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The Expected Difficult Airway

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Introduction

The primary purpose of airway management is to oxygenate the patient, as loss of the airway is associated with hypoxemia causing significant morbidity and mortality. Patients need successful airway management as part of a general anesthetic or for resuscitation when a patient is in extremis. Difficulty achieving satisfactory ventilation and oxygenation is a medical emergency, where prevention is better than the cure, and adverse outcomes follow rapidly with unprepared attempts by unskilled practitioners. Since the ASA closed claims studies¹, the critical importance of recognizing the difficult airway and preventing hypoxia has been a primary aspect of airway training. The advent of neuromuscular relaxants in the 1950s ushered in an era of tracheal intubation as this was considered the most effective way to ensure adequate ventilation during surgery. As a result, the vast majority of published literature looks at prediction of difficult tracheal intubation. However, mask ventilation is an equally critical component of successful airway management. Successful mask ventilation provides practitioners with a rescue technique during unsuccessful attempts at laryngoscopy and unanticipated difficult airway situations. Difficulty with both tracheal intubation and mask ventilation is associated with increased risk of patient injury. Several clinical models and tests have been described for the prediction of difficult intubation and mask ventilation. These screening tests use history elements and quantitative or estimated measures of various aspects of the face, upper airway, and neck to ascribe either high or low risk of an expected difficult airway. In order to better understand the performance and accuracy of these tests, a working understanding of the anatomy of the structures of interest is essential. A variety of systemic and local tissue factors impact the ease of tracheal intubation and mask ventilation. While the elective situation permits a rigorous examination of the airway, certain urgent and emergent clinical scenarios preclude a complete and thorough airway examination, making difficult airway situations more likely but less predictable. Irrespective of the urgency of airway instrumentation, clinical suspicion of a difficult airway helps prepare the practitioner for backup airway management strategies that often require additional personnel, equipment, and techniques for successful tracheal intubation. The purpose of this chapter is to describe the clinical features associated with the difficult airway and explore the clinical utility of these features on prediction of difficult mask ventilation and difficult tracheal intubation.

Anatomy of the Difficult Airway

The difficulty of achieving a patent airway varies with several anatomic factors related directly to the upper airway, and these anatomical features can be routinely assessed on patients prior to anesthesia. The upper airway refers to the air space including and above the laryngeal inlet. The upper airway is subdivided into the nasal and oral cavities that lead into the pharynx and down into the laryngeal inlet. The patency and function of these air spaces is maintained by a framework of bony skeleton and several muscles primarily innervated by the vagus, glossopharyngeal, and hypoglossal nerves.

An important contributory factor for upper airway closure relates to alterations in the volume of the tongue in comparison with the effective pharyngeal space. Anatomical factors that increase this incompatibility result in upper airway closure. Additionally, the sharp angle between the oral axis and the pharyngeal axis impacts the ability to visualize the larynx without adequate head extension. In order to better understand the individual components of anatomical variables of interest, these important primary mechanisms are explored in further detail below.



Figure 2.1. (Figs. 3.3.2 pg 129 from "Diagnosis in Otorhinolaryngology" by Matin Onerci) Patients with sleep apnea often present with tonsillar hypertrophy secondary to the increased upper airway fat deposition and Bernoulli effect.

Factors Affecting Tongue-Pharyngeal Volume Disproportion

The anatomical balance of soft tissue and bony framework of the upper airway is affected by conditions that increase tongue size, reduce pharyngeal size, or both. The tongue is attached to the mandible and the hyoid bone through various muscles, thereby limiting the space available for it to be compressed during laryngoscopy. Variations in tongue size are well described in the literature, especially in the presence of coexisting genetic disorders, developmental diseases, obesity and obstructive sleep apnea (OSA). Other congenital and acquired conditions that may result in glossopharyngeal disproportion include macroglossia resulting from hypothyroidism, Beckwith-Wiedemann Syndrome, acromegaly, amyloidosis, angioedema, anaphylaxis, prolonged Trendelenburg positioning, and trauma. The contribution of reduced pharyngeal volume is unclear in the general population, but immediately obvious in patients with upper airway edema, infection, and excessive adipose tissue. The impact of this imbalance on likelihood of airway closure has been explored in cephalometric studies of the upper airway². Patients with OSA were shown to have significantly larger tongues than patients without the disease. The same study also confirmed a more caudal location of the larger tongue in OSA (Figures 2.1 and 2.2).

The contribution of physical forces driven by the Bernoulli Effect³ on the progression of upper airway narrowing has also been established. Patients with OSA have redundant tissue in the upper airway secondary to the negative pressure caused by orifice flow during obstructive epochs in sleep. The net effect of increased upper airway soft tissue is that the forces that work to maintain airway patency fail during sleep and anesthesia, resulting in total airway collapse⁴.

Factors Affecting Access to the Upper Airway

One of the important causes of a difficult airway relates to the physical inability to introduce a laryngoscope into the upper airway with sufficient clearance to allow oral or nasal manipulation of an endotracheal tube. When performing direct laryngoscopy, there must be room for the laryngoscope blade, the endotracheal tube as well as a direct line of sight. Thus, conditions that affect mouth opening all contribute to the difficult airway problem. In addition to fixed limitation of mouth opening, certain conditions such as mandibular trauma and upper airway infection can cause dynamic limitation of mouth opening, primarily related to pain (Figures 2.3 and 2.4).

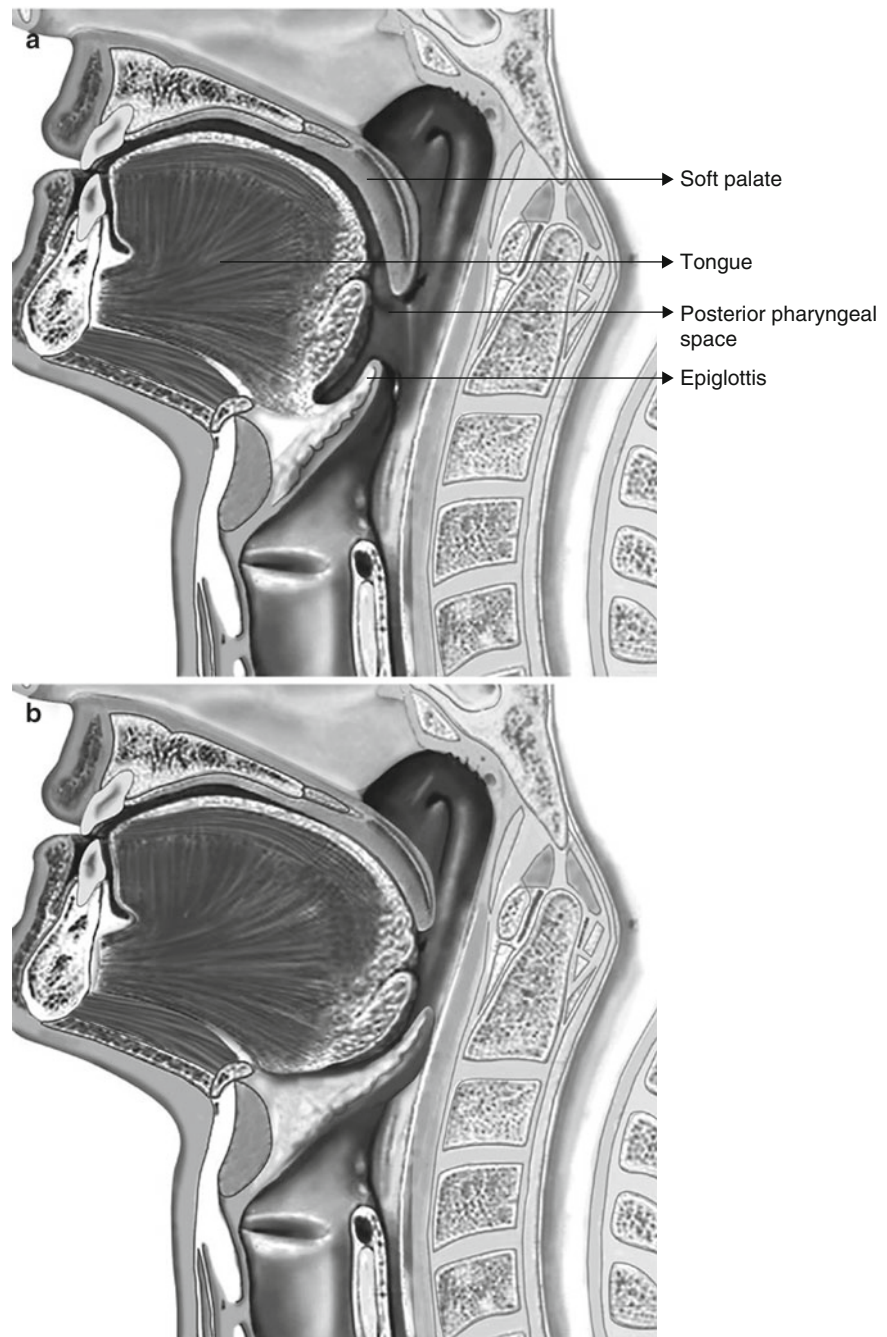


Figure 2.2. (Fig. 3.3.3 (a and b) pg 129 From "Diagnosis in Otorhinolaryngology" by Martin Onerci). Patients with obstructive sleep apnea (b) have significantly larger tongues than patients without the condition, predisposing them to airway obstruction.

Factors Affecting Laryngoscopic Visualization Vector

Although the concept of aligning the oropharyngeal axis with the direct laryngoscopy visualization axis is commonly promulgated during didactic airway sessions, this classical concept has not been supported by recent real-time magnetic resonance imaging of the airway. Nevertheless although the exact alignment of the axis is rarely achieved, optimizing the relationship between these axes remains a major goal of direct laryngoscopy. As a result, a focused analysis of the factors limiting this optimization is necessary during discussion of the expected difficult airway.



Figure 2.3. (Fig. 3.9.30 (b) pg 158 from "Diagnosis in Otorhinolaryngology" by Matin Onerci) Squamous cell carcinoma which fills the oral cavity and prevents access to the upper airway through the oral route.

Neck Mobility

Optimal laryngoscopic visualization of the larynx is critically dependent on the ability to align the oral and pharyngeal long axes (Fig. 2.5). A direct vector of sight would not be able to reach the larynx if neck mobility is restricted. Although classic teaching suggests



Figure 2.4. (Fig. 3.9.31 (a and b) pg 158 From "Diagnosis in Otorhinolaryngology" by Martin Onerci) (a) Squamous cell carcinoma of the retromolar trigone causing destruction of the mandible. (b) Invasion of the pterygoid muscles causes significant trismus, precluding traditional oral approach to tracheal intubation. Failure to detect this preoperatively could result in an airway emergency after induction of anesthesia.

that the sniffing position is required for optimal laryngoscopic visualization⁵, recent literature shows that head extension is the more significant factor in the majority of patients^{6,7}, except in the presence of obesity, where the sniffing position is advantageous⁴. The caveats to this rule include presence of normal teeth, adequate submental space for tongue compression, normal glottic structure, and position of the larynx. Excessive laryngoscopic force in patients with reduced head extension causes the cervical spine to bow forward, directly pushing the glottis to a more anterior position which is out of reach of the laryngoscopic visualization vector⁸.

Dental Factors

Size of the upper incisors has an increasing impact on the visualization vector with progressive limitation of neck mobility. Accordingly, absence of upper incisors permits a better laryngoscopic vector alignment and presence of long upper incisors adversely impacts ease of laryngoscopy and tracheal intubation. It is also important to note that partial loss of upper teeth could cause the laryngoscope blade to get "stuck" between teeth and impede vector alignment⁹. The impact of dental structure on mask ventilation is less clear. Previous studies have indicated that edentulous patients are associated with difficult

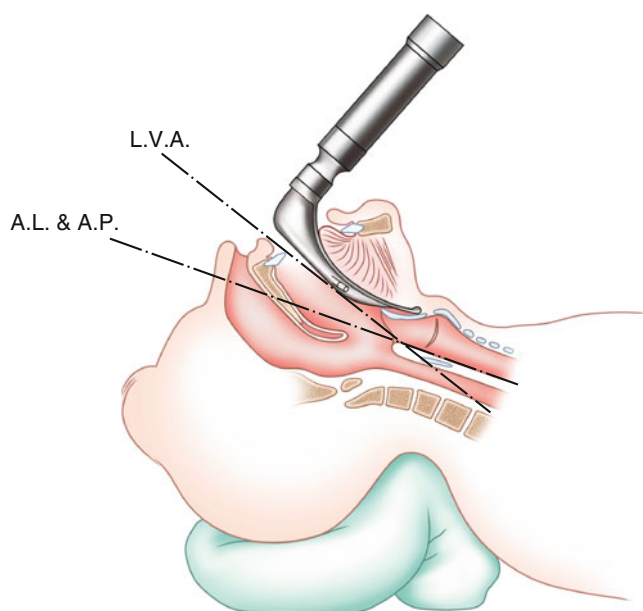


Figure 2.5. (Fig. 7.6 pg 188 From "Principles of airway management" by Finucane and Santora) For the laryoscopic visualization axis (LVA) to permit laryngeal visualization, appropriate positioning of the head and neck is essential. Inability to extend the neck will result in the divergence of line of sight from the laryngeal visualization vector and persistently poor views. Failure to detect limited head extension is commonly associated with difficult intubations.

mask ventilation, but edentulous state was not an independent predictor of difficult or impossible mask ventilation in the largest studies to date^{10,11}. Dentures may help maintain upper airway structure and permit a tighter mask fit, but expert opinion on retaining dentures during airway management is unclear.

Submental Factors

The bony cage that makes up the framework of the upper airway is formed by the maxilla, mandible, hard palate forming the "roof," and the cervical vertebral column at the back. Conditions that reduce the anteroposterior distance of the mid-face, mandibular length, and position of the hyoid bone all adversely impact the ease of mask ventilation and tracheal intubation. The floor of the upper airway is formed by soft tissue that is bounded anteriorly and laterally by the mandibular edges and the hyoid bone posteriorly. This virtual space, often referred to as the submentum or the submental space, is of crucial importance to the success or failure of laryngoscopy. The tongue is attached to the mandible and the hyoid bone through upper airway muscles, primarily the genioglossus, the hyoglossus, and the mylohyoid. The mylohyoid extends like a diaphragm across the floor of the submental space. This places a finite limitation to the volume of tongue that can be displaced during laryngoscopy. Tongue volumes in excess of the critical capacity of the submental space influence the laryngoscopic view. Similarly, disease states that reduce the compliance of the submental tissues namely scarring from surgery, burns, or radiation therapy will also impact laryngoscopic view. Correct positioning of the laryngoscopic blade tip in the fold between the tongue and the epiglottis causes the epiglottis to fold upward, bringing the larynx into view. Factors that may interfere with correct placement of the laryngoscope blade include vallecular cysts and lingual tonsillar hypertrophy. The forces that are exerted by the tip of the laryngoscope in this position pull the glosso-epiglottic ligament¹² and cause the hyoid bone to tilt forward. The hyoid bone has ligamentous attachment to the epiglottis, and this forward tilting movement causes the epiglottis to tilt up, opening up the glottic inlet.

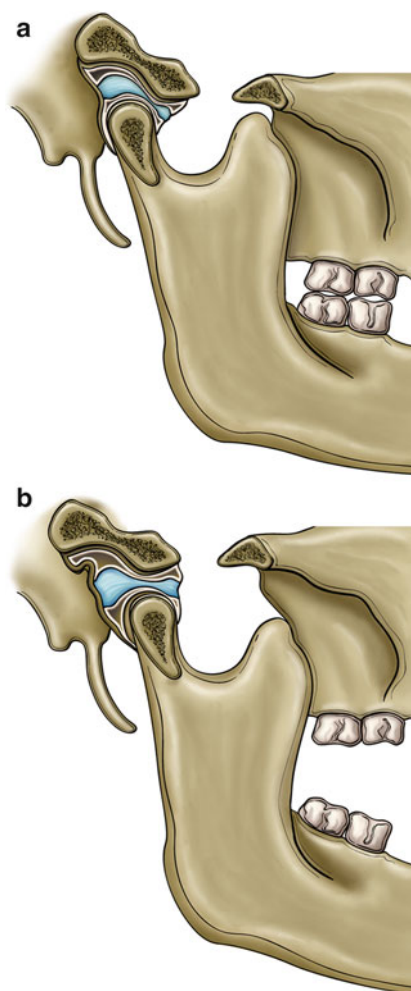


Figure 2.6. (Fig. 5.3 pg 135 From "Principles of airway management" by Finucane and Santora) Temporo-mandibular joint in closed (a) and open (b) positions. Note the forward sliding and rotation of the mandibular condyle.

The mechanics of the hyoid bone are uniquely different in patients with difficult airways. This was demonstrated in a study where lateral radiography was performed during laryngoscopy in patients with a history of failed tracheal intubation¹³. In these patients the blade tip failed to make contact with the hyoid and instead, the tongue was compressed into a pear shape. This pear-shaped deformity of the tongue pressed down the epiglottis and forced the hyoid to tilt in the opposite direction, with resultant downward folding of the epiglottis onto the posterior pharyngeal wall. This mechanism was confirmed in a subsequent mathematical modeling of osseous factors in difficult intubation¹⁴. The net effect of this scenario is a persistent epiglottic view on laryngoscopy, because the effective submental volume is critically smaller than the minimum volume displacement of tongue needed to optimally position the laryngoscope tip. Straight laryngoscope blades with smaller displacement volumes than the curved blade offer better laryngeal views based on this mechanistic explanation. The same factors come into play with significant upper incisor overbite, where the effect of a relatively anterior maxilla mimics the effect of a recessed mandible.

Mandibular Subluxation

The process of jaw-thrust causes the mandible to slide forward out of the mandibular socket, resulting in the forward displacement of the tongue and attached submental tissues (Figure 2.6). Disease states associated with a reduction in this mobility have been shown

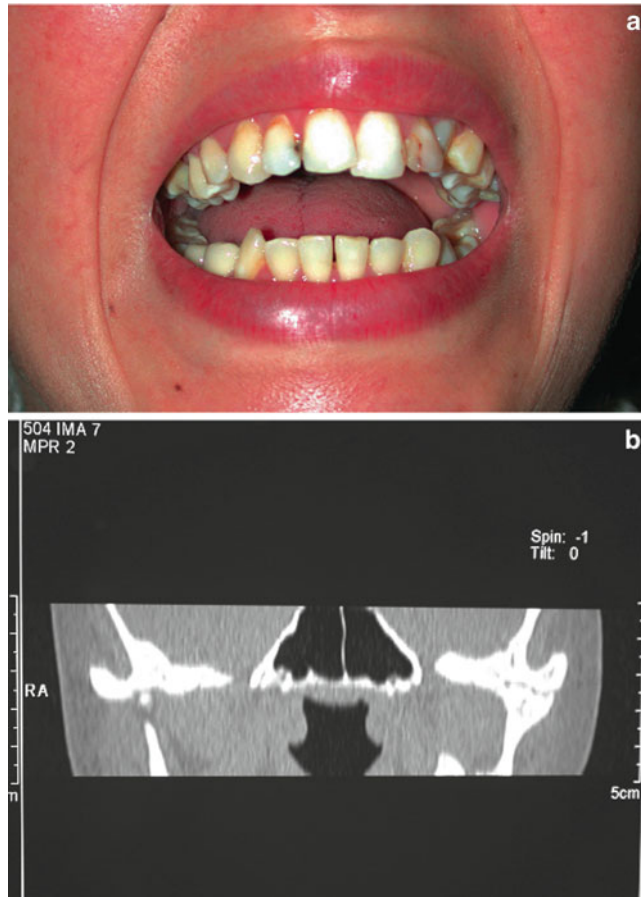


Figure 2.7. (Figs. 3.4.6 (a and b) pg 133 From "Diagnosis in Otorhinolaryngology" by Matin Onerci) Impact of diseased temporomandibular joint on mouth opening. Here *left sided* TMJ ankylosis seen on the coronal CT causes severe trismus and impossible laryngoscopy.

to be associated with difficult mask ventilation and tracheal intubation (Figure 2.7). This component of the laryngoscopic visualization vector has been historically underappreciated and understudied.

Factors Affecting Laryngeal Structures

Successful tracheal intubation is also dependent on the size of the glottic opening and subglottic structures. Fixed or dynamic abnormalities of the laryngeal structures prevent successful tracheal intubation, even in the presence of optimal laryngoscope vector visualization. Several acute and chronic conditions affect laryngeal, subglottic, and tracheal caliber. These conditions typically are associated with clinical signs such as stridor and increasing levels of distress with increasing degrees of airway narrowing.

Anatomy and Physiology of the Compromised and Critical Airway

One way to describe airway narrowing is as follows: occult airway narrowing, stable critically narrowed airway, and compromised airway. Both the latter conditions are associated with a significant risk of difficult mask ventilation, failed tracheal intubation, and the eventual need for surgical airway. Subclinical airway narrowing refers to occult diseases affecting airway caliber with no accompanying signs or symptoms. There is no way to identify these patients prior to laryngoscopy using standard airway physical exam elements. A high index

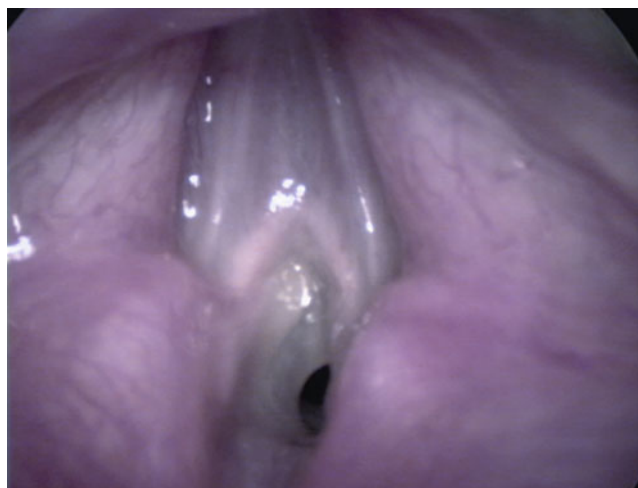


Figure 2.8. (Figs. 3.5.3 pg 135 From "Diagnosis in Otorhinolaryngology" by Matin Onerci) Laryngeal web almost completely occluding the airway. As a rule, presence of hoarseness, stridor, or respiratory distress should alert anesthesiologists to the need for rapid airway management. Such airway pathology requires a great deal of skill as repeated manipulation of the airway could convert a stable airway narrowing to a compromised airway situation.

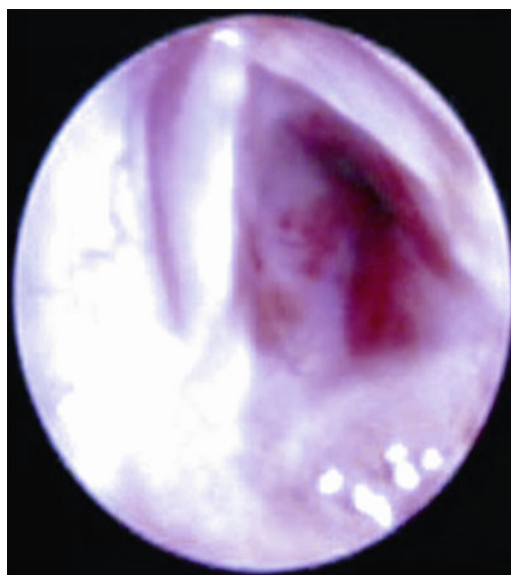


Figure 2.9. (Fig. 3.5.4 pg 135; From "Diagnosis in Otorhinolaryngology" by Matin Onerci) Subglottic hemangiomas are the most common congenital tumors causing stridor. They are generally asymptomatic at birth and may become symptomatic later in life.

of suspicion should be used in certain syndromes and disease conditions that predispose to airway narrowing such as thyroid or anterior mediastinal masses. The stable critically narrowed airway refers to the presence of stridor in the absence of respiratory failure or hypoxia. The implication here is that there is sufficient time to assess the airway thoroughly and plan for successful tracheal intubation, with contingency plans in the event the primary technique fails. However, the margin for error in this class is significantly lower than the subclinical airway narrowing group. The compromised airway refers to stridor in the presence of accompanying respiratory distress or hypoxia. The presence of stridor in an acute setting should alert the practitioner to the presence of a difficult airway, with high likelihood of rapid progression to acute respiratory compromise (Figures 2.8, 2.9, and 2.10).



Figure 2.10. (Fig. 3.5.11 pg 136 From "Diagnosis in Otorhinolaryngology" by Matin Onerci) Juvenile laryngeal papillomatosis is the most common benign tumor of the larynx. Patients with this diagnosis often present with increasing degree of stridor and they should be managed with caution.

The upper airway caliber has a great impact on work of breathing as defined by the gas flow equation (for laminar flow ³):

$$\text{Flow} \propto \frac{\text{Radius}^4 \times \text{Pressure differential across obstruction}}{\text{Viscosity of inspired air} \times \text{length of upper airway}}$$

Two important clinical implications exist for this equation. Flow is proportional to the fourth power of the radius measured at the narrowest point of the airway. As a result of this fourth power, when the airway caliber is doubled, the flow increases by 16 times and more importantly, when the airway caliber is halved, the flow decreases by 16 times. Thus the pressure differential needed to maintain adequate airflow in the presence of airway narrowing is significantly greater, causing a huge burden on the respiratory muscles. Often, in the presence of chronic airway narrowing, compensatory mechanisms develop resulting in an altered pattern of ventilation with minimum acceptable utilization of respiratory muscle strength. However, this scenario is altered in the presence of acute decompensation. Stridor is associated with turbulent flow³, where the influence of reduced airway caliber on flow and work of breathing is further exaggerated compared to laminar flow. Turbulent flows need significantly greater pressure differential and increased respiratory effort to achieve satisfactory flow rates. As a result, this is associated with significantly reduced time to secure the airway, introducing an additional time constraint to the difficult airway management and increasing the need for expert airway management.

Clinical Assessment of the Airway

Clinical prediction of the difficult airway follows detailed review of pertinent history, general physical examination, and specific airway-related assessment. The clinical conditions associated with difficult airway can be classified loosely into congenital diseases, traumatic conditions, systemic diseases, airway tumors, and upper airway infections.

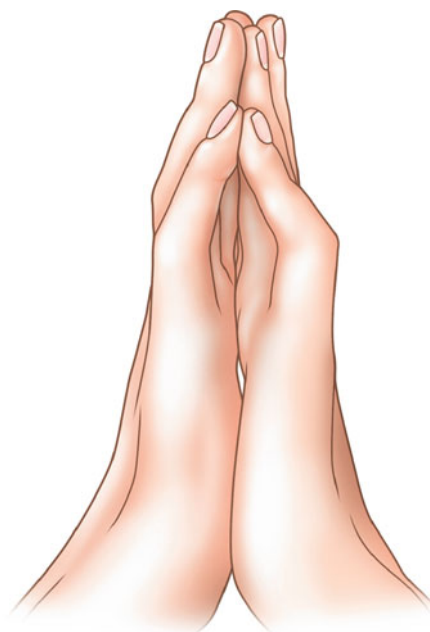


Figure 2.11. (Fig. 5.1 pg 132 From "Principles of airway management" by Finucane and Santora) Prayer sign—inability to oppose palms due to progressive stiffening of the joints caused by diabetes mellitus. It is estimated that about a third of long-term early onset diabetics develop stiff joint syndrome, and its presence is an extremely accurate predictor of difficult airway.

Systemic Conditions

Pregnancy

Pregnancy is associated with increased risk of difficult mask ventilation, difficult intubation, and rapid progression of hypoxemia¹⁵. Recent research shows that labor is associated with dynamic increases in Mallampati class, secondary to upper airway edema that settles over time after labor¹⁶. Rocke and colleagues⁹ identified difficult intubation in 7.9 % of pregnant patients. Associated features for difficult intubation in pregnancy are pre/eclampsia, short neck, obesity, absent or excessively large maxillary incisors, and receding mandible.

Diabetes Mellitus

The association between diabetes and difficult airway relates to the glycosylation of joints and development of stiff joint syndrome¹⁷. The primary joints affected in patients with difficult laryngoscopy are the TMJ and the cervical spine, presenting limitation of mouth opening, mandibular subluxation, and head extension. The two tests described to identify stiff joint syndrome are the palm print test¹⁸ and the prayer sign¹⁹. The former tests the ability to make full contact with a flat surface, and increasing risk of difficult airway is seen with decreasing surface contact. The prayer sign refers to the ability to place the palms together “in prayer,” with diabetic stiff joint patients having progressive difficulty to achieve this (Figure 2.11). It is estimated that about a third of long-term early onset diabetics develop stiff joint syndrome²⁰, and its presence is an extremely accurate predictor of difficult airway¹⁹.

Rheumatoid Arthritis

This is one of the more common autoimmune conditions with unique implications for airway management. Severe joint involvement of the TMJ, cervical spine, and extremities

directly impacts access to the airway, visualization vector, and mandibular subluxation. The more important implication is cervical spine instability. Symptoms suggestive of nerve root or spinal cord compression, and limitation of neck movement should alert the practitioner to the risk of permanent neurological injury with direct laryngoscopy and intubation, although this is an extremely rarely reported outcome. Hoarseness, dysphonia, or stridor could suggest significant laryngeal distortion from joint involvement^{21,22}, and awake flexible bronchoscopic techniques or a surgical airway may be preferable in these cases.

Trauma

Trauma to the head and neck impacts the airway²³ typically due to direct injury with attendant airway distortion, bleeding, trismus, and airway edema. Stridor, inability to speak, laryngeal cartilage fracture, or neck emphysema suggests airway disruption and signals the emergent need for airway management by practitioners experienced in bronchoscopy and tracheotomy. Blind endotracheal intubation is likely to produce a catastrophic loss of airway with high risk of patient death in this clinical scenario. Injury precautions for the cervical spine are a mechanical impediment to achieving a satisfactory laryngoscopic visualization vector and may impair mouth opening. In the presence of known cervical spine injury, the force of laryngoscopy can worsen compression of the spinal cord and affect neurological outcome, by causing anterior bowing⁸ and displacement of the mid-lower cervical vertebrae^{24,25}.

Burns

Acute head and neck burns, exposure to explosions or fires in enclosed spaces, and airway burns are associated with difficult airway²⁶. The mechanisms include airway edema secondary to thermal injury and tracheobronchial disruption from shock waves related to explosions. Difficult intubation is seen in patients with significant tongue edema and submental edema. Presence of hoarse voice, oral burns, singed nasal hairs, noncompliant submental tissues, and facial swelling should alert the practitioner to potentially difficult intubation, and emergent flexible bronchoscopic intubation should be performed where feasible²⁷. Chronic anterior head and neck scarring from thermal and chemical burns produces extreme difficulty with the airway, through limitation in neck mobility and mouth opening. Chemical ingestion causes significant distortion of the upper airway, making identification of the glottic inlet impossible using conventional laryngoscopy in many patients, with false passages and grossly narrowed airway caliber²⁸.

Airway Tumors

Tumors developing from and close to the upper and lower airway present independent challenges to airway management²⁹. Tumors within the airway lumen include oral cancers, laryngeal tumors, and bronchogenic carcinoma. Oral cancers can increase tongue volume or reduce pharyngeal and submental compliance, or affect mouth opening³⁰ (Figure 2.12). Laryngeal tumors predispose to sudden loss of airway and often present physical impediments to passage of endotracheal tubes³¹. Bronchogenic carcinoma produces significant airway narrowing and distortion. All these conditions are easily traumatized, causing bleeding into the airway.

Extrathoracic tumors that lie outside the lumen of the airway influence airway management in one of several ways^{32–34}. Large goiters produce significant physical impediment to laryngoscopy and are associated with airway compression secondary to erosion of tracheal rings³⁵ (Figure 2.13). Anaplastic thyroid carcinoma has been known to erode the tracheal wall and cause airway collapse, distortion, or bleeding though this is very uncommon³⁶. Thyroid masses are a physical impediment to successful surgical airway access. Life-threatening hemorrhage has followed thyroid injury during attempted tracheotomy.



Figure 2.12. (Figs. 3.9.27 -a and b- pg 157; From "Diagnosis in Otorhinolaryngology" by Matin Onerci) Squamous cell carcinoma of the tongue causes swelling and induration, thereby reducing tongue and submental tissue compliance. Inability to compress the tongue into the submental space results in difficult laryngoscopy.



Figure 2.13. (Fig. 3.10.13- pg 167; From "Diagnosis in Otorhinolaryngology" by Matin Onerci) Anaplastic thyroid carcinoma. Long-standing goiters cause distortion of the trachea and tracheomalacia. Symptoms of airway obstruction in supine position should increase suspicion of tracheomalacia.

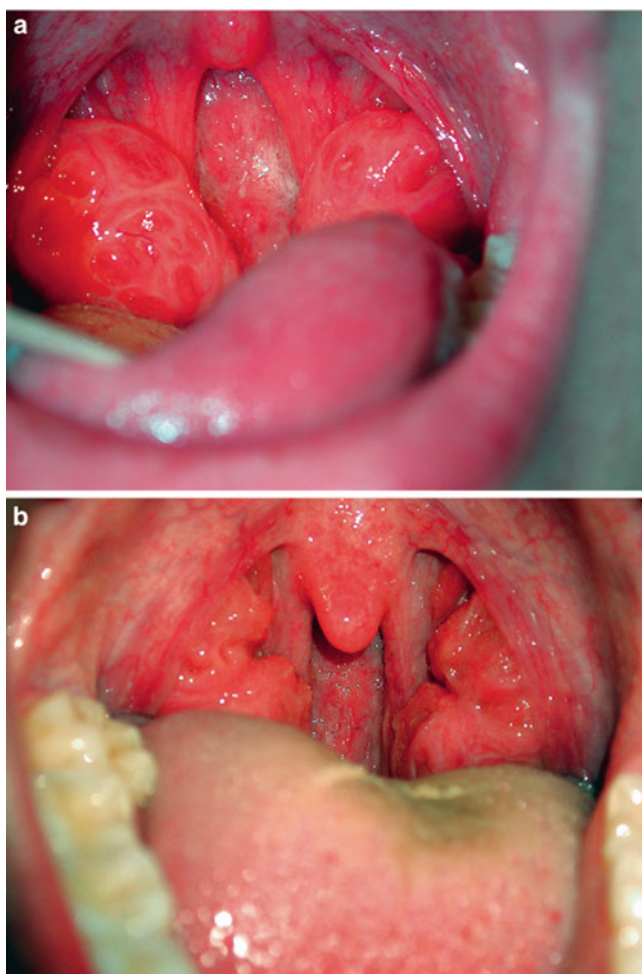


Figure 2.14. (3.1.6-a pg 124; From "Diagnosis in Otorhinolaryngology" by Matin Onerci) Chronic tonsillitis predisposes to tonsillar abscess formation. Such upper airway infections have the potential to result in rapid loss of airway under anesthesia.

Intrathoracic tumors related to the airway present several problems. Patients with these tumors can exhibit positional or dynamic airway obstruction. Superior vena cava syndrome can significantly impact the airway management³⁷. Superior vena cava syndrome is associated with head and neck plethora, increased airway edema, and a risk of airway collapse. The loss of airway tone related to loss of consciousness in these patients is due to intrathoracic airway compression. Tracheal intubation may not be adequate to ventilate the patient due to the loss of airway patency distal to the endotracheal tube.

Upper Airway Infections

Infections related to the tonsils, teeth, epiglottis, and retropharyngeal tissues cause distortion of airway, reduced submental compliance, and increase risk of airway soiling due to accidental abscess rupture with instrumentation. Quincke or tonsillar abscesses are rare but significant causes of airway loss under sedation or anesthesia^{38, 39} (Figure 2.14). Ludwig's angina refers to the multiplane infection of the submental tissues usually caused by molar root infection, resulting in brawny induration (Figure 2.15). Retropharyngeal abscess causes difficulty swallowing and typically presents with drooling, odynophagia, and significant airway narrowing secondary to posterior pharyngeal wall edema and abscess. All these conditions have significant risks of failed mask ventilation and difficult or



Figure 2.15. (3.10.12 - pg 166; From "Diagnosis in Otorhinolaryngology" by Martin Onerci) Deep neck space infection, commonly related to dental sepsis. The loss of submental tissue compliance coupled with increase in peri-airway soft tissue results in difficult airway. It is essential that a clear airway management plan and back-up plans are made in conjunction with ENT surgeons.

impossible intubation. Cautious flexible bronchoscopic or surgical airway access should be performed by experienced practitioners. While recognition of these conditions should prompt a high-index of suspicion that airway difficulties are highly probable, lingual tonsillar hyperplasia may be entirely occult and associated with difficult mask ventilation and laryngoscopic intubation⁴⁰.

Specific Airway Assessment

In this section we will look at some of the commonly used upper airway measurements and qualitative assessments.

Measures of Tongue-Pharyngeal Volume Disproportion

Modified Mallampati Test

The modified Mallampati classification⁴¹ correlates tongue size to pharyngeal size. This test is performed with the patient in the sitting position, head in a neutral position, the mouth wide open, and the tongue protruding to its maximum. Patient should not be actively encouraged to phonate as it can result in contraction and elevation of the soft palate leading to a marked improvement in the Mallampati class. Classification is assigned according to the extent the base of tongue masks the visibility of pharyngeal structures (Figure 2.16):

- Class I: Visualization of soft palate and uvula
- Class II: Visualization of the soft palate and tonsillar pillars
- Class III: Visualization of only the soft palate
- Class IV: Visualization of only hard palate (this class is the additional modification by Samsoon to the original Mallampati classification⁴²)

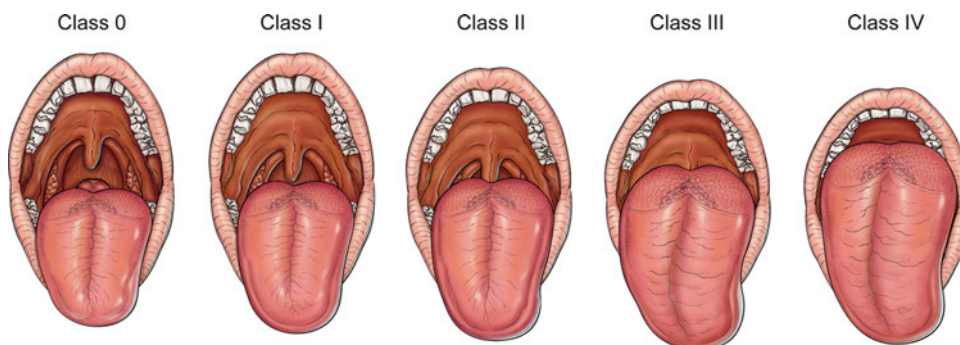


Figure 2.16. Modified Mallampati test. From Finucane, B.T., Tsui, B.C.H., and Santora, A.H., *Principles of Airway Management*, 4th ed., New York: Springer, 2010.

Extended Mallampati Score

The predictive value of the modified Mallampati class is improved when the patient's craniocervical junction is extended rather than neutral (Extended Mallampati Score)^{43,44}. Compared to the modified Mallampati class and other tests, an extended Mallampati score class of 3 or 4 and a diagnosis of diabetes mellitus were the only statistically significant predictors of difficult laryngoscopy in the morbidly obese⁴³.

Measures of Laryngoscopic Visualization Vector

Neck Mobility

Head extension is measured or estimated with the patient sitting from the neutral head position. The examiner estimates the angle traversed by the occlusal surface of upper teeth with maximal head extension⁵. It is important to note that the movement of interest is at the head level, and shoulder movement should be discouraged as this will mask underlying limitation of head extension. Measurement can be by simple visual estimate or more accurately with a goniometer. Significant limitation defined as $\leq 20^\circ$ movement from the neutral position or $< 80^\circ$ of maximum extension from the fully flexed position.

Submental Space: Thyromental Distance

Thyromental distance is defined as the distance from the mentum to the thyroid notch with the patient's neck is fully extended. Reduced thyromental distance is < 3 finger breadths or < 6 cm in adults. Alternatively, the mentohyoid distance (mandibular length from mentum to hyoid with patient in full head extension) has been used to quantify the submental space with < 4 cm suggesting reduced distance.

Mouth Opening

Reduced mouth opening is measured as less than 4 cm or two adult finger breadths between the incisors.

Mandibular Protrusion

This test is performed by asking the patient to protrude the lower jaw maximally forward to bite the upper lip⁴⁵. The inability to achieve a more forward position of the lower incisors in relation to the upper incisors is a significant finding suggestive of significant maxillary overbite, recessed mandible, or poor subluxation at the TMJ.

Other Airway-Related Tests

Neck Circumference

Neck circumference >43 cm at the laryngeal cartilage level has been described for prediction of difficult intubation⁴⁶. However, qualitatively assessed thick neck is sufficient to ascribe increased risk of airway closure during mask ventilation^{10,11}. No difference has been described between muscular necks and excessive fat deposition in the neck region as both increase the weight on the upper airway predisposing to loss of patency in sleep and unconsciousness.

Beard

The presence of a beard increases the risk of difficult mask ventilation^{10,11}. In addition to the fact that this is a male phenomenon, the increased levels of testosterone predispose to upper airway collapse and OSA. Beards impede a quality seal of the face mask and may conceal a retrognathic mandible resulting in an unanticipated difficult intubation.

Clinical Prediction of the Difficult Airway

Clinical Prediction of Difficult Intubation

Difficult tracheal intubation is a relatively rare event with an incidence ranging from 1 to 3 % due to the varying definitions used^{11,47} though the inability to visualize the larynx by direct laryngoscopy may in fact be encountered in nearly 6 % of adults⁴⁸. As a result, clinical prediction models for difficult intubation suffer from lack of positive predictive value. Most clinical prediction models described in the literature describe difficult laryngoscopy based on Cormack and Lehane⁴⁹ laryngoscopy views. This is technically different from difficult intubation, although grade III and IV views are associated with difficult intubation. In practice, difficulty in maneuvering the endotracheal tube in place is seen in some cases with grade II views. The presence of risk factors for difficult tracheal intubation and mask ventilation should alert the practitioner to the potential need for flexible endoscopic techniques to secure the airway or surgical airway access.

El-Ganzouri Multivariable Prediction of Difficult Laryngoscopy

El-Ganzouri and colleagues⁵⁰ identified seven independent predictors of difficult intubation namely reduced mouth opening, reduced thyromental distance, Mallampati class 3 (using the unmodified Mallampati scale), reduced neck mobility, inability to prognath, body weight >110 kg, and history of difficult tracheal intubation. The sensitivity was extremely low for individual test components. In other words, there were significantly greater numbers of false negatives compared to true positives. Thus each component had limited or no value individually for prediction of difficult airway. Combining two or more predictors in a simplified airway risk index reduced the false negative rate significantly, and presence of four or more risk factors reduced the false positive rate to acceptable values. The small numbers of patients with difficult intubation and difficult mask ventilation potentially confound the robustness of the simplified airway risk index.

Rose and Cohen Clinical Predictors

The authors found that univariate risk factors for difficult tracheal intubation were male gender, age from 40 to 59 years, and obesity⁵¹. Clinical characteristics associated with

difficult intubation by direct laryngoscopy were decreased mouth opening (relative risk, 10.3); shortened thyromental distance (relative risk, 9.7); poor visualization of the hypopharynx (relative risk, 4.5); and limited neck extension (relative risk, 3.2). Presence of any two of these characteristics (relative risk, 7.6), and more than two of these characteristics (relative risk, 9.4) increased the risk of difficult tracheal intubation. No summary measures of accuracy were described for the prediction of difficult intubation by direct laryngoscopy based on these risk factors.

Clinical Prediction of Difficult Mask Ventilation

Difficult Mask Ventilation

A range of definitions of difficult mask ventilation have been used in the literature, resulting in an incidence ranging from 1.5 to 5 %. Several studies have noted that obesity, presence of a beard, and advanced age are independent predictors of difficult mask ventilation. Although initial work by Langeron et al. identified edentulous dentition as an independent predictor of difficult mask ventilation, a more strict definition of difficult mask ventilation did not confirm the lack of teeth as a predictor. Of note, limited mandibular subluxation identified by an abnormal jaw protrusion test was identified as an important predictor of difficult mask ventilation in a study of more than 15,000 mask ventilation attempts.

Impossible Mask Ventilation

Impossible mask ventilation defined as the inability to exchange air during bag-mask ventilation attempts despite multiple providers, airway adjuvants, or neuromuscular blockade is a very rare event, with an estimated incidence of 0.15 %¹¹. Neck radiation changes, male gender, sleep apnea, modified Mallampati class III or IV, and presence of a beard were identified as independent predictors of impossible mask ventilation. The caveats to this study include the presence of an active decision process to perform awake fiberoptic intubation in a significant number of patients, and as such the results represent the prediction of unanticipated impossible mask ventilation.

Difficult Mask Ventilation Combined with Difficult Intubation

The prediction of difficult mask ventilation or difficult direct laryngoscopy may be dismissed by some as an academic activity given the low positive predictive value of most indices. More importantly, predicting either airway outcome—mask ventilation or intubation—as a stand-alone entity does not reflect the primary goal of airway management, namely establishing a sustainable means of oxygenation and ventilation. Ostensibly, some patients that are difficult to intubate may be easily mask ventilated while those that are difficult to mask ventilate may be easily intubated. Clinical factors predictive of difficult mask ventilation combined with difficult intubation should be the foundation of an outcome-driven airway exam. The largest published series of difficult mask ventilation combined with difficult intubation events identified an incidence of 0.37 %. Limited jaw protrusion, obese neck anatomy, sleep apnea, snoring, and obesity were statistically significant predictors in a multivariate model.

Clinical Prediction of Need for Awake Surgical Airway

No studies have been performed to predict the need for or difficulty performing an awake surgical airway. Local practices affect rates of awake surgical airway, but by all published evidence, this is an extremely uncommon method of securing the airway in the absence of imminent airway obstruction. Gillespie and colleagues reviewed the indications and

outcomes of emergent awake tracheotomy and cricothyroidotomy with failed mask ventilation or tracheal intubation⁵². The underlying medical conditions that resulted in the need for emergency airway management included cardiac or pulmonary arrest in 13 patients (37 %), head and neck cancer in 12 patients (34 %), and trauma in 10 patients (29 %). The following causes were identified: upper airway edema (40 %), difficult anatomy with inability to visualize the vocal cords (23 %), obstructing mass lesion of the oropharynx or larynx (20 %), or maxillofacial or neck trauma (17 %). In another study⁵³, the majority of patients presented with hoarseness, dyspnea, and stridor, underlining the importance of these findings in the emergent setting. Altman and colleagues⁵⁴ reviewed awake tracheotomies in another study and identified dyspnea in 50 %, dysphagia (75 %), odynophagia (22 %), hoarseness or voice change (56 %), and stridor (43 %) as the common presenting features in patients. In this study, 80 % of patients had aero-digestive cancer or neck tumors with direct compression of the airway.

Summary

Clinical screening for the difficult airway can be achieved by performing a series of simple tests that assess the tongue-pharyngeal volume disproportion, access to the airway, laryngoscopic visualization vector, and laryngeal anatomy. Attention to detail is critical to preventing false negative, and preempting a clinical situation resulting in hypoxemia should be the goal of airway management in the elective, urgent, and emergent scenarios. As a dictum in all cases, airway instrumentation should be preceded by primary and backup plans. The presence of two or more risk factors for difficult mask ventilation or difficult intubation should alert the practitioner to consider awake (endoscopic) intubation of the trachea. Finally, safe airway management especially in the compromised airway requires considerable expertise, and sufficient efforts to ensure that trained staff and equipment are available at all times is essential to preventing morbidity and mortality related to inability to secure the airway.

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