Preoperative Airway Assessment

3

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Key Messages

1. Pre-operative or pre-procedure assessment of the airway is mandatory, even in emergency as it directly contributes to patient safety.
2. History, physical examination, review of previous medical records, and investigations form the cornerstones of assessment.
3. Assessment should recognize difficult airway, help to develop a plan for management, and establish a rapport with the patient.
4. Multiple predictors of difficult airway have been described, with different sensitivity, specificity, and positive predictive values. It is impossible to identify the difficult airway in 100% patients.
5. Guidelines have been developed for assessment, various new concepts are emerging and investigations have enhanced the understanding of the airway as well as nature of difficulty.

1 Introduction

Airway complications significantly contribute to anesthesia related morbidity and mortality. The incidence of serious airway complications during general anesthesia has been found to be 1 in 22,000, ICU admissions due to airway morbidities was 1 in 29,000, and incidence of brain damage/deaths was 1 in 180,000 [1]. Inadequate assessment, failure to recognize the predictors of difficult airway, both from anatomical and physiological perspective, and failure to formulate appropriate plan even when difficulty is anticipated, are among the different contributory factors for airway related complications.

Airway management is a complex dynamic interaction between patient and surgical related factors, anesthesiologist, airway devices, and environmental factors. Foundation for a cohesive plan to effectively manage the entire spectrum of airway management is a detailed and careful assessment and documentation of the findings. For better understanding, important definitions and descriptions are also added here.

2 Normal, Compromised, and Obstructed Airway

A normal airway can be described as having these features: a proportionate facial contour in terms of bone and soft tissues. A temporomandibular joint (TMJ) movement which allows insinuation of a finger, sufficient mouth opening (≥2 fingers), and adequate neck extension (Thyromental distance more than three fingers)

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these three measurements are referred to as 1-2-3 rule. The teeth are not crooked, lose or absent and no dentures are present. The tongue is normal sized (Mallampati class 1 and 2). Neck is proportionate in size, shape, length, and the range of movement is acceptable (flexion and extension). The submandibular space is free of swelling/infection and has normal compliance (easily compressible). The person is not obese with an unobstructed non labored breathing pattern and has adequate cardio-respiratory reserve.

A *compromised* airway is one wherein there is a potential for obstruction due to the presence of internal or external pathology. Any further insult to such an airway can convert it into an obstructed airway. A classic example is a patient with huge thyroid swelling with a retrosternal extension. A compromised airway can be anatomically normal or can have features of difficult airway. It can be converted into an obstructed airway with any further insult.

An *obstructed* airway is where the airway lumen is partially blocked, at any level due to external or internal pathology/ anatomical or physiological causes resulting in difficulty/inability to breathe or ventilate.

3 Definitions of Difficult Airway

The difficult airway (DA) has been defined by the American Society of Anesthesiologists (ASA) Practice Guidelines for Management of the Difficult Airway as "a clinical situation in which a conventionally trained anesthesiologist experiences difficulty with face mask ventilation of the upper airway, difficulty with tracheal intubation, or both" [2]. The Canadian Airway Focus Group (CAFG) advocates airway assessment at multiple levels and in its definition of DA it has added difficult video laryngoscopy, supraglottic airway device (SAD) use, and surgical airway [3]. The Italian Recommendations for Adult DA (IRDA) in addition to the above focuses on the type of equipment used in their definition of DA [4].

3.1 Difficult Mask Ventilation

Difficult mask ventilation is defined as "it is not possible for the anesthesiologist to provide adequate ventilation because of one or more of the following problems: inadequate mask or supraglottic airway device seal, excessive gas leak, or excessive resistance to the ingress or egress of gas" [2]. The IRDA and CAFG added the inclusion of manipulations to improve mask ventilation like adjustments of the head and neck, use of adjuvants (e.g., an oral or nasal airway), use of exaggerated jaw lift, two/three-handed face mask application, assistance of a second operator, and switching of face mask for any extraglottic device or intubation [3, 4]. Difficult mask ventilation occurred in 0.66% of patients in the Danish Anaesthesia Database and was unanticipated in 94% [5].

3.2 Difficult Supraglottic Airway Device Placement

Difficult SAD placement is defined as "SAD placement requires multiple attempts, in the presence or absence of tracheal pathology" [2]. The CAFG definition added failure of oxygenation and ventilation with an SAD, achieving a seal, or ventilating the lungs in addition to difficulties in accessing the patient's mouth or hypopharynx thus highlighting the importance of gas exchange when managing a difficult airway [3].

3.3 Difficult Laryngoscopy

Difficult laryngoscopy has been defined as "it is not possible to visualize any portion of the vocal cords after multiple attempts at conventional laryngoscopy" [2]. A shortcoming of this definition is the endpoint has not been specified and no maneuvers to improve the view have been included. The CAFG definition has included Cormack-Lehane grade 3 and 4 as difficult laryngoscopy and IRDA has added failure to visualize cards despite external manipulation [3, 4].

3.4 Difficult Tracheal Intubation and Difficult Transtracheal Surgical Airway

Tracheal intubation requiring multiple attempts, in the presence or absence of tracheal pathology is defined as difficult tracheal intubation. The CAFG definition, in addition, considers if more than one operator required, use of adjuncts such as a tracheal tube introducer and requirement of an alternative intubation device following the unsuccessful use of the primary "Plan A" device.

3.5 Difficult Surgical Airway

The difficult transtracheal surgical airway is only defined by CAFG as one that requires excess time or multiple efforts [3].

Above definitions assume that the anesthesiologist is conventionally trained and reasonably competent. Same can be assumed for non-anesthesiologist clinicians.

4 Airway Assessment Tools

Remember that a previously difficult airway can be normal in the present setting or a previously normal airway can be difficult.

4.1 History, Congenital Anomalies, and Comorbidity

A focused history on previous medical/surgical problems, allergy, last oral intake, and details of the patient's current condition including medication should be taken. Difficult/failed intubations are most common in patients aged 45–75 years. The risk for failed/difficult intubation is increased significantly in patients undergoing emergency surgery (OR 1.80), obese patients (OR 2.48), higher ASA physical status, and increased Charlson Comorbidity Index [6]. Males have been associated with a higher incidence of difficult mask ventilation [7]. If available, review of previous medical records can be invaluable. Snoring and sleep apnea is seen in patients with obstructive sleep apnea (OSA) and obesity, both of which are associated with difficult airway. History of tobacco chewing is very important as it may be associated with oral submucosal fibrosis/oropharyngeal malignancies which may restrict mouth opening interfering with airway management techniques. History of chronic systemic diseases such as diabetes mellitus, rheumatoid arthritis, ankylosing spondylitis, acromegaly, etc. should be noted (discussed in detail below). History of previous cervical spine trauma/surgeries, neck surgeries, irradiation to the head and neck should be sought for as it is associated with restricted neck extension and distortion of the airway.

Congenital Abnormalities The incidence of difficult airway is higher in children with craniofacial abnormalities compared to normal children, requiring a detailed airway assessment. Craniofacial abnormalities are due to the developmental abnormalities of the first and second arches. There are many syndromes with a constellation of systemic manifestations with associated airway anomalies (Table 3.1) [8]. Also it is difficult to remember all the manifestations of these syndromes it would be prudent for the attending anesthesiologist to educate themselves before managing such rare cases.

Diabetes mellitus, the most common endocrine disease with multisystem involvement, is associated with a higher incidence of DA [7]. Often these patients are often obese, and hypertensive increasing the difficulty of airway management and the associated physiological response. Metabolic changes in diabetes results in glycosylation of proteins and collagen accumulation periarticular structures results in changes in the connective tissue. This may lead to diabetic stiff joint syndrome (diabetic cheiroarthropathy), incidence of 8–50% in all patients with type 1 diabetes and it may also be seen in type 2 diabetes [9]. Most frequently affected joints are the small joints of the hands, but can

Table 3.1 Congenital conditions causing airway difficulty

Congenital conditions (site of difficulty)	Anatomical airway abnormalities	Anticipated difficult airway techniques
Down's syndrome (HF)	Large tongue, Facial defects	MV
Treacher Collins syndrome, Goldenhar's Syndrome (HF)	Malar and mandibular hypoplasia	MV, DL
Pierre Robin sequence (HF)	Micrognathia, glossoptosis (backwards displacement of the tongue base), airway obstruction	MV, DL
Klippel-Feil syndrome (N, O)	Short neck, restricted neck motion due to fused cervical vertebrae	MV, DL
Mucopolysaccharidosis (HF, N, O)	Large tongue, small mouth opening, narrow upper airway, and atlanto-axial instability	MV, DL

HF head and face, *N* neck, *O* other, *MV* mask ventilation, *DL* direct laryngoscopy

affect the spine as well. When atlanto-occipital joint is affected, the extension of the neck during airway management is severely restricted. The "prayer sign" and palm print test are used to identify the stiff joint syndrome. The prayer sign is based on the ability to approximate the palms and fingers of the hands due to lack of mobility of the small joints [10]. The degree of the inter-phalangeal joint involvement can be assessed by scoring the ink impression made by the palm of the dominant hand as proposed by Reissell et al. [11].

Grade 0: all phalangeal areas visible

Grade 1: deficiency in the inter-phalangeal areas of 4th and/or 5th digit

Grade2: deficiency in the inter-phalangeal areas of 2nd to 5th digit

Grade 3: only the tips of digits seen.

A defective palm print is a warning sign for difficult laryngoscopy and has been found to be the most sensitive index in predicting difficult laryngoscopy. It has been found to have a sensitivity of 76.9%, specificity 89.4%, positive and negative predictive value 71.4% and 91.3%, and accuracy 86.7%, respectively [12].

Obesity is associated with difficult airway, the risk for failed/difficult intubation is significantly higher in obese patients (OR 2.48) and the incidence of difficult intubation is twice more frequent in ICU than in the OT (16.3% vs. 8.2%, $P <$ 0.01) [6, 13]. There is deposition of adipose tissue in the pharyngeal walls which results in upper airway collapse even with spontaneous ventilation, causing difficulty in mask ventilation and/or intubation. Symptoms and signs of cardiac failure and OSA should be sought actively. BMI and neck circumference have a strong association with difficult airway in obese patients and are inversely related to safe apnea time [14]. Among these neck circumference more than 43 cm in males and 40 cm in females have been found to be the single most important predictor of difficult airway in obese and should be used as a screening tool [15]. The risk factors for difficult intubation are a Mallampati score III/IV, OSA, and reduced mobility of cervical spine, while limited mouth opening, severe hypoxemia, and coma risk factors for difficult intubation only in ICU [13].

Ankylosing spondylitis (AS) is an autoimmune seronegative spondyloarthropathy, characterized by painful chronic inflammatory arthritis with intermittent of flare ups. It primarily affects the spine and sacroiliac joints, eventually causes fusion and rigidity of the spine (bamboo spine). Fixed cervical flexion result in chin on chest deformity [16]. AS is associated with temporomandibular joint involvement resulting in limited mouth opening in 10% of patients, and in long standing disease this increases to 30–40%. Arthritis of the cricoarytenoid joint is seen very rarely, which may cause to hoarseness of voice, vocal cord fixation, and breathlessness. Preexisting neurological deficits should be documented during the pre-anesthetic evaluation. Neck movements in extension and flexion should be assessed and confirmed by radiological screening. There is a high risk of neurological injury with excessive neck extension in patients with chronic cervical AS. Neck extension during airway manipulation may result in vertebrobasilar insufficiency due to bony encroachment on the vertebral artery, injuries to the cervical spine and spinal cord due to dislocation of C6 vertebra may occur and rarely result in quadriparesis [16, 17].

Rheumatoid arthritis (RA) is chronic progressive autoimmune inflammatory disorder that primarily affects the small joints of the hands and feet. Cervical spine involvement has been reported in 45% of RA patients, the findings include vertebral endplate/spinous process erosions, osteoporosis, fusion, and the most dangerous lesions subluxations [18]. Anterior atlanto-axial subluxation is the most common type, with a prevalence of 24% and the prevalence of cervical myelopathy in RA patients is 5% [18]. Acute subluxation may result in spinal cord compression and/or compression of the vertebral arteries leading to quadriparesis/sudden death during airway instrumentation. Care should be taken to look for and document preexisting neurological deficits. Larynx may be affected in approximately 80% of patients, the most serious complication being cricoarytenoid dysfunction. Preoperative indirect laryngoscopic assessment may be needed in some patients [19]. The temporomandibular joint (TMJ) may be involved, resulting in limitation of mouth opening.

In pregnancy, the overall incidence of failed tracheal intubation is 2.6 (95% CI 2.0–3.2) per 1000 general anesthetics. There is a high incidence of death associated with a failed airway 2.3 (95% CI 0.3–8.2) per 100,000 general anesthetics for cesarean section (one death per 90 failed intubations) [20]. Although advanced planning is often not possible among parturients, chronic conditions involving the airway should be identified during airway assessment, which can be scheduled during the antenatal check up in the last trimester. The independent predictors of failed tracheal intubation are older parturient, higher BMI, and those with a recorded Mallampati score of >1 [21]. Short neck, protruding maxillary incisors, and receding mandible have been found to be associated with difficult intubation [22]. There is a 34% increase in the number of the modified Mallampati class 4 at 38 weeks of gestation compared to 12 weeks of gestation due to fluid retention [23]. There are also significant reductions in oral volume, pharyngeal area and volume after labor and delivery [24].

Acromegaly is a rare disorder due to excessive production of growth hormones. The incidence of difficult airway in acromegalics is approximately four to five times higher than the normal population. There is hypertrophy of soft tissues in the airway, prognathism, enlarged tongue, large epiglottis, restricted head and neck mobility. The prevalence of Mallampati grade IV is 4.5–10% and of the Mallampati classes III and IV together is 27.2–61% [25, 26]. Preoperative Mallampati scores of 3 and 4 in acromegalics were of value in predicting difficult laryngoscopy [26]. The thyromental distance is increased in patients with a long duration of disease, but this increased thyromental distance is not associated with difficult laryngoscopy [25].

Patients and relatives should be enquired about any serious problems, including airway difficulties, occurring during previous anesthetics. History of previous difficulty in airway management is a very good predictor of future airway problems.

4.2 Clinical Examination

A detailed general physical examination should be done for all patients. The mental state, apprehension level, and comprehension of patients should be assessed as cooperation is very important for awake techniques.

The airway should be examined thoroughly and features predictive of difficult of airway should identified. Non-assuring features in the *Head and Face (HF)* area are asymmetry of face, nose (deformed/blocked/narrow) micro or retrognathia, acromegaly or thick facial features**,** beard, restricted TMJ movement, restricted mouth opening, inability to protrude jaw, edentulous, irregular dentition, protruding teeth, cleft lip/palate,

Table 3.2 Acquired conditions causing airway difficulty

Conditions (site of difficulty)	Anatomical airway abnormalities	Anticipated difficult airway techniques
Trauma, burns (HF, N, C)	Distorted/edematous airway	MV, DL, FOB
Diabetes mellitus (N, C)	Stiff joint syndrome, involvement of the atlanto-occipital joint	MV, DL
Obesity (HF, N, O, C)	Small mouth opening, large tongue, short thick neck, decreased neck motility, large breasts, obstructive sleep apnea	MV, DL insertion
Ankylosing spondylitis (N, O)	Ankylosis of the cervical spine and rarely temporomandibular joint	MV, DL
Rheumatoid arthritis (O)	Atlanto-axial subluxation, temporomandibular and Cricoarytenoid dysfunction	DL
Infection/abscess/Ludwigs angina (HF, N, O, C)	Edema and airway distortion	MV, DL, FOB
Acromegaly (HF)	Large tongue, prognathism	MV

HF head and face, *N* neck, *O* other, *MV* mask ventilation, *DL* direct laryngoscopy, *FOB* fiberoptic bronchoscopy

high arched palate, large tongue (macroglossia) or glossoptosis and trauma to the airway. A beard may hide deformities and scars of previous surgeries on the head and neck. Even without scars, a long beard increases difficulty of mask ventilation. An important step in airway examination is viewing the lateral/profile look of the head which will help in identifying micrognathia/retracted mandible that might not be recognized with only a frontal examination.

The non-reassuring features in the *Neck (N)* are reduced thyromental distance (<3 fingers), sternomental distance (<12.5 cm), short neck, thick neck (circumference more than 43 cm), swelling (thyroid, especially retrosternal), neck contracture, infections, submandibular abscess, and any obstruction of airway.

Other *(O)* non-reassuring features in systemic examination are vertebral anomalies (syndromes, ankylosis spondylitis, rheumatoid arthritis), systemic diseases (Diabetes mellitus), connective tissue disorders, obesity, and head and neck trauma (Table 3.2). Lastly, there may be *complicating physiological factors (C)* suggestive of a non-reassuring airway such as a low room air saturation/hypoxemia, breathlessness at rest, ASA 3 and 4, raised ICP, hypotension, severe metabolic acidosis and right ventricular failure [27]. A non-mnemonic, non-scoring-based “line of sight” (LOS) method of focused airway assessment has been described recently [28].

5 Airway Assessment Tests

5.1 Mallampati Test

> Affected by mouth size, opening and tongue size. Used to predict difficult laryngoscopy and intubation.

It is a simple and the most popular airway test, it was initially proposed in obstetric patients by Dr. Seshagiri Rao Mallampati, an Indian origin anesthesiologist [29]. His original descriptions had only three grades. The test was later modified by Samsoon and Young who added the fourth grade (Fig. 3.1) [30]. It is based on the hypothesis that the large volume of tongue relative to the volume of the oropharynx will hamper laryngoscopic view. The test is conducted with patient in sitting position, head in neutral position, and the mouth wide open with the tongue fully protruding and without phonating.

Mallampati *class 0* was described by Erzi T where the tip of epiglottis is visualized, and it is generally associated with a Lehane and Cormack grade I view at laryngoscopy [31]. However, in a few reports it was associated with an anterior larynx thus a poor view on laryngoscopy and difficult mask ventilation. This was attributed to a large epiglottis [32].

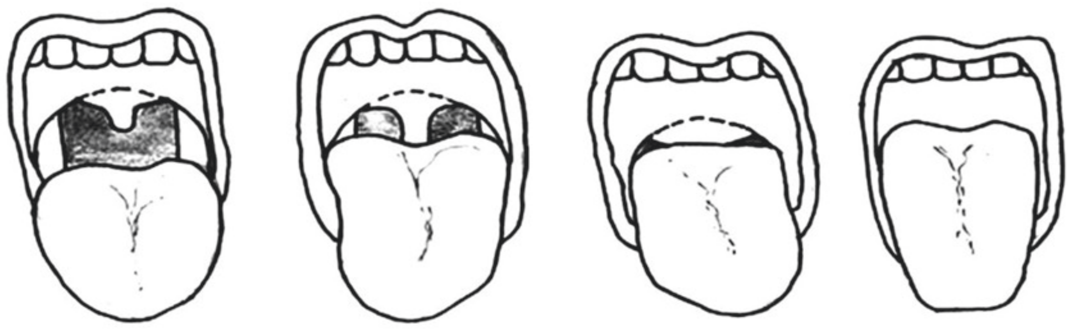

Fig. 3.1 Mallampati grades (see text for description). Class I: soft palate, fauces, entire uvula, anterior and posterior tonsillar pillars visualized. Class II: soft palate, fauces, uvula visualized. Class III: soft palate and base of uvula visualized. Class IV: only hard palate visualized. *Classes III and IV are considered predictive of difficult intubation*

Mallampati grading can go up by 1 grade (33%) or sometimes 2 grades (5%) during labor probably due to changes in airway, excessive straining, and airway edema [24]. Some studies have found that supine position improves the Mallampati grades by 1–2 and are superior to upright Mallampati scoring to predict difficult tracheal intubation in adults [33, 34]. Phonation during Mallampati grading also improves the scores. Although phonation improves Mallampati score (oropharyngeal view), it reduces correlation with Cormack-Lehane grade (laryngoscopic view) [35].

In another study, phonation improved the Mallampati class in supine position compared to upright position [36]. A recent study has found that Mallampati test with phonation, tongue protrusion, and supine position correlated most with Cormack-Lehane grading when compared to the standard Mallampati test [37]. Thus, more evidence is required for such modifications of Mallampati test to be recommended for use in routine clinical practice. Recently, Cochrane database has found the modified Mallampati test had the highest sensitivity for predicting difficult tracheal intubation compared to the other tests [38].

Tests 5.2–5.4 below assess mandibular mobility, important for mask ventilation, direct laryngoscopy, and intubation

5.2 Inter-incisor Gap (IIG)

The IIG is the distance between the upper and lower incisors. It measures both the hinge movement and the gliding movement of the TMJ. It is measured with the patient sitting in the neutral position and mouth maximally open (Fig. 3.2). An IIG of at least 5 cm or 3 finger breadth is associated with easy laryngoscopy. An IIG of less than <3 cm is generally accepted as a non-reassuring sign because a 2 cm flange on blade can be easily inserted between teeth. A mouth opening of at least 2cm or two finger breaths is required for insertion supraglottic airway device (SAD).

5.3 Upper Lip Bite Test

It is a measure of mandibular displacement anteriorly, i.e., the sliding movement of the temporomandibular joint during laryngoscopy [39]. The patients are asked to bite their upper lip with lower incisors as high as they can, in sitting position with head in neutral position (Fig. 3.3).

Class I: lower incisors can bite the upper lip above the vermilion line
Class II: lower incisors can bite the upper lip below the vermilion line
Class III: lower incisors cannot bite the upper lip (Predictive of difficult intubation).

Fig. 3.2 Inter-incisor gap (see text for description)

Fig. 3.3 Upper lip bite test (see text for description)

If the anesthesiologist demonstrates the test to the patient, it enables better patient compliance.

A recent Cochrane study has found that ULBT provided the highest sensitivity compared to the other tests, for predicting difficult laryngoscopy [38].

5.4 Calder's Jaw Protrusion Test

This test also predicts the mandibular displacement during laryngoscopy [40]. The patient is asked to protrude the lower jaw as far as possible (Fig. 3.4). The degree of protrusion is classified as:

Class A: the lower incisors can be protruded anterior to the upper incisors.

Class B: the lower incisors can be brought "edge to edge" with the upper incisors, but not anterior to them.

Class C: the lower incisors cannot be brought "edge to edge" (Predictive of difficult intubation)

> 5.5–5.8 are predictors of neck extension and ability to displace the tongue into submandibular space, both of which are important for direct laryngoscopy.

5.5 Thyromental Distance (TMD)/Patil's Test

It was proposed by Patil in 1983 as a measure of head extension, small mandible, anterior larynx and thus reduced submandibular space (space

Fig. 3.4 Calder's jaw protrusion test (see text for description)

Fig. 3.5 Thyromental distance/Patil's test (see text for description)

where the tongue can be displaced during laryngoscopy thus giving a better laryngeal view), which are factors of in determining the ease or difficulty of intubation. TMD is measured with a ruler in the upright sitting position from the mentum to the superior notch on the thyroid cartilage when the patient's neck is fully extended (Fig. 3.5).

In patients with an easy airway, it is more than 6.5 cm or three finger breadths. Smaller the TMD, the greater the probability of a difficult airway. A TMD less than 6 cm is predictive of difficult intubation. Most anesthesiologists use three fingers as a measurement and is the most common method of measuring thyromental distance. But this correlates poorly with the commonly accepted cut-off point of 6.5 cm and using three finger widths to measure this distance overestimates the true measure. Measurement of three finger width at the proximal inter-phalangeal (PIP) joint has found a wide range from 4.6 to 7.0 cm (mean 5.92 cm). The TMD is increased in acromegaly; especially in patients with a long duration of disease, but this increased thyromental distance is not associated with difficult laryngoscopy [25]. Knowing the width of each finger of the clinician/anesthesiologist at the PIP joint, improves the usefulness, by converting it into accurate number. Using a ruler for measurement of TMD increases the sensitivity of prediction of the difficult airway threefold when compared to using fingers [41].

5.6 Thyromental Height Test (TMHT)

It was proposed by Etezadi F and colleagues as a surrogate for frequently cited anthropometric measures like the amount of mandibular protrusion, dimensions of submandibular space and anterior position of the larynx [42]. The height between the anterior border of the thyroid cartilage (on the thyroid notch between the 2 thyroid laminae) and the anterior border of the mentum (on the mental protuberance of the mandible),

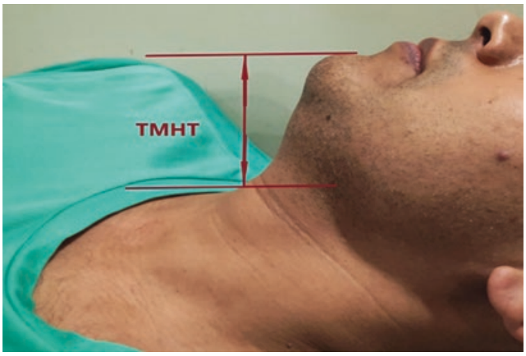

Fig. 3.6 Thyromental height test (see text for description)

with the patient lying supine with her/his mouth closed is measured (Fig. 3.6).

Ideally it is measured using a depth gauge, but a simple scale can be used. There is a close association between small thyromental height ≤50 mm and occurrence of difficult laryngoscopy. TMHT is an objective assessment and is less likely to be affected by inter-observer variability.

A more anterior larynx is often associated with difficult laryngoscopy and this correlates with a shorter thyromental height. Backward, upward, and rightward pressure can be used to improve the laryngoscopic view, this posterior displacement increases the TMD, effectively increasing the thyromental height.

5.7 Sternomental Distance (SMD)/Savva Test

SMD was proposed by Savva D as an indicator of head and neck mobility [43]. It is measured with the head fully extended on the neck with the mouth closed, in sitting position. The straight distance between the upper border of the manubrium sterni and the mentum is measured. A SMD of <12.5 cm is considered as predictive of difficult intubation (Fig. 3.7).

A derived value is sternomental displacement (SMDD) is calculated by subtracting SMD neutral from SMD extension. A recent study the cut-off values for SMD and SMDD has been found to be ≤14.75 cm (sensitivity 66%, specificity 60%) and ≤5.25 cm (sensitivity 70%, specificity 53%), respectively, for predicting DL [44].

Fig. 3.7 Sternomental distance/Savva test (see text for description)

5.8 Delilkan's Test

This test assesses the neck extension. The patient is asked to look straight ahead with the head in the neutral position. The index finger of the left hand of the observer is placed under the tip of patient's jaw and the index finger of the right hand is placed on the patient's inferior occipital prominence (IOP) (Fig. 3.8a). The patient is asked to look at the ceiling. The relative position of each finger is assessed. This mento-occipital level is a rough indicator of SMD. If the finger under the chin is higher than the IOP, then this indicates a SMD of >12.5 cm (Fig. 3.8b). If the mentum-IOP points are at the same level, or if the IOP point is higher than the mentum (on full extension), higher grades of difficulty are predicted; this is a positive sign and would correspond to a SMD of <12.5 cm [45]. Both Delilkan's test and SMD asses the extension at the atlanto-occipital joint using different points of reference.

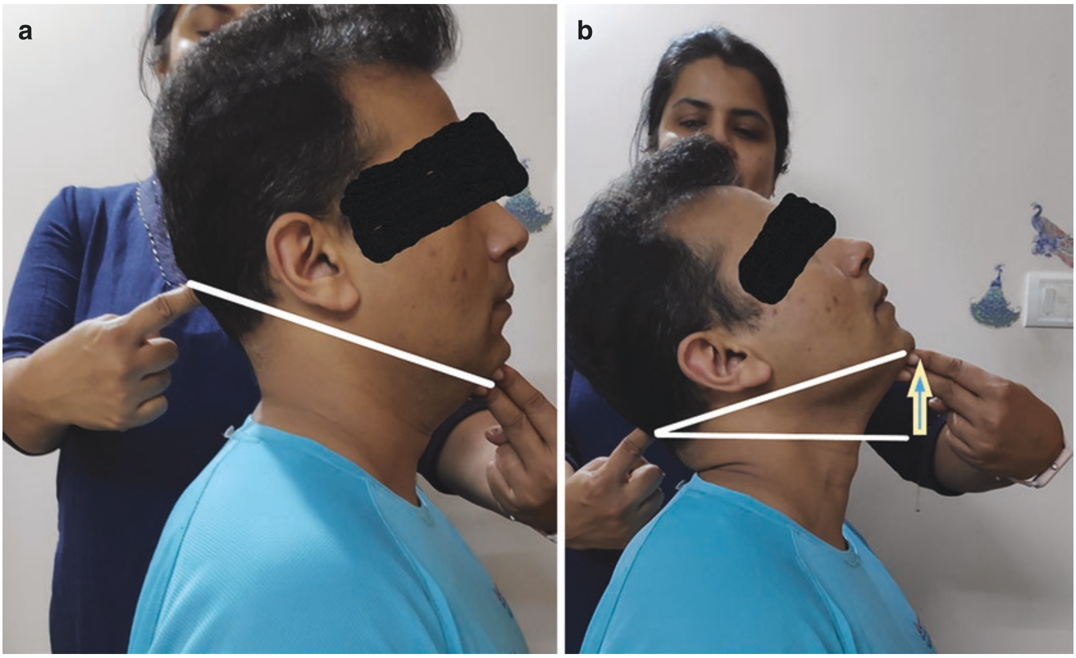

Fig. 3.8 Delilkan's test (see text for description). (**a**) Neutral position. (**b**) Extension

Delilkan recommended this simple bedside test to be used as a routine airway assessment test especially in geriatric patients.

Composite Tests

Individual tests have varied sensitivity and specificity for predicting difficult airway, some anesthesiologists have proposed combination of tests to improve the accuracy of predicting the difficult airway. These combined tests are also not very accurate.

5.9 Wilson's Score

Wilson and colleagues proposed a score based on five risk factors for predicting difficult airway in 1988 (Table 3.3) [46] A total score of 2 or more is associated with an increased incidence of difficult intubation.

Table 3.3 Wilson risk sum score

Airway factors	Grade	Score
Weight	<90 kg 90–110 kg >110 kg	0 1 2
Head and neck movement	>90° ±90° <90°	0 1 2
Jaw movement	Inter-incisor gap >5 cm, *SLux > 0 Inter-incisor gap 5 cm, SLux = 0 Inter-incisor gap <5 cm, SLux < 0	0 1 2
Receding mandible	Normal Moderate Severe	0 1 2
Buck teeth	Absent Moderate Severe	0 1 2

**SLux* subluxation is the maximal forward protrusion of the lower incisors beyond the upper incisors

5.10 El-Ganzouri Risk Index/ Simplified Airway Risk Index (SARI)

El-Ganzouri and colleagues in 1996 combined and stratified seven variables derived from factors associated with difficult intubation producing a score ranging from 0 to 12 (Table 3.4) [47]. A higher SARI score is more specific for difficult intubation. A score of more than three advocates the need to keep/use a video laryngoscope and a score greater than seven prompts an awake fiberoptic intubation. A score of ≥3 has also been found to be the optimal cutoff for predicting a DMV with a sensitivity of 66% and a specificity of 77 [48].

Table 3.4 El-Ganzouri risk index

Airway factors	Grade	Score
Mouth opening	>4 cm 4 cm <4 cm	0 1 2
Thyromental distance	>6 cm 6–6.5 cm <6 cm	0 1 2
Mallampati class	I II III	0 1 2
Neck movement	>90° 80–90° <80°	0 1 2
Jaw protrusion	Yes No	0 1
Body weight	<90 kg 90–110 kg >110 kg	0 1 2
History of difficult intubation	None Questionable Definite	0 1 2

6 Laryngoscopic View Grading

6.1 Cormack and Lehane (C&L) Grading

The four-grade scoring system was described by Cormack and Lehane in 1984 [49]. It is the most widely used score to describe the view obtained with direct laryngoscopy (Fig. 3.9).

Grade 1: Full view of the glottis
Grade 2: Partial view of the glottis
Yentis and Lee modified grade 2 view into 2a (part of the cords visible) and 2b (only the arytenoids or the very posterior origin of the cords visible) [50].
Grade 3: Only the epiglottis can be seen
Grade 4: The epiglottis and glottis cannot be seen.

Cook has modified the grade 3 views in which the grade 3a is the epiglottis is visible and can lifted, for e.g., with a gum elastic bougie. Grade 3b is when the epiglottis is fallen to pharynx and cannot be lifted. Grades 1 and 2 are accepted as an easy airway, and Grades 3 and 4 considered as a difficult airway.

6.2 POGO (Percentage of Glottic Opening) Score

The POGO score is a simple, easy way to categorize laryngeal view [51]. In this score the CL grade I and II are modified and the area of the glottis inlet visualized is scored as a percentage.

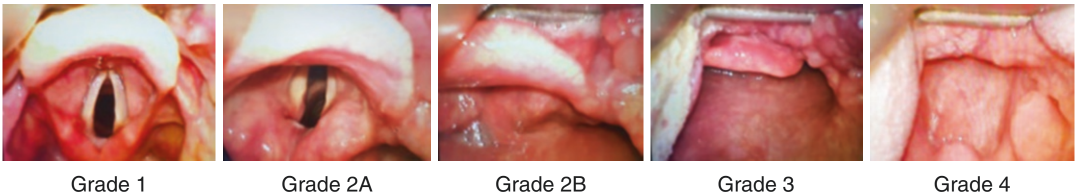

Fig. 3.9 Cormack and Lehane grading (see text for description)

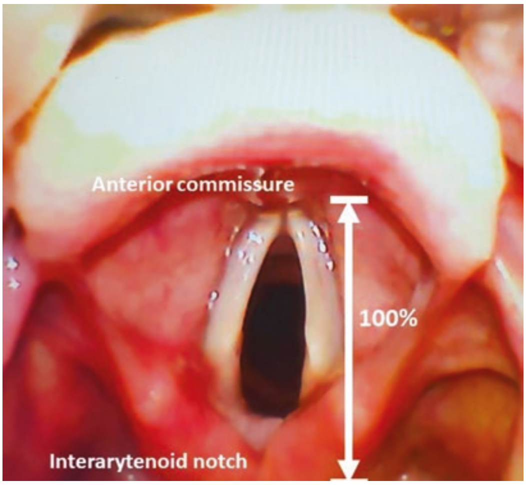

Fig. 3.10 POGO (percentage of glottic opening) score (see text for description)

It is defined anteriorly by the anterior commissure and posteriorly by the interarytenoid notch. The score ranges from 0% when none of the glottis is seen to 100% when the entire glottis including the anterior commissure is seen. Therefore, a POGO score of 100% denotes visualization of the entire glottic opening in linear fashion from the anterior commissure to the posterior cartilages and if none of the glottic opening is seen, then the POGO score is 0% (Fig. 3.10). It has been found to have better inter-physician reliability than CL grading and is more useful for statistical analysis.

6.3 Freemantle Score

The Fremantle score is a simple, three-element score describing view of the vocal cords, ease of intubation and device used (Table 3.5) [52].

Table 3.5 Freemantle score

Freemantle component	
Best achievable view of the vocal cords	Full (F) = CL grade I/POGO 100%
	Partial (P) = CL grade II/POGO 50%
	None (N) = CL grade III/POGO 0%
Ease of intubation	1—intubation at first attempt
	2—intubation is successful after two or more attempts/use of adjuncts/change of technique
	3—failed intubation
Device used	Name of the laryngoscope and blade used

The device used describes the name of the laryngoscope including blade used. For example, a successful intubation in which an incomplete view of the vocal cords is obtained and a bougie is used to successfully intubate on first attempt using a CMAC (Karl Storz,) size 3 blade, would be a "P 2 CMAC3."

The Fremantle score has been found to be easy to understand and use.

6.4 The Intubation Difficulty Scale (IDS)

In 1997, Adnet introduced the IDS [53]. This scale is accurate and complete, but difficult to apply in practice. Also, it is a post intubation score. IDS have seven variables:

1. N1: Number of attempts: each additional attempt adds 1 point
2. N2: Number of additional operators: each additional operator adds 1 point

3. N3: Alternative techniques utilized: each alternative technique adds 1 point
4. N4: Cormack-Lehane grade: CL grade obtained minus 1 is the points to be added
5. N5: Force exerted on the laryngoscope: 1 point if subjectively increased lifting force is necessary
6. N6: Facilitation maneuvers: 1 point if external laryngeal pressure is used
7. N7: Position of the vocal cords: 0 if vocal cords in abduction; 1 point if the vocal cords in adduction.

The total IDS score ranges from zero to infinity where 0 = easy intubation; 0 to ≤5 = slight difficulty; ≥5 moderate to major difficulty; ∞ = impossible intubation.

The IDS is intended for assessing the technical difficulties involved in intubation, not the clinical efficiency or effectiveness of the technique or device used. Value of each parameter becomes important if the reason for the increase is mentioned. For example, if N1 score is 3, it could be either a difficult intubation, if it were performed by an experienced anesthesiologist, or could simply be insignificant if the two attempts were by trainees.

7 Radiological Evaluation of Airway

The use of imaging modalities can help us to confirm our clinical assessment and make the prediction of the airway more precise. Imaging helps us to visualize bony structures, air columns, and soft tissues thus confirming our assessment of the airway [54].

7.1 X-ray

The humble X-ray is the most common, widely available, and economical imaging modality available. The most common views are lateral view and anterior–posterior (AP) view. The lateral view gives information regarding compression of the airway due to tumors, abscesses, degenerative conditions (cervical spondylosis, rheumatoid arthritis, and ankylosing spondylitis). The AP view is useful for detecting deviation of the trachea and to a certain degree compression of the trachea. The lateral view in flexion and extension is used rarely to assess the atlanto-axial subluxation (distance >3 mm between odontoid process and the atlas with the neck in flexion). Also, difficult airway is associated with reduced C1–C2 joint space, large osteophytes/spurs, ossification of ligaments or fractures of the spine. A longer mandibulohyoid distance, effective mandibular length less than 3.6 times the posterior depth of mandible, shorter length of mandibular ramus, increased mandibular angle greater posterior depth and anterior depth of the mandible suggest difficult intubation [54]. A well exposed X-ray gives information not only about the air column, it allows measurement to calculate the size of the ETT/double lumen tubes.

7.2 Computerized Tomography (CT)

CT is accessible, fast, provides excellent details of the airway and surrounding tissues, and is the mainstay of airway imaging in delineating congenital airway abnormalities in pediatric population, infectious pathologies, characterization of laryngotracheal lesions, and evaluation of airway narrowing/deviation due to extrinsic or intrinsic masses. CT images provide a good air–tissue interface, which aids in accurate determination of airway dimensions [53]. CT images can be used for airway reconstruction and for creating virtual bronchoscopy, which has been found to be more useful than CT alone in prediction of the airway [55].

7.3 Ultrasonography

Ultrasound is a rapidly evolving modality in the field of anesthesiology, finding applications in airway assessment too. Applications of ultrasound in airway assessment are discussed in detail in Chap. 4.

8 Preoperative Endoscopic Airway Examination (PEAE)

Patients with known or suspected upper airway pathology who present for elective diagnostic or therapeutic procedures may pose a unique challenge to the anesthesiologist. The lesions of the base of tongue, epiglottis, glottic aperture, or larynx can interfere with conventional airway management, these may not be fully appreciated during a standard airway examination. These anatomic structures are not typically visualized during a preoperative examination, in addition the clinical signs and symptoms may not be reliable indicators of the significance of such lesions. In addition, few patients may have undergone prior surgical procedures or radiation therapy and their routine airway examination predicts a difficult airway, but they may not have airway lesions that prevent safe airway management. Thus, the anesthesiologist responsible for the care of such patients may lack adequate information to choose the best/safest technique of airway management. The paucity of comprehensive information regarding the architecture of the airway lesions often leads the clinician to consider techniques of awake intubation to avoid catastrophic outcomes. Rosenblatt et al in their landmark study found that that PEAE can be an essential component of the preoperative assessment of patients with airway pathology; they found that preoperative airway visualization reduces the number of unnecessary awake intubations by 25% while providing superior information about the airway architecture [56].

PEAE is performed in preop room under topical anesthesia. The patient is positioned with the patient in propped up position of 15–30°. A 65-cm-long, 3.7-mm-diameter FOB is introduced via the nares and advanced till the tip of the epiglottis is identified. The FOB is then maneuvered to visualize the vallecula, vocal cords, right and left pyriform sinuses. The patient is asked to vocalize during the true cord visualization to identify any lesions and palsies. To standardize the reporting of the transnasal flexible endoscopic laryngoscopy examinations, Gemma et al. [57] have proposed the Endoscore, a five-grade scoring system based on the modified C & L grading to standardize reporting of the predictive findings of the ENT evaluation, also to facilitate understanding and cooperation between ENT and anesthesia specialists. Grade 1: complete view of the vocal folds, including the anterior commissure; Grade 2a: incomplete view of the vocal folds, anterior commissure not visible; Grade 2b: incomplete view of the vocal folds, anterior two-thirds of the vocal folds not visible, only vocal process of the arytenoid cartilages can be visualized; Grade 3: vocal folds not visible, only epiglottis can be visualized and Grade 4: larynx not visible, only base of the tongue can be visualized. The Endoscore predicted modified C & L grading and IDS only when evaluated with tongue protrusion and not in the resting position or with hyperextended neck.

The use of PEAE especially in patients with airway pathology has been found to reduce the number of unnecessary awake intubations and increase the patient safety by providing the anesthesiologist with superior anatomic information. In addition, PEAE can be done quickly in the preoperative room with minimal patient discomfort and will increase the clinician's confidence in his airway plan.

9 Three-Column Model for Airway Assessment

Greenland KB in 2008 proposed that airway can be considered as a three-column structure: anterior, middle, and posterior. Airway assessment tests must be done to evaluate each column (Fig. 3.11) [58].

(a) Anterior column is an inverted triangular pyramid with the hyoid bone as the apex, the incisors of the mandible, and the temporomandibular joints form the edges of the base. The cephalic surface of tongue and floor of mouth forms the base.

The contents of the submandibular space are the submandibular gland, submandibular lymph nodes, fat, muscles and tissues. These tissues are compressed during laryn-

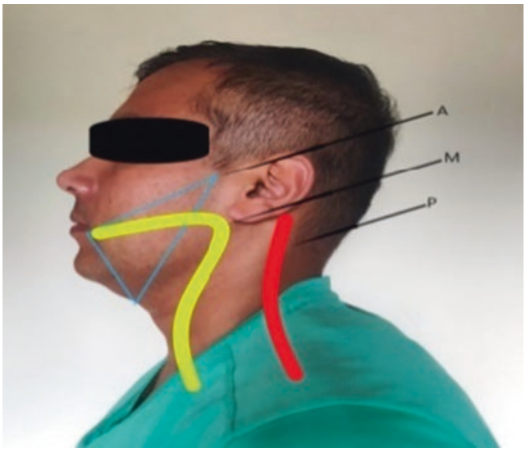

Fig. 3.11 Three-column model for airway assessment: A—anterior column, M—middle column, P—posterior column

goscopy to accommodate the muscle bulk, so that an adequate line of sight to visualize the glottis inlet is obtained. Low or reduced compliance of the submandibular tissues will lead to difficult laryngoscopy, as these tissues cannot be compressed into the space. The reduction in the volume of the submandibular space may be absolute (micrognathia/retrognathia) or relative (large tongue relative to the bony limits, prominent incisors). This is assessed by Mallampati test, TMD, and observation of facial features/dentition.

A broad array of pathological processes may reduce the compliance of the submandibular tissues. There is no way to measure the compliance, only history will give some insight into the reduced compliance of submandibular tissues. History of previous radiotherapy to the head/neck, neck masses, prior surgeries of the neck/mandible, hematoma or infection of the submandibular space and burns of the neck. Connective tissue disorders like Hunter's and Hurler's syndrome will reduce the compliance of the submandibular tissues.

TMJ forms the base of the inverted pyramid; it has two movements, hinge movement for initial opening of the mouth and subluxation or gliding movement for further movement. Any cause of TMJ dysfunction like ankylosis, fractures or contractures will reduce the movement in the joint. It is assessed by measuring the inter incisor gap and the upper lip bite test/Calder's test.

Airway difficulty includes mask ventilation and direct laryngoscopy. These can be managed by awake FOB and video laryngoscopy.

(b) Middle column is formed by the airway passage from the mouth to the trachea. The airway can be encroached by many conditions like large tonsils, infections (parapharyngeal/retropharyngeal), tumors, fat, etc. It is also affected by changes in both the anterior and posterior column. In addition, a large portion of the air column cannot be assessed by routine clinical tests.

The assessment of the middle column is by history of snoring/stridor/noisy breathing and gross examination of the oral cavity. Imaging modalities of the airway like X-ray, CT or magnetic resonance imaging scanning are used to assess the middle column. Recent advances in technology have made it possible for images to be reconstructed using data from helical CT to show CT bronchography (external rendition of airways) and virtual bronchoscopy (visualizing the airways from inside). Performing PEAE preoperatively will aid in accurate evaluation of airway pathology and aid in formulating an airway management plan.

Airway difficulty related to middle column abnormalities include mask ventilation and complete airway obstruction, direct laryngoscopy, and difficult SGA placement. In addition to video laryngoscopy and flexible endoscopy, need for front of neck surgical access should be considered.

(c) Posterior column is formed by the cervical spine and the occiputs-atlanto-axial complex. It is tested by the ability to achieve sniffing position by the patient. The sniffing position is achieved by flexion of the lower cervical spine and extension of the occipito-atlanto-axial complex. Conditions like ankylosing spondylosis, rheumatoid arthritis, diabetes mellitus, spinal injury are some of the examples of conditions affecting posterior column.

Assessment of the posterior column is done by thyromental distance, sternomental distance, and Delilkan's test. Additional evaluation can be done by performing X-ray cervical spine lateral view, CT, and MRI.

Airway difficulty include poor view on direct laryngoscopy as positioning is difficult and techniques like video laryngoscopy and flexible video endoscopy should be included in the planning.

10 Commonly Used Mnemonics for Prediction of Difficult Airway

There are multiple factors associated with a non-reassuring airway. A few of the commonly used mnemonics for prediction of difficult airway are listed in Table 3.6.

Table 3.6 Commonly used mnemonics for prediction of difficult airway

1. Difficult Mask Ventilation MOANS	M Mask seal inadequate. Beards, secretions or blood, facial fractures, retrognathia, facial mass O Obesity. BMI >26 kg m^{-2}, obstetric patients A Age >55 years N No teeth, edentulous S Snoring or stiff ventilation. OSA, bronchospasm. Neck radiation
2. Difficult Laryngoscopy and difficult Intubation LEMON	L Look externally injury, large incisors, large tongue, beard E Evaluate the 3-3-2 rule 3 finger breadth mouth opening 3 finger breadth Thyromental distance 2 finger breadth thyrohyoid distance M Mallampati class ≥ III O Obstruction of airway, obesity, obstetric N Neck mobility restricted
3. Difficult Supraglottic airway device R O D S	R Reduced mouth opening: <2 cm O Obstruction: airway obstruction at or below the level of the glottis cannot be overcome by the insertion of a SAD D Distorted airway: distorted airway anatomy may prevent the proper seal of SAD S Stiff neck or lungs: may be difficult to place the SAD or poor lung compliance may cause difficult ventilation
4. Difficult Video laryngoscopy BORN	B Blood or secretion in airway: poor visualization O Obesity/large breasts: difficulty in insertion R Reduced mouth opening: <3 cm N New devices which the user may not familiar
5. Difficult surgical rescue techniques SHORT	S Surgery on the neck previously H Hematoma or infection O Obesity, obstetric R Radiotherapy to the neck T Tumors of the neck
6. Difficult Extubation DASH	D Difficult/traumatic intubation A Agitated/uncooperative patient S Surgery on the airway/poor access to airway H Head and neck surgery

(continued)

Table 3.6 (continued)

<table>
<tr><td>7. Difficult intubation in emergency room
HEAVEN criteria [59]</td><td>H Hypoxemia
E Extremes of size
A Anatomic challenges
V Vomit/blood/fluid
E Exsanguination/anemia
N Neck mobility issues</td></tr>
<tr><td>8. Difficult intubation in the intensive care unit [60]
MACOCHA</td><td>
<table>
<tr><td>**Factors**</td><td>**Points**</td></tr>
<tr><td colspan="2">**Factors related to patient**</td></tr>
<tr><td>**M**allampati score III or IV</td><td>5</td></tr>
<tr><td>Obstructive sleep **A**pnea syndrome</td><td>2</td></tr>
<tr><td>Reduced mobility of **C**ervical spine</td><td>1</td></tr>
<tr><td>Limited mouth **O**pening <3 cm</td><td>1</td></tr>
<tr><td colspan="2">**Factors related to pathology**</td></tr>
<tr><td>**C**oma</td><td>1</td></tr>
<tr><td>Severe **H**ypoxemia (<80%)</td><td>1</td></tr>
<tr><td colspan="2">**Factor related to operator**</td></tr>
<tr><td>Non-**A**nesthesiologist</td><td>1</td></tr>
<tr><td>**Total**</td><td>**12**</td></tr>
</table>
0 = easy; 12 = very difficult</td></tr>
</table>

11 Infraglottic Airway Assessment

Assessment of infraglottic segment of airway or the lower airway is crucial in many patients. Asymptomatic conditions of this regions could be easily missed. The consequences of failure to diagnose a infraglottic pathology can be life-threatening or brain threatening. A high degree of suspicion on the part of the clinician and a detailed history is often helpful.

These patients could be asymptomatic or present with varying degrees of obstruction. In history it is important to identify aggravating and relieving positions, progression of symptoms and any previous diagnostic/therapeutic interventions. Obstruction could be (a) intra or extrathoracic, (b) intraluminal or extraluminal, and (c) dynamic or static. Extent of evaluation and type of investigations are determined by clinical findings, diagnosis, and planned intervention. X-ray chest, airway ultrasound, indirect laryngoscopy, CT, and magnetic resonance imaging chest, and awake fiberoptic bronchoscopy can be used to assess the airway depending on the urgency [61]. Imaging of the airway is an advanced aspect of airway assessment and management and is discussed in full detail in Chap. 4.

The anesthetic management of patients with infraglottic airway obstruction can be complicated due to the pressure effects of a mass on the airway, narrowing of the airway or any pathology interfering with ventilation. Clinical conditions include congenital or acquired subglottic stenosis, compression due to aberrant subclavian artery, mediastinal mass, foreign body in the airway, and airway fistulae. The management of infraglottic airway lesions is challenging, it requires meticulous planning and cooperation between the surgical and anesthetic teams [62].

12 Conclusion

Bedside airway examination tests, for assessing the physical status of the airway in adults with no apparent anatomical airway abnormalities, are designed as screening tests. The screening tests are expected to have high sensitivities, but most of the airway assessment tests have relatively low sensitivities with high variability [38]. Therefore, although there are multiple tests to predict the difficult airway, there is no one test or combination of tests that will accurately predict the difficult airway. Some studies suggest that attempting to predict difficult intubation is unlikely to be useful. But the most important benefit of this ritual: it forces the anesthesiologist at least to think about the airway, and for this reason we should continue doing it [63]. A simple and a quick airway examination routine should be done as a routine preoperatively for all cases regardless weather the case has been planned under general, regional or even monitored anesthesia care.

A simple airway assessment routine

- Focused history
- Look externally face, neck, body habitus and weight
- Mouth opening
- Assess ULBT
- Mallampati grade
- Thyromental distance

If any test is predictive of difficult further evaluation/experienced help/equipment may be required

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