according to international study. OSA is quiet, therefore 20-30% of middle-aged OSA patients have no symptoms. OSA rates are rising fast along with worldwide obesity and are unlikely to slow. OSA is linked to lung, diabetes, and cardiovascular illnesses, making it a major public health issue. (Mannarino 2012, Maspero 2015)

Anatomical and neurological abnormalities cause OSA. It is well-recognized that OSA is caused by a constricted or collapsed upper airway. Multiple imaging studies reveal that OSA patients have a smaller static cross-sectional area of the pharyngeal airway than non-OSA individuals. (Maspero 2015, Neelapu 2017) Obesity creates a collapsed airway due to fat tissue around the throat. The location of fat accumulation may matter. A current study reveals that the mandible and maxilla can modify pharyngeal airway cross-sectional dimensions. (Degache 2013, Kim 2014)

Polysomnography (PSG) is the fundamental method used to diagnose OSA. Polysomnography (PSG), commonly referred to as a sleep study, is a procedure that involves the continuous monitoring of various neurophysiological and cardiorespiratory changes. This monitoring usually takes place over the course of one night and provides information on the quality and duration of sleep, as well as any disturbances during sleep. The diagnosis is significantly impacted by the patterns of these physiological changes that occur throughout the sleep period. (Kramer and Millman 2011) PSG plays a crucial role in both the diagnosis of obstructive sleep apnea (OSA) and the assessment of the effectiveness of treatment. Nevertheless, the sole method to obtain a precise diagnosis is by integrating it with the patient's clinical history and radiographic assessment.

## 2. Radiographic assessment of OSA:

### *2.1. Two-Dimensional(2D) versus Three-Dimensional (3D) Imaging*

Understanding skeletal and soft tissue architecture and function is crucial to understanding OSA pathology. The illness position prevents direct vision, complicating clinical evaluation. Multiple image-based studies should check upper airway space, skeletal bone structures, and nearby soft tissues. (Indriksone and Jakobsone 2014) 2D and 3D imaging can assess the oropharyngeal airway and its anatomy using Magnetic Resonance Imaging (MRI), Computed tomography (CT), Cone-Beam Computed Tomography (CBCT), and cephalometric radiography. (Zinsly 2010)

Complete radiographic evaluations should identify sleep-changing anatomical causal structures. (Whyte and Gibson 2018) Long ago, 2D cephalometric scans were reliable for distinguishing OSA from other diseases. Without 3D scanning, the airway's complicated outline cannot be assessed. (Momany 2016) CT imaging gives several thin sections in different planes to evaluate the upper airway's microscopic anatomy without partial volume artifacts. CT's main downside is radiation exposure. Additionally, CT imaging sleep monitoring has logistical challenges. MRI can properly represent the airway's soft tissue form, but its noise and extensive scan time limit its use.

CBCT 3D imaging has transformed craniofacial imaging from 2D to volumetric in data collection, reconstruction, image display, and interpretation. With less radiation than Multi-Slice CT, CBCT scanners can scan the entire head with one C-arm rotation. (Conley 2014) Soft tissues are not well-depicted by CBCT, but the imaging technique does a great job of differentiating between hard structures like bone and more porous ones like empty spaces and soft tissues. CBCT is the gold standard for dental-sleep 3D imaging for that reason. (Lenza 2010)

*2.2 Role of Cone Beam Computed Tomography in OSA:*

CBCT in upper airway studies includes volume rendering, identification of anatomical features, nasopharyngeal airway dimensions, size of the soft palate, length of the airway, and volume. These performances help distinguish between people with OSA and those without the condition. Also, the degree of blockage along the upper airway can be better assessed with the use of CBCT pictures. So, CBCT is useful for referring patients who may have OSA to the right place at the right time. (Aboelmaaty and Isaac 2022, Barrera 2017, Chen 2016, Conley 2014, Enciso and Clark 2011, Enciso 2010, Linder-Aronson 1970, Liu 2016, Ogawa 2005, Scarfe 2012, Shigeta 2010, Shigeta 2008, Solow 1996, Yamashina 2008)

*2.2.1 CBCT Segmentation*

Volume rendering was developed because connecting structures in orthogonal planes is difficult. Selected volumetric data is used in "volume rendering" to aid visualization. This method can segment the airway and isolate it from nearby structures. CBCT data provides the most accurate 3D segmented airway volume since it is 3D reconstructed and has the highest spatial resolution. (Scarfe 2012)

*2.2.1 CBCT Linear Measurements and Airway Morphology Interpretation*

CBCT imaging evaluates bony structural characteristics that can alter the upper airway size and predispose it to collapse during sleep and apnea. CBCT midline reconstruction metrics indicate the skeletal connection. Along with a small maxilla and mandible, a high-arched palate is linked to oropharyngeal crowding and OSA. A lower hyoid bone and a longer oropharynx are connected to obstructive sleep apnea severity in several CBCT investigations. (Barrera 2017, Chen 2016) Local airway components may cause OSA, such as a long soft palate. The soft palate of sleep apnea patients is larger and longer, according to CBCT research. In snoring and OSA patients, the soft palate and uvula demonstrate severe flaccidity and muscle atrophy. The CBCT midsagittal cross-sectional area of the soft palate showed that OSA patients had a longer soft palate than controls. (Enciso and Clark 2011)

The maximum airway length is usually the upper airway space between the palatal plane and the parallel-created plane at the lowermost boundary of C4. Abramson et al. found in a CBCT study that OSA is linked to a longer airway (76.7 ± 11.1 mm) compared to controls (66.3 ± 10.1 mm).(Abramson 2010) OSA patients had concave or elliptic airways, while non-OSA controls had concave, round, or square airways. (Ogawa 2007)

#### *2.2.2 CBCT Volumetric Measurements Interpretation*

Most upper airway static morphology measurements are taken at the retro-palatal or retroglossal areas. Three volumetric assessments of airway volume are retropalatal, retroglossal, and total. CBCT is the gold standard for linear and angular measures like MSCT, according to various studies. CBCT appears to be accurate and dependable for imagining the upper airway and quantifying its volume when employing an airway phantom. (Conley 2014, Enciso 2010)

#### *2.2.3 Identifying the Level of Collapse in the Airway*

The oropharynx, which extends from the back of the nose to the epiglottis, is the part of the airway that is most prone to obstruction in the upper airway. A state-of-the-art 3D imaging method with a low radiation dose that reliably measures collapse level was discovered in a novel CBCT study that was confirmed by the dynamic Drug-Induced Sleep Endoscopy (DISE) method.

To aid in the evaluation of upper airway dysfunction, CBCT is a useful imaging adjunct. The CBCT views, particularly the end-expiration views in orthogonal plane interpretation, were decisive in OSA patients with tongue/palate contact or a protracted palate. Although CBCT is not a replacement for other imaging modalities in determining the severity of a collapse, it is an effective adjunct imaging tool for determining the extent of upper airway failure. (Aboelmaaty and Isaac 2022)

### *2.3 Potential limitations of CBCT in OSA imaging:*

It is important to use caution when interpreting metrics derived from software analysis of the airway because of certain limitations. Since the majority of CBCT systems capture airway pictures while the patient is either seated or standing, their relevance in assessing OSA is questionable. The capacity of the patient's airway to expand in the A-P plane during picture acquisition may be affected by their alignment, according to a recent study. (Aboelmaaty and Isaac 2022)

To add insult to injury, the airway room is minimal while the patient is awake. In addition, the tonicity of the muscles has a different effect on the anatomical features of the upper airway when the patient is lying down as opposed to when they are upright. Also, DISE is the way to go for dynamic examinations of airway blockage at the laryngeal and laryngopharyngeal levels, as static imaging cannot confirm it. The CBCT scan results should not be taken at face value but rather as a relative measure of airway blockage. (Tsuiki 2005)

In addition, the airway measures taken are very sensitive to where the jaw is throughout the scan. Scan conditions such as centric relation, centric occlusion (maximum dental intercuspation), or the presence of a dental orthotic can impact the accuracy of volume and area measurements. Because the patient's tongue's retro position can constrict the airway and influence the hyoid's location, it is helpful to teach them how to hold their tongue during the scan. Because of this, it is critical to show patients and make sure they understand how to hold their mouths in a specific way for scanning. The size of the airway can be affected by the posterior placement of the tongue, as seen by CBCT scans that show an air gap between the tongue and the hard palate. Some patients have been known to follow the Mueller Maneuver while they undergo scans. The patient is instructed to cover their mouth and nostrils while taking a deep breath through their nose and mouth. This will make it seem like the upper airway is collapsing toward the base of the tongue. (Camacho 2014)

Furthermore, there is still a large range of accuracy, even though there is a high level of consistency among various software packages. This is dependent on the thresholding method employed for airway volumetric segmentation, which can be implemented using tools like ITK-Snap, OnDemand3D CyberMed, Materialise, Mimics, and Dolphin3D. (Souza 2013)

## 3. Conclusion:

CBCT is a low-radiation 3D imaging technique that has the potential to identify OSA as a byproduct and lead to early referrals for patients. When compared to healthy individuals, patients with obstructive sleep apnea have smaller airways, larger airway distances, and narrower airway passages. Moreover, CBCT has the potential to enhance surgical outcome prediction.

## Disclosure

The author reports no conflicts of interest in this work.

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