Obstructive Sleep Apnea Syndrome - What every radiologist should know

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Learning objectives

After viewing this exhibit, learners should:

- Understand the etiopathology of Obstructive Sleep Apnea Syndrome (OSA).
- Recognise clinical findings and risk factors associated with the disease.
- Read and report computed tomography (CT) examinations in OSA patients.
- Use cephalometry and CT to identify normal measurements and anatomical abnormalities.

Background

Introduction

Obstructive Sleep Apnea Syndrome (OSA) is a common sleep disorder in which complete (apnea) (Fig.1) or partial airway obstruction (hypopnea) (Fig.2) is caused by pharyngeal collapse during sleep. Its symptoms include loud snoring or choking, frequent awakenings, disrupted sleep, excessive daytime sleepiness, fatigue and impaired cognition. \(^{(1,2)}\)

This syndrome is defined and measured by apnea-hypopnea index (AHI) as five or more episodes of apnea and hypopnea per hour of sleep, when associated with other symptoms or as 15 or more obstructive apnea-hypopnea events per hour of sleep regardless of associated symptomology. Apnea or hypopnea requires treatment if associated with symptoms or cardiovascular disease. For an AHI > 15 it has to be treated regarding symptoms or cardiovascular disease. \(^{(1,2)}\)

Several reports in the literature link OSA with severe complications such as major cardiovascular disorders, neurocognitive sequelae and mood disorders. There is also growing evidence of strong correlation between this disease and hypertension, coronary artery disease, heart failure, arrhythmias and stroke. Cognitive impairment with changes in attention and concentration, executive function and fine-motor coordination are common complaints of these patients. \(^{(1,2)}\)

Epidemiology

The reviewed literature suggests that 4% of men and 2% of women over the age of 50 years suffer from symptomatic OSA.\(^{(3)}\) However, this disease is often asymptomatic and its true prevalence in the middle-aged population might be as high as 20-30%. \(^{(4)}\)
The most relevant risk factors for OSA are obesity, male gender and increasing age. A 10% weight gain increases the risk of developing OSA by six-fold, making obesity the most important (reversible) risk factor.\(^{(1,2,5)}\)

The androgenic pattern of body fat distribution, in particular deposition in the trunk and the neck area, may predispose men to OSA.\(^{(6)}\)

The relation between ageing and obstructive sleep apnea is complex. In children, obstructive sleep apnea after adenotonsillar hypertrophy is well described and in older persons over the age of 65, the prevalence of OSA increases two to three times when compared to younger individuals.\(^{(1,7)}\)

Other risk factors mentioned in the literature are postmenopausal, black race, alcohol and tobacco consumption.

**Clinical Presentation**

This syndrome's symptoms usually develop insidiously being present years before the diagnosis is established.

The typical clinical presentation of OSA includes signs of upper airway obstruction during sleep, insomnia and diurnal hypersomnolence. Obstructive breathing symptoms include snoring, snorting, gasping and choking. Patients may report intermittent awakenings and insomnia, with reduced total sleep time, fragmented sleep or early morning awakenings. Chronic fatigue and daytime sleepiness, secondary to sleep fragmentation, are the most significant diurnal complaints. Other daytime symptoms include morning headaches, dry mouth and waking up with a sore throat.\(^{(1,2)}\)

OSA is also associated with a two to seven-fold increase in the risk of motor vehicle accidents.\(^{(8)}\)

**Pathogenesis**

The development of upper airway obstruction is associated with both anatomical and neuromuscular factors.

The human pharynx is a collapsible tube with several purposes including speech, swallowing and respiration. Since it is not supported by a rigid skeleton, the maintenance of pharyngeal patency implies an equilibrium between factors promoting its collapse (negative pressure within the airways's lumen and increased extraluminal pressure...
provided by the soft tissues) and factors promoting its patency (tonic and phasic contractile activity of the dilator muscles).\(^{(9)}\)

A narrow upper airway is generally more prone to collapse than a larger one and several factors contributing to these anatomical changes are stated:

- Obesity with excessive fat deposits, particularly enlarged parapharyngeal fat pads (moreover it may also increase pharyngeal collapsibility through reduction in lung volumes);
- Nasal polyps
- Nasal septal deviation
- Thickness of the lateral parapharyngeal muscular walls;
- Tonsillar and tongue hypertrophy;
- Retrognatia;
- Inferior displacement of the hyoid bone;
- Greater length of the pharynx;

Some of the pathologies above referred contribute either to hypopneas and apneas while others just cause snoring.

From a neuromuscular perspective, the phasic activity of some dilator muscles has been found to decline while sleep, even in healthy individuals, leading to a smaller pharyngeal cross-sectional area during sleep than during wakefulness. This narrowing of the airway is related to the reduced activity of the reflex mechanisms (mediated by chemoreceptors and mechanoreceptors) that control the activity of pharyngeal dilator muscles.\(^{(1,2)}\) In patients with OSA, the onset of sleep is associated with a significantly larger decrement in the activity of these muscles when compared to controls. \(^{(10)}\)

*Diagnosis*

A thorough medical history and physical examination are keystones for the clinical diagnosis of OSA. The examination must include evaluation for obesity, neck circumference, retrognathia, micrognathia, macroglossia and inferior displacement of the hyoid bone. The severity of daytime hypersomnolence can be quantified by questionnaires as the Epworth Sleepiness Scale.

Polysomnography remains the gold standard to confirm clinical suspicion, measure severity and guide the therapeutic management, by assessing the apnea-hypopnea index (AHI) during sleep, through the use of pulse oximetry, electroencephalogram, electro-oculogram, nasal and oral air flow measurements, chest wall, electromyogram and electrocardiogram. It does not, however, recognise the exact anatomical site of obstruction as can imaging studies, such as cephalometry and CT, used for the anatomical evaluation and surgical planning of the upper airway.
Although polysomnography is capable of identifying OSA-afflicted individuals and guiding management, it cannot determine the site or cause of the airway obstruction.

This educational exhibit strives to emphasise the role of a radiologist in providing information about anatomic abnormalities, as well as determining the location and degree of airway narrowing through the use of cephalometry and CT.

CT can demonstrate the lateral or anterior-posterior narrowing of the airway with great anatomical detail, as caused by large tonsils, a long and thick soft palate/uvula, a prominent tongue base or a posteriorly deviated epiglottis.

Cephalometry identifies other craniofacial characteristics that might also be associated with this disease, sometimes to the point of requiring surgical correction.

In patients with suspected OSA, the identification of the possible sites of upper airway obstruction is crucial for the appropriate surgical planning. In this educational exhibition we focus on the two radiologic studies with widespread availability, which easily allow precise location of potential anatomical abnormalities.

Lateral Cephalometric Radiographs

Lateral cephalometry is commonly used in clinical practice because of its relative simplicity, accessibility, low cost and minimal radiation. (11)

This radiograph provides a lateral view of the head and neck in standard plane with specific emphasis on bone and soft tissue landmarks, which may reveal a variety of soft and hard tissue abnormality that may indicate patients with narrow and collapsible upper airways such as posteriorly placed mandible, narrow posterior airway space, enlarged tongue / soft palate and inferiorly positioned hyoid bone. (12,13)

Commonly these cephalometric measures may also be obtained on the CT-Scout.

The most significant cephalometric measurements in the identification of patients with OSA include: (Figure 3 and 4 )

- Tongue Size
- Soft palate length (PNS-U)

Distance from the posterior nasal spine (PNS) to the tip of the uvula (U)

- Maximum thickness of the Soft palate (SP-max)

Maximum thickness of the soft palate perpendicular to PNS-U
• **Posterior airway space (PAS):**

Distance from the base of the tongue to the posterior pharyngeal wall on the line between the supramentale and gonion;

Some authors have added the minimal posterior airway space (MPAS) as the narrowest point between the base of the tongue and the posterior pharyngeal wall

• **Mandibular plane-hyoid distance (MPH):**

Distance between the plane parallel to the inferior mandibular border and the hyoid.

• **Sella-Nasion-Anterior nasal spine Angle (SNA):**

Angle between the sella, nasion, and anterior nasal spine. Assesses the relationship of the cranium and the maxilla.

• **Sella-Nasion-Supramentale Angle (SNB):**

Angle between the sella, nasion, and supramentale. Assesses the relationship of the cranium and the mandible.

The values of these measurements should be within the normative data summarised in Figure 5.

Several authors have classified pharyngeal and upper airway anatomy for OSA. One of the classification systems mentioned on the literature is the Moore Classification, according to which the lower pharynx may be classified based on cephalometric x-rays in four types of obstruction: Type A is upper tongue base obstruction with normal lower tongue base and epiglottis; Type B is a combined upper tongue base and epiglottic obstruction; Type C is combined upper and lower tongue base and epiglottic obstruction; Type C is epiglottic obstruction.

**Computed Tomography (CT)**

Lateral cephalometric studies has the drawback of evaluating a complex three-dimensional structure, such the pharynx, as a two-dimensional projection in the awake, upright patient and not taking into account the cross-sectional changes of the upper airway during breathing, sleep or supine position. As such, its value in the evaluation of OSAS is low and additional evaluation techniques are needed.

CT is performed in the supine position and eventually in different phases of respiration providing information about airway cross-sectional area and site of collapse.
Nevertheless CT still studies the awake patient and only during a short period of time, besides presenting an increased radiation exposure risk. Hence, cephalometry and CT are complementary techniques in the evaluation of the skeletal system and soft tissues in OSAS. (11,14)

CT images should be acquired during full expiration, allowing the measurement of the upper airway caliber at the level of nasopharynx, oropharynx and hypopharynx, as well as the luminal area of the airway.

Cross-sectional imaging facilitates the recognition of parapharyngeal fatpads surrounding the collapsible segment of the pharynx and the measurement of the neck circumference. The latter is an index of local adiposity and has been shown to correlate with the size of the tongue, soft palate and position of the mandible, maxilla and hyoid bone. CT is also able to exclude other pathology such as malformations, tumors and infections.

The most common anatomical anomalies diagnosed by cephalometry and CT are:

Obesity with excessive fat deposits and enlarged neck circumference (Fig. 7 e 8)

- Nasal Obstruction (Fig. 9,10,11,)
- Long, thick soft palate (Fig. 12)
- Retrognatism (Fig. 13)
- Narrowed oropharynx (Fig. 14)
- Redundant pharyngeal tissues (Fig. 14)
- Large lingual tonsil (Fig. 15)
- Large tongue (Fig. 16)
- Large or floppy Epiglottis (Fig. 17 e 18)
- Retro-displaced hyoid complex

Join the Puzzle - How to Report Cephalometric radiograph and CT in OSA

1 - Evaluate all the measures listed on lateral cephalometric radiographs and correlate them with the normal values listed on table 1.

2 - Analyse CT scan step by step:

- Initiate with a general morphologic / anatomical evaluation of head and neck
- Orbits/Paranasal Sinuses/Skull Base: Identify causes of upper airway obstruction such as nasal polyps or nasal septal deviation and potential craniofacial malformations associated with OSA.
- Nasopharynx: Evaluate the soft palate, the nasal choanes and the adenoids
- Suprathyoid Neck: Evaluate the oropharynx observing the soft palate, the valleculae, the anterior tonsillar pillars, the base of the tongue the lingual tonsils in the anterior part, and the faucial tonsils laterally which
are part of the Waldeyer's ring. Evaluate also the parapharyngeal and the retropharyngeal space.

- Infrahyoid Neck: Evaluate the hypopharynx observing the piriform sinus, postcricoid area and posterior hypopharyngeal wall. Evaluate the larynx, observing the thyroid, cricoid and pyramidal cartilages, vocal cords and epiglottis.

**Learn Based Cases - OSA**

Clinical Case nº 1 - Young child that snores (Fig 19)

Clinical Case nº 2 - Middle age male with symptoms of snoring an dysphagia (Fig 20)

Clinical Case nº 3 - Middle aged male with symptoms of snoring, diurnal hypersomnolence and chronic fatigue (fig. 21, 22)

Clinical Case nº 4 - Middle aged male with symptoms of snoring (Fig. 23)

Clinical Case nº 5 - Middle aged female with odynophagia (Fig 24)

**Images for this section:**
Fig. 1: Apnea: Absence of airflow, with maintenance of the respiratory effort giving rise to an arousal.

Fig. 2: Hypopnea: 50% decrease of the nasal airway flow giving rise to an arousal
Fig. 3: Posterior airway space (PAS) is measured from the base of the tongue to the posterior pharyngeal wall on the line between the supramentale and gonion;
**Fig. 4:** Mandibular plane-hyoid distance (MPH): Measures the distance between the plane parallel to the inferior mandibular border and the hyoid; Sella-Nasion-Anterior nasal spine Angle (SNA) and Sella-Nasion-Supramentale Angle (SNB): S is the midpoint of the sella, A is the deepest point on the premaxillary outer counter and B is the deepest point on the outer mandibular countour.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Normal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft palate length (PNS-U)</td>
<td>34 ± 6 mm</td>
</tr>
<tr>
<td>Posterior airway space (PAS)</td>
<td>11 ± 2 mm</td>
</tr>
<tr>
<td>Mandibular plane-hyoid distance (MPH)</td>
<td>15 ± 3 mm</td>
</tr>
<tr>
<td>Sella–Nasion–Anterior nasal spine Angle (SNA)</td>
<td>82°</td>
</tr>
<tr>
<td>Sella–Nasion–Supramentale Angle (SNB)</td>
<td>80°</td>
</tr>
</tbody>
</table>

**Fig. 5:** Normal values for cephalometric measurements (12-15)
Fig. 6: SNA and SNB angles lower than the normal value, and also a MPH increased. These abnormal measures contribute to a smaller PAS.
Fig. 7: Obesity and enlarged neck circumference
Fig. 8: Parapharyngeal fat-pads
Fig. 9: Nasal Septum deviation
Fig. 10: Axial CT of a large nasal choanal polyp obstructing the airway
**Fig. 11:** Sagital CT of a large nasal choanal polyp obstructing the airway
Fig. 12: Upper pharyngeal obstruction resulting from long and thick soft palate (PNS-U = 46, 3 mm)
Fig. 13: Sagital CT - retrognathism
Fig. 14: Axial CT shows that in both patients there is anterior-posterior reduction of the airway, nevertheless the patient at the right side has a smaller airway area due to pharyngeal tonsils enlargement.
Fig. 15: CT. Coronal plane - Large pharyngeal tonsils
Fig. 16: CT sagittal plane - large tongue base resulting in oropharyngeal obstruction
Fig. 17: Axial CT showing a floppy epiglottis obstructing the airway
**Fig. 18:** Left: sagital CT with normal epiglottis; Right: sagital CT with a floppy epiglottis obstructing the airway
Fig. 19: Tonsillar hypertrophy ("kissing tonsils")
Fig. 20: Retropharyngeal schwannoma
Fig. 21: Volume rendering air structure sagittal and coronal planes: airway area reduction caused by soft palate and epiglottis obstruction
Fig. 22: Sagittal CT, same patient: retrognathism; soft palate and epiglottis airway obstruction
Fig. 23: Upper pharyngeal obstruction resulting from long and thick soft palate
Fig. 24: status after uvulopalatopharyngoplasty. It's possible to identify a post-surgical short soft palate.
Conclusion

Radiology has an important role in the diagnosis and follow-up of these patients. It is therefore essential for the radiologist not only to comprehend the etiopathology, clinical findings, and risk factors, but also to recognise the anatomical anomalies characteristic of this disease, namely concerning the upper airway and craniofacial malformations. Last of all, one must be aware of the limitations expected of imaging techniques.

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