3 Surgical Evaluation and Airway Assessment of Patients with OSA

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3.1 Introduction

Obstructive sleep apnea is the most common sleep-related breathing disorder in the world, with its prevalence continuing to increase. Sleep-disordered breathing is a continuum beginning with primary snoring to upper airway resistance syndrome to obstructive sleep apnea and ending with obesity-hypoventilation syndrome. Obstructive sleep apnea is further subdivided into mild, moderate, and severe. Although the pathophysiology of obstructive sleep apnea is multifactorial, it is generally due to obstruction or collapse of the upper airway at one or more of the following levels: the nasopharynx, oropharynx, and hypopharynx [1]. Some sleep physicians also include the larynx as the fourth anatomical location for possible site of obstruction in patients with OSA [2]. In order to accurately evaluate patients with OSA, one must have an understanding of the relevant surgical anatomy.

3.2 Relevant Surgical Anatomy

From the nares, air funnels through two valves, which are the narrowest point of passage. Deformities and the collapse of the alar cartilage can obstruct or stenose the external nasal valves. Internal nasal valve collapse or constriction can also lead to decreased nasopharyngeal airflow, which can easily be evaluated clinically by performing a Cottle test. Between the external and internal nasal valves, septal deviations and enlarged inferior turbinates can further contribute to obstruction of flow. Maxillary constriction, a high-arched palate, and dental occlusal crossbites will further narrow the nasal floor and constrict air flow. The oropharynx is the most

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common site of obstruction in patients with OSA [3]. This area extends from the soft palate to the epiglottis and includes the palatine tonsils, posterior tongue, and pharyngeal constrictors and is influenced by the position of the maxilla and mandible, soft palate, and adenotonsillar region. A retrognathic maxilla and/or mandible can lead to decreased space posterior to the hard palate and tongue. The thickness and length of the soft palate, lymphoid hyperplasia especially in the adolescent patient, and certain craniofacial skeletal abnormalities all contribute to airway flow deficiencies. Airway flow can be unintentionally inhibited postsurgically, such as status-post cleft palate repair surgeries or pharyngeal flaps. Chronic OSA has even been shown to cause the palate to thicken, elongate, and descend, further worsening airway flow. The hypopharyngeal region extends from the cephalad border of the epiglottis to the cricoid cartilage inferiorly. Lingual tonsillar hypertrophy and a lax epiglottis can lead to decreased airway space and obstruction in this region. Constriction in these areas is not only limited to anterior-posterior dimensions but lateral and concentric dimensions, all of which can contribute to upper airway obstruction.

3.3 Clinical Assessment

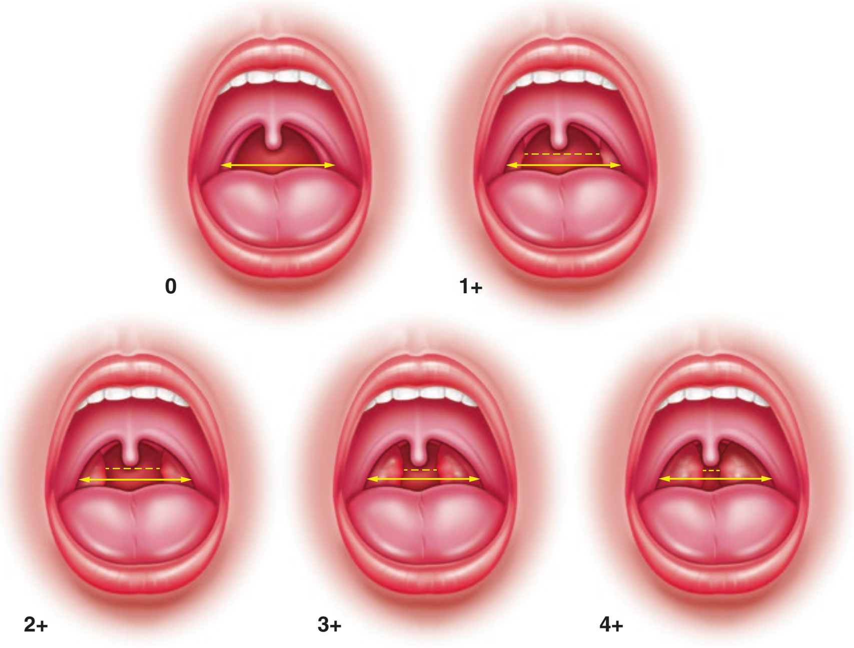
The assessment of patients with suspected sleep-disordered breathing should begin with examining the patient's history, comorbidities, and basic sleep questionnaires, preferably with their partner present. A comprehensive sleep history should include an evaluation for snoring, witness apneas, excessive or early daytime somnolence, total sleep time, and assessment of sleepiness severity by the Epworth Sleepiness Scale (ESS) [4]. An ESS of ten or greater warrants further investigation as it indicates an increased likelihood of sleep-disordered breathing. Another simple questionnaire that can easily be completed, which includes some physical findings as well, is the STOP-Bang Questionnaire [5]. This questionnaire consists of four questions (STOP), snoring, tiredness, observed apneas, and treatment for high blood pressure, and four clinical findings (Bang), BMI > 35, age > 50, neck circumference greater than 40 cm or 16 in., and male gender. The probability of moderate to severe OSA increases in direct proportion to an increased STOP-Bang score. When categorizing moderate to severe OSA, those with scores less than 3 can be considered low risk, and those with scores 5 or greater as high risk [6]. Along with these questionnaires and review of sleep history, clinical findings associated with OSA should be examined. Common clinical exam findings in patients with OSA include but are not limited to the following: nasal abnormalities, mandibular micro- or retrognathia, high-arched palate, tonsillar hypertrophy, elongated soft palate, macroglossia, obtuse thyromental angle, large neck circumference, and obesity.

Beginning with the nasal exam, assessment for the following clinical findings should be performed:

- External and internal nasal valve collapse
- Septal deviation
- Turbinate and/or mucosal hypertrophy

Oropharyngeal, maxillary, and mandibular skeletal exam signs consistent with an increased risk of having OSA are as follows:

- Constricted maxilla
- High-arched palate
- Elongated soft palate/uvula
- Narrowing of tonsillar pillars
- Adenotonsillar hypertrophy (grade 3 or 4) (Fig. 3.1)
- Micro- and retrognathia
- Microgenia



Tonsil size is most often described on a scale from 0 to 5:

- 0 – Tonsils are entirely within the tonsillar pillar, or previously removed by surgery.
- 1+ – Tonsils occupy less than 25 percent of the lateral dimension of the oropharynx, as measured between the anterior tonsillar pillars (solid yellow arrow).
- 2+ – Tonsils occupy 26 to 50 percent of the lateral dimension of the oropharynx.
- 3+ – Tonsils occupy 51 to 75 percent of the lateral dimension of the oropharynx.
- 4+ – Tonsils occupy more than 75 percent of the lateral dimension of the oropharynx.

Fig. 3.1 Brodsky Tonsil Grading Scale

- Modified Mallampati III or IV (inability to visualize posterior oropharyngeal wall) (Fig. 3.2)
- Friedman tongue position III or IV (Fig. 3.3)

Hypopharyngeal exam findings are difficult to assess clinically without the aid of fiber-optic endoscopy, but an enlarged neck circumference, short neck, and low hyoid positions should be clues to the practitioner of the patient's

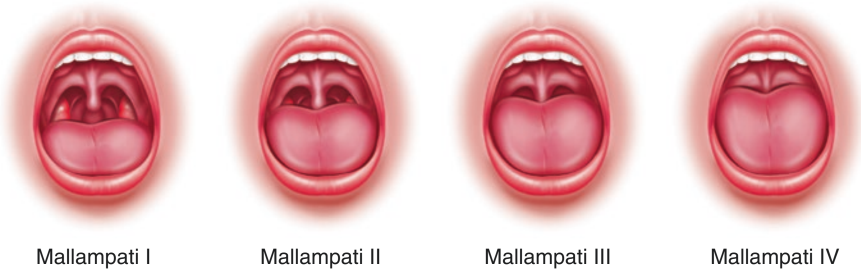


Fig. 3.2 Modified Mallampati Scale

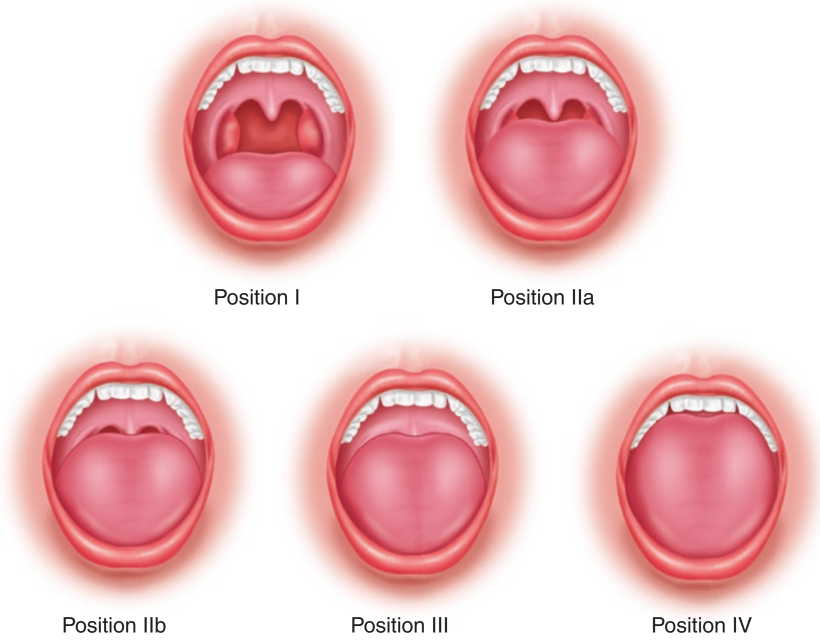


Fig. 3.3 Friedman Tongue Position

Stages	Friedman Tongue Position	Tonsil Size	BMI
I	I, IIa, IIb	3 or 4	<40
II	I, IIa, IIb III or IV	0, 1, or 2 3 or 4	<40 <40
III	III or IV	0, 1, or 2	<40
IV	All	All	>40

Fig. 3.4 Friedman Staging System

higher risk for having upper airway obstruction. Masses or lesions at any location in the upper airway can also lead to obstruction and require further evaluation.

Prior to proceeding with further investigations, such as endoscopy and radiographic imaging, based on clinical exam findings, the Friedman Staging System (FSS) can be utilized to guide surgical interventions and accurately predict the success of surgical outcomes (Fig. 3.4). FSS combines Friedman tongue position (I–IV), tonsil size (0–4), and BMI and separates them into four stages [7]. This system was originally devised to predict surgical success of uvulopalatopharyngoplasty (UPPP) but is a useful assessment and documentation tool for any patient undergoing surgical intervention for the treatment of OSA.

3.4 Upper Airway Endoscopy

Along with a comprehensive history and physical exam, it is imperative to perform flexible nasopharyngoscopy to completely assess the upper airway in detail. This can be performed both awake and asleep, i.e., drug-induced. There are benefits and limitations to both approaches.

Drug-induced sleep endoscopy (DICE) involves the assessment of the upper airway during pharmacologically induced sleep with agents such as propofol, midazolam, dexmedetomidine, and/or opioids. Kezirian et al. introduced a new classification system for obstruction during DICE in 2011 [8]. The VOTE classification not only localizes the site of obstruction but also defines it in regard to degree of obstruction and configuration (i.e., anterior-posterior (AP), lateral, and/or concentric). The agents used to induce sleep intrinsically lead to decreased tone of pharyngeal airway musculature and impart the risk of inducing complete airway obstruction requiring airway protective interventions. Another limitation to DICE is the inability to have the patient perform a Mueller's maneuver to assess for site(s) of obstruction. In 2017, a European position paper on DICE was updated with general recommendations on performing and evaluating sleep endoscopy of OSA [9]. DICE should be performed in an operating room or endoscopy suite setting, after the patient has undergone a type 1, 2, or 3 sleep study. The European position paper also recommends the use of propofol and midazolam together or midazolam alone as the sedative agent. Positioning should mimic the patient's natural sleep position as well. Regarding classification systems, no consensus was obtained; however, the

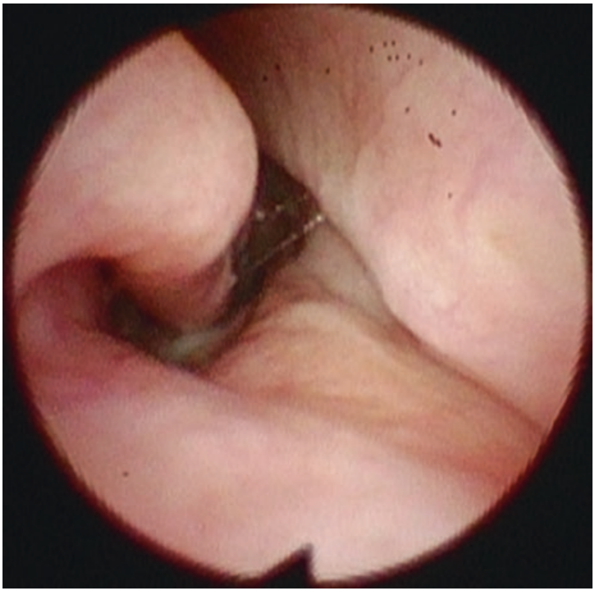


Fig. 3.5 Intranasal image from nasopharyngeal endoscopy

VOTE classification system was recommended along with including a grading system for degree of obstruction/collapse [9].

Awake endoscopy is performed while the patient is supine. The patient's position can then be changed to perform Mueller's maneuver. Mueller's maneuver is performed while the patient is upright with a closed mouth and pinched nose with maximum inspiration. The increased intraluminal negative pressure with this maneuver attempts to duplicate the sleep-related pressure changes to more accurately assess the presence of dynamic upper airway collapse. The limitation of awake endoscopy is the inability to visualize the anatomical site(s) of obstruction during sleep, pharmacologically induced or not.

Both techniques, however, allow for visualization of the entire upper airway in detail as well as aid in objectively assessing surgical changes and/or success in treating the site(s) of obstruction postoperatively [10]. Endoscopic examination allows the practitioner to visualize the nasal cavity, assessing for septal deviation, turbinate hypertrophy, nasal polyps, etc. (Fig. 3.5) [11]. Working further into the nasopharynx, assessment of velopharyngeal obstruction can be performed. Collapse in all three dimensions, AP, lateral, and concentric, can occur at this site (Fig. 3.6). Entering the oropharynx, the lateral pharyngeal walls and tonsillar pillars can be assessed for lateral collapse and/or adenotonsillar hypertrophy. And finally, the base of the tongue can be evaluated for both AP collapse and lingual tonsillar hypertrophy (LTH), along with assessment of the epiglottis for laxity leading to airway obstruction (Fig. 3.7). Lingual tonsillar hypertrophy can be graded on a scale from 0 to 4 as follows (Fig. 3.8) [7]:

- Grade 0—complete absence of lymphoid tissue
- Grade 1—lymphoid tissue scattered over the tongue base

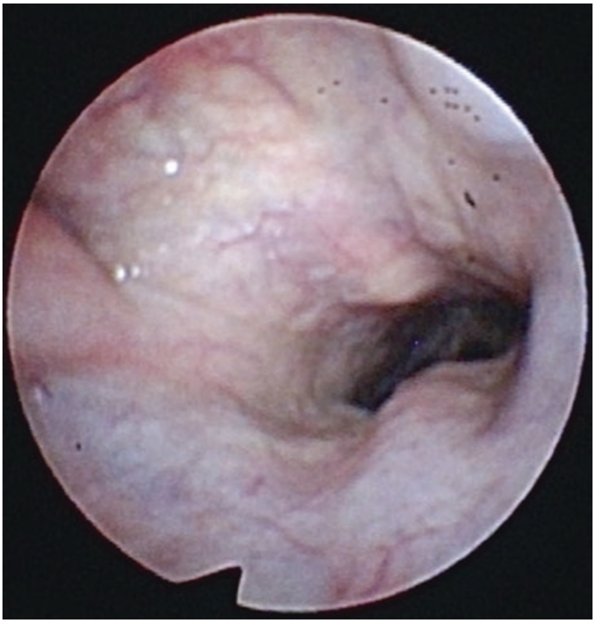


Fig. 3.6 Soft palate image from nasopharyngeal endoscopy

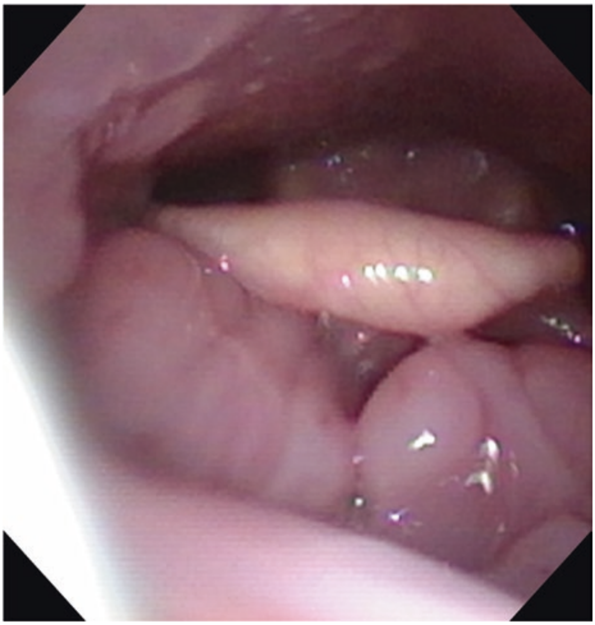


Fig. 3.7 Lingual tonsil image from nasopharyngeal endoscopy

- Grade 2—lymphoid tissue covering the entirety of the tongue base with limited vertical thickness
- Grade 3—significantly raised lymphoid tissue (5–10 mm thick)
- Grade 4—lymphoid tissue 1 cm or more thick rising over the epiglottis

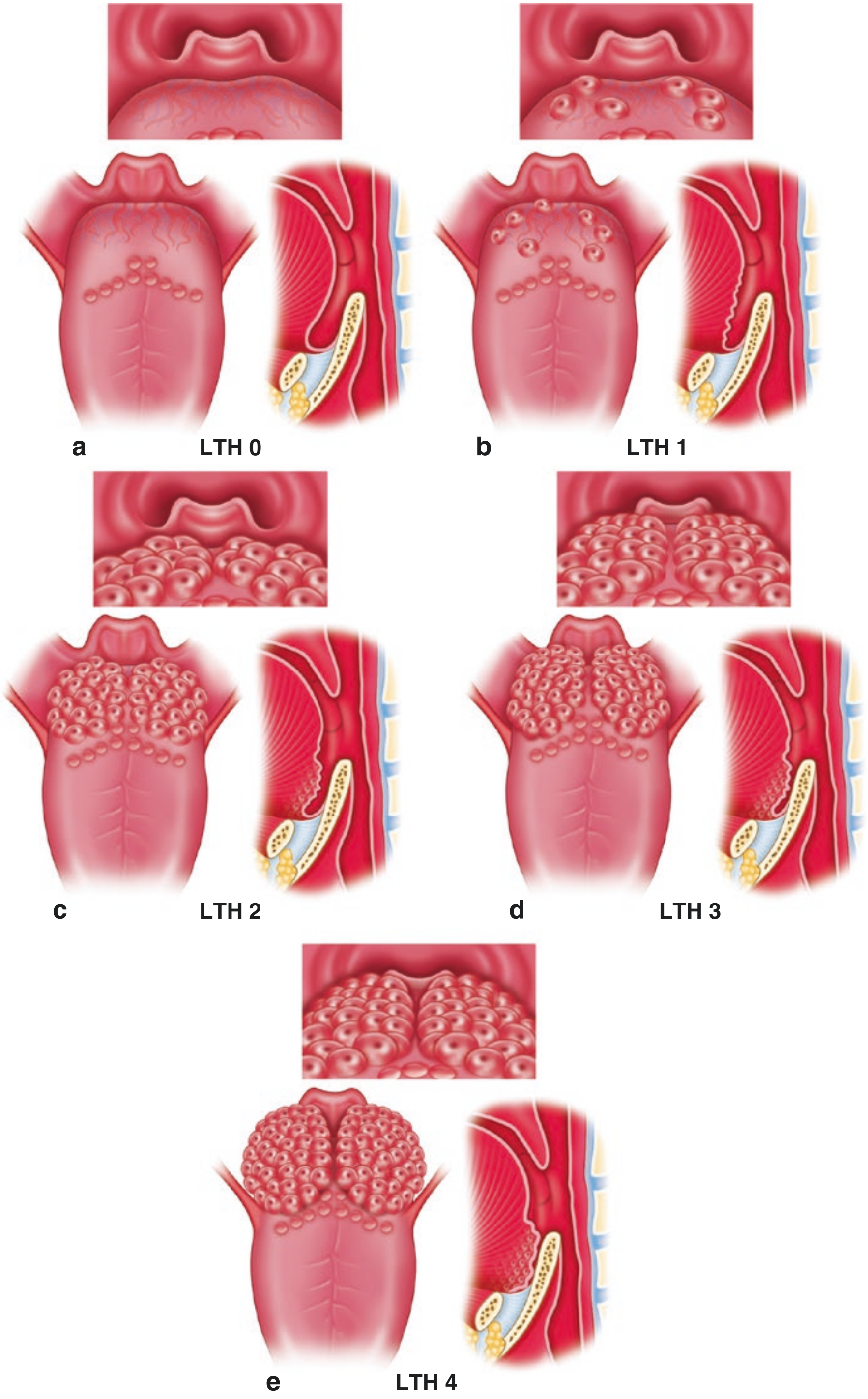


Fig. 3.8 Lingual Tonsil Hypertrophy (LTH) Grading Scale

A meta-analysis performed by Lee and Cho in 2018 concluded that upon endoscopic examination, patients with OSA were more likely to have multilevel obstruction rather than single-site obstruction [12]. Of the patients included in the meta-analysis, 84.1% had obstruction at the soft palate, 51.6% at the base of the tongue, 34.3% at the epiglottis, and 32.8% at the tonsils [12]. This further demonstrates the importance of performing nasopharyngeal endoscopy for evaluation of patients with OSA, due to the multilevel location of upper airway collapsibility and inability to appropriately assess these anatomical sites with only a clinical exam.

3.5 Radiographic Imaging

There are several options for radiographic imaging of patients with OSA. Depending on the sleep physician's preference and accessibility to certain types of imaging, multiple modalities can be utilized. The quickest and cheapest option for imaging is a lateral cephalogram (Fig. 3.9). This option is easily accessible to most oral and maxillofacial surgeons and is a quick tool to assess the anterior-posterior dimension of the patient's upper airway. Mandibular or maxillary position can easily be assessed with this form of imaging, and patients with skeletal deficiencies are more prone to have airway obstruction retropalatally and at the base of the tongue [13]. Several measurements can be obtained from a lateral cephalogram that can indicate the likelihood or increased risk of a patient having OSA, including, but not limited to, PNS-P (posterior nasal spine to caudal aspect of palate) length greater than 37 ± 3 mm, MP-H (mandibular plane to hyoid) greater than 15.4 ± 3 mm, and PAS (posterior airway space as measured from the continuation of a line B-point to Gonion to the posterior pharyngeal wall) less than 11 ± 1 mm. Although this modality is an upright, static, two-dimensional image, Riley and colleagues demonstrated a statistically significant correlation between PAS measured on lateral cephalograms and pharyngeal airway volume measured on computer tomography scans [14].

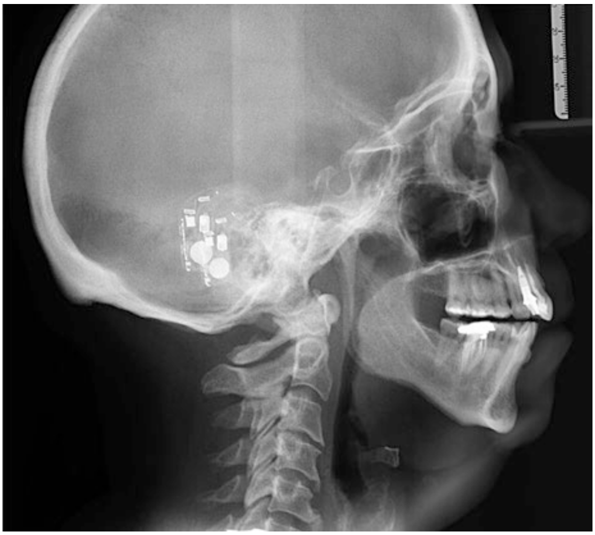


Fig. 3.9 Lateral cephalogram demonstrating decreased airway space and low-positioned hyoid

Another radiographic option, also commonly accessible to many practitioners, is computed tomography. An upright cone beam computed tomography (CBCT) provides more information than a two-dimensional lateral cephalogram. Visualization of the upper airway three-dimensionally can provide the specific location of airway obstruction in both anterior-posterior and lateral dimensions (Fig. 3.10) [15]. Airway space measurements, including volume and cross-sectional area, have been shown to be quite accurate by use of CBCT scans. Although this is a static image, and predominately completed in an upright position, multivariate analysis shows airway narrowing on CBCT to be predictive of an elevated degree of obstruction [16]. CBCT imaging is also beneficial and utilized for virtual surgical planning in cases requiring skeletal surgery, i.e., maxillomandibular and/or genioglossal advancement. Postsurgical images can be used to compare and quantify an increase in upper airway space, which can then be correlated to the patient's decrease in AHI.

Conventional computed tomography (CT) in supine position, although more time-consuming and costly, can also be utilized for preoperative assessment of the patient undergoing upper airway obstruction surgery (Fig. 3.11). In regard to base of the tongue procedures, the location of the dorsal lingual artery can be visualized and incorporated in the surgical plan to decrease the risk of injury. Three-dimensional measurements similar to CBCT images can be obtained as well, with visualization of anterior-posterior and lateral collapse. Li et al. demonstrated a relationship between upper airway area and probability of suffering from OSA based on CT analysis. They concluded that there is a high probability of severe OSA with an airway area of less than 52 mm^2, an intermediate probability if the airway is between 52 and 110 mm^2, and a low probability if the airway is greater than 110 mm^2 [17].

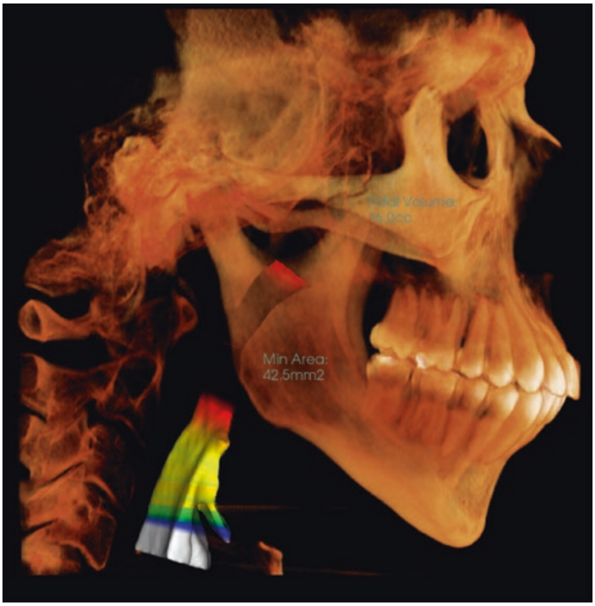


Fig. 3.10 Cone beam CT scan 3D airway assessment [Software—Invivo6, Anatomage, San Jose, CA]

Fig. 3.11 CT scan indicating lingual tonsillar hypertrophy and elongated soft palate

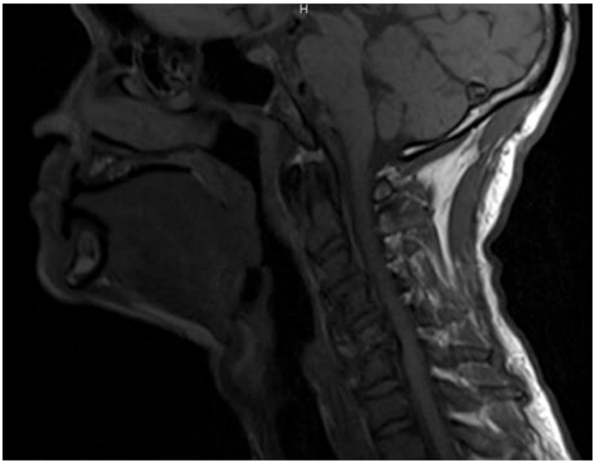


Fig. 3.12 MRI demonstrating and elongated soft palate and retropalatal obstruction

A common critic of radiographic imaging is that they do not accurately capture airway anatomy during obstruction or airway collapse. Recent studies have been performed with drug-induced CT imaging, similar to the concept of DICE [18]. Results demonstrate the vast majority of patients (89%) exhibit multilevel obstruction, with the most common sites of obstruction occurring in the retropalatal level (86%), retroglossal level (57%), oropharyngeal lateral walls (49%), and epiglottis (26%) [19].

Finally, magnetic resonance imaging (MRI) can be utilized for further evaluation of the upper airway (Fig. 3.12) [20]. This modality is by far the most time-consuming and costly option but can provide precise analysis of the upper airway during obstruction. Kavcic et al. published a study utilizing this modality during natural sleep as monitored by electroencephalogram in an attempt to dynamically capture the specific site(s) of obstruction. Their group found that in 47% of patients, the palate was attached to the tongue base and both moved posteriorly to obstruct the airway, in 33% the soft palate was detached from the tongue base and solely moved posteriorly, and in 20% of the patients, both mechanisms of obstruction were noted [21].

3.6 Summary

A thorough and detailed upper airway examination is critical for patients undergoing surgical management of sleep-disordered breathing. The pathophysiology of obstructive sleep apnea is multifactorial and is most commonly due to obstruction or collapse of the upper airway at multiple levels. A complete surgical evaluation includes a comprehensive physical exam, nasopharyngeal endoscopy, and radiographic imaging. Unfortunately, beyond tracheostomy, there is not a single treatment that predictably leads to a cure for all patients; therefore treating patients with a "one-size-fits-all" mentality is contrary to the standard of care. Treatment should be individually targeted for patients based on their OSA severity and clinical, endoscopic, and radiographic findings to target and address the specific site(s) of obstruction.

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