Chapter 2
Airway Assessment: A Critical Appraisal

Zahid H. Khan

Abstract The ability to predict the difficult airway to preempt difficult intubation would decrease the most common damages seen in the administration of anaesthesia. Many tests have been put forth over the years, some necessitating detailed quantitative measurements like the sternomental distance, thyromental distance and inter-incisor gap but others like the upper lip bite test is of a qualitative nature which makes it easier to use and is more precise. The setback in most tests has been their sensitivity, specificity, positive and negative predictive value to allow accurate prediction of the possibility of difficult intubation. Combination of the tests has not improved the various attributes to improve accuracy. The most important impediment to the continued search of a comprehensive test is the low occurrence of the difficult airway. There may be a combination of complex factors interacting in an incomprehensible manner to make the process of intubation difficult.

Keywords Difficult airway · Prediction · Airway assessment tests

History and Definition

The foremost responsibility of an anesthesiologist is to maintain patency of the airway to allow oxygen to move down into the lungs to ensure adequate gas exchange. Inability to maintain ventilation and oxygenation for several minutes after the patient is rendered apneic following induction of anesthesia results in catastrophic complications including death. Such problems account for 30 % of deaths occurring during anesthesia [1, 2]. These figures are certainly high in the developing world. In the published analyses of records of the UK medical defense

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societies, problems with tracheal intubation are the principal causes of hypoxemic anesthetic death and brain damage [3–5].

Closed claims analysis has found that the vast majority (85 %) of airway related events involve irrevocable damage to the brain or death [1], and nearly one third of deaths attributable solely to the process of anesthesia have been related to the inability to safeguard the patency of the airway [3]. Compared with 1985–92, death or brain damage from difficult airway management associated with induction of anesthesia did show a decrease in 1993–99, but death or brain damage associated with maintenance, extubation and recovery was found not to be significantly different in the two line periods [6]. This reflects that although significant advances have been made regarding airway management armamentarium and strategies, the situation still appears far from hopeful.

According to the definition forwarded by the American Society of Anesthesiologists (ASA), a difficult intubation (DI) is one during which the insertion of the endotracheal tube takes more than 10 min, and or requires more than three attempts by an experienced anesthesiologist [7]. Langenstein and Cunitz [8] also defined an intubation as difficult, if a practicing anesthesiologist needed more than 3 attempts or more than 10 min for a successful endotracheal intubation. It appears that the ASA has been too magnanimous in granting a 10 min period for insertion of the endotracheal tube before being labelling a case as that of DI. If a patient cannot be ventilated by mask after being rendered apneic, the 10 min period need to be substantially curtailed in terms of a cut off value otherwise the end result would be a patient with irreversible brain damage who can neither successfully be mask ventilated nor intubated and yet falls within the allowable time period of 10 min not trespassed in milliseconds. The incidence of DI reported in the literature varies markedly between studies, ranging from 0.05 to 18 % [9–11]. These large variations could be attributed to the different definitions used during such studies and the incorporation of different grades of the Cormack–Lehane grading (CLG) for the laryngoscopic view [12]. DI has been defined as repeated attempts at intubation, the use of a bougie or other intubation aid but the most widely used classification is that of Cormack and Lehane [12], which describes the best view of the larynx seen at laryngoscopy. For the ease of understanding different terms and definitions such as DI, difficult tracheal intubation and difficult laryngoscopy (DL) have been introduced into our anesthesia literature but the final inability to perform endotracheal intubation is in fact the total sum of DL, patients' innate anatomical characteristics and other circumstances that are still beyond our comprehension.

To surpass the ever present life threatening risks of the difficult airway, guidelines have been published by North American [13, 14], French [15], Canadian [16], and Italian [17] national societies. Unfortunately, they do not serve to be useful when prompt decisions are to be made as in emergency situations. The flow charts in the European [18, 19] or American Heart Association [20], and Advanced life Support guidelines offer simple steps that could be of value in emergency situations.

Out of the total of 6,750 anesthesia malpractice claims, Cheney et al. [21] could find that 23 % of the respiratory events were exclusively due to DI. Of the first 4,000 incidents reported to the Australian Incident Monitoring study (AIMS), 160

dealt with problems pertaining to endotracheal intubation. Difficulties in intubation were not predicted in 77 cases. Paix et al. [22] concluded that simple tests such as limited mouth opening and/or neck extension could have prevented unexpected difficulties in 32 of the cases.

The Conundrum of a Difficult Airway

The difficult airway can be represented by difficulty with laryngoscopy, intubation and mask ventilation. Before an anesthetic is administered, it is of paramount importance to correctly diagnose and clinch potential airway problems to choose alternative modalities of airway management [13, 23]. It is a kind of dress rehearsal before a potentially hazardous march on the enemy and should under no circumstances be under estimated. Approximately half of all cases of DI are not predicted [24] and this is particularly alarming as it can potentially turn into a life threatening event. This figure is alarming to say the least, and it is because of the inevitable fear of a DI that the American Society of Anesthesiologists Task Force on the management of different airways unequivocally state that all anesthesiologists should have a preformed or preconceived strategy for intubation of the difficult airway [13]. The most generally accepted belief that a Cormack–Lehane grade III and IV laryngoscopic views represent DI has been challenged by Arne et al. [25] on the premise that many of the grade III and IV views were actually easy intubations. Till such time that we have another gold standard with which to assess the degree of difficulty, the CLG system would continue to serve as the gold standard for the assessment of DI, although the different terminologies of DI and DL would be used interchangeably to depict the same problem or malady and this would account for the wide range of figures quoted in the literature for DI and DL.

Difficult Airway and Its Diagnosis

Difficulty in airway management is the most common concern of anesthesiologists as it leads to irrevocable insult. A thorough history would bring to limelight issues such as DI in the past, maxillofacial trauma, facial burns or surgery of the face, neck, pharynx and larynx, and radiotherapy of the neck. The presence of signs such as dyspnea, stridor, dysphagia and or snoring correlate with DI and help the anesthesiologist in carving out an alternative plan for airway management. Certain conditions such as obesity, pregnancy, a short neck, buck teeth, receding mandible and the presence of beard obviously go in favor of DI providing suggestive evidence that a DI might be in the offing.

Accurate preoperative prediction cannot be correctly comprehended with the available quantitative tests which lack in sensitivity (Se) and specificity (Sp), resulting in a low positive predictive value (PPV) for any single test. Nonetheless,

different bedside tests are routinely conducted in an effort to rule out DI. We would mention the tests that are commonly employed and later draw out conclusions regarding the feasibility and applicability of the tests when used singly or in combination. We would also focus on other airway assessment aids and tools that are currently used for the prediction of DI.

Mallampati classification: Mallampati et al. [26] towards the end of the last century proposed a classification which estimates the size of the tongue relative to the oral cavity and the ability to open the mouth, and suggested that a large tongue having occupied most of the oral cavity would obscure the oropharyngeal structures thus heralding DI. Based on the structures visible in the oropharynx, with maximal mouth opening, the patient was graded into 3 grades. Later Samson and Young [27] added a fourth grade to the original classification, and presently the modified version is commonly used known as the modified Mallampati test (MMT) (Fig. 2.1). The Mallampati score based on the size of the tongue relative to the oropharynx has a good correlation with the CLG (Fig. 2.2) for visualization of the larynx, however many studies were not promising and have pointed out inter—observer variability with the Mallampati score [28–30]. Mallampati et al. [26] found a Se close to 100 % and a Sp of 80 % for their test, but these figures were not reproduced in studies conducted later. In the original study, Mallampati et al. [26] did not specify whether the patient should phonate or not thus leaving future researchers with the leverage to apply phonation or avoid it during the assessment of the airway. Lewis et al. [31] recommend that the Mallampati test be performed with the patient in the sitting position, the head fully extended, the tongue protruded with phonation. Khan et al. [32] concluded that the Mallampati test in the supine position without phonation had better compatibility in predicting difficult mask ventilation. Frerk [33] reported that the MMT had a PPV of 17.3 %, a Se of 81.2 % and a Sp of 81.5 %. They had included grade 2 in the CLG system in the DI. However, when grades 3 and 4 of the CLG system were applied, the PPV would decrease from 17.3 % to as low as 5.8 %. Yamamoto et al. [34] questioned the reliability of the MMT owing to its very low PPV of 2.8 %. They also found comparatively lower values of 67.9 and 52.5 % for Se and Sp respectively. Cattano et al. [35] demonstrated a good correlation between the Mallampati scale and the CLG system, although the Mallampati scale lacked the sensitivity to be a good predictor when used alone. Owing to a high incidence of false positives, the test was also not specific enough. Contrary to the findings by Cattano et al. [35] in which they demonstrated a good correlation between the Mallampati scale and the CLG, Khan et al. [36] describe a case that had a CLG of 1 on laryngoscopy despite a Mallampati class 4, revealing no correlation and no agreement between the Mallampati class and the CLG.

Thyromental distance: Thyromental distance (TMD) is measured along a straight line from the thyroid notch to the lower border of the mandibular mentum with the head fully extended and categorized as >6.5, 6.0–6.5 or <6.0 cm. The TMD gives us a clue regarding the mandibular space. In patients with a short mandibular space, the tongue cannot be accommodated anteriorly during laryngoscopy and is pushed posteriorly thus obscuring the glottic view. Logically, a

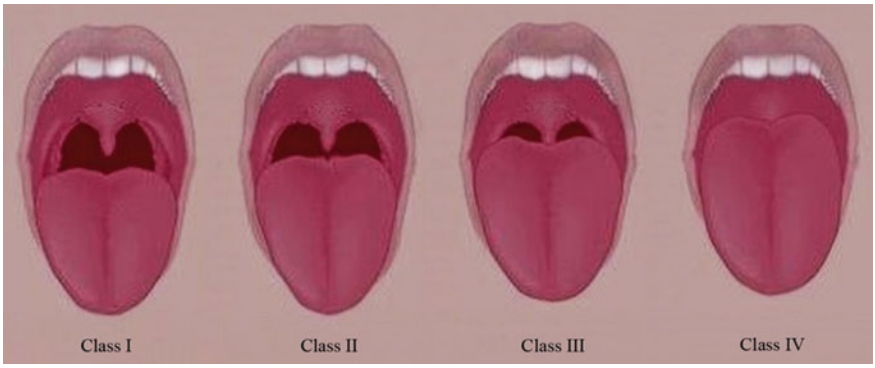

Fig. 2.1 Schematic classification of the pharyngeal structures based on Samsoon and Young's modification of the original Mallampati classification

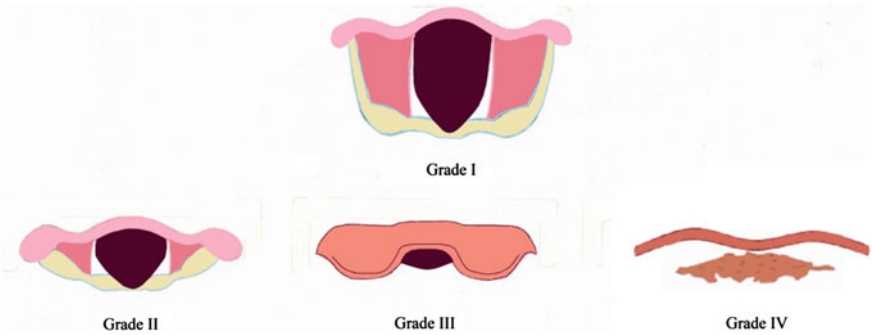

Fig. 2.2 Schematic Cormack–Lehane grading of the laryngoscopic views

short TMD should present problems with intubation. For practical purposes, a distance less than 3 finger breadths between the thyroid cartilage and the mandible is considered to indicate a receding mandible [37]. Different distances have been suggested ranging from <6 to 7 cm but neither the Se nor the Sp of TMD has been high enough to employ this landmark as the only predictor of a difficult laryngoscopy [31, 33, 38]. Although generally regarded to be of poor predictive value [38–41], TMD continues to be popular among investigators and is invariably included in almost every study. In their multivariate risk index study, El-Ganzouri et al. [42] showed that TMD was of exceedingly poor predictive value as it could only correctly predict 7 % of all difficult intubation cases. Similarly, Brodsky et al. [43] also reconfirmed that the TMD failed to show any difference between those with easy and those with difficult intubations. Some investigators [44, 45] have proposed a TMD <6 cm to be related to difficult intubation.

However, an exact reduction in the cut off value of TMD to the desired value to be of significant predictive value is still in its evolving stage. In corollary with other studies that have questioned the predictive value of TMD for difficult laryngoscopy

[29, 30, 38], Wong and Hung [46] failed to find TMD useful in predicting DI in Chinese women raising the often posed question that predictive values based on absolute anatomical measurements were of little value in predicting DI. Bilgin et al. [47] found that TMD had the lowest Se and negative predictive value (NPV), and the highest Sp and PPV compared to other assessment methods.

In Frerk's [48] investigation, a TMD <7 cm could again fetch high scores of 90.9 and 81.5 % for Se and Sp. Tse et al. [39] in contrast reported a Se and PPV for TMD to be 32 and 20 % respectively. These discrepancies cannot be fully explained and can best be attributed to the different definitions used for DI. Butler and Dhara [38] when using a cut off value of 6 cm as the predictor of DL reported values of 62, 25 and 16 % for Se, Sp and PPV for TMD. Surprisingly, there was no correlation with laryngoscopic grading in a large number of patients presenting with TM distances above or below the cut off value of 6 cm.

Hyomental Distance

Hyomental distance (HMD) is measured as the distance from the symphysis of the mandible colloquially called as the chin to the body of the hyoid bone to which the tongue is attached. This measurement also gives the clinician a clue to the potential space where the tongue would be displaced during laryngoscopy. In patients in whom the neck circumference is large, palpation of the hyoid bone would be rather difficult and the test would perhaps fetch a false positive result.

Inter-Incisor Gap

For inter-incisor gap (IIG) or mouth opening (MO), the patient maximally opens his mouth and the distance between the upper and the lower incisors in the midline is usually measured (30–40 mm or 2 large finger breadths). MO indicates movement of the temporo-mandibular joint (TMJ), and that significantly limited MO hinders exposure of the larynx. Several studies based on multivariate analysis indicated that limited MO is strongly associated with DI [30, 42, 49]. There was no correlation between IIG and, view on laryngoscopy [30] in contrast to a previous study by Wilson et al. [49]. Patients with an IIG of 4.6 cm were considered to have easy intubation and those with a mean IIG of 3.8 cm were considered to have DI [49]. Sava et al. [30] are of the opinion that laryngoscopy may be more difficult in those patients where the IIG was <2 cm rather than 5 cm as suggested by Wilson et al. [49] but this is a supposition and requires further study to ascertain its validity. Different cut off values have been forwarded by different investigators but there is hardly any consensus on an IIG that would be able to forecast a true difficulty in terms of DL.

Sternomental Distance

Sternomental distance (SMD) is measured as the distance between incisura jugularis of the sternal bone and symphysis of the mandible with the patient's head in midline neutral position, neck fully extended and the patient lying supine.SMD may be a good indicator of maximum neck extension therefore enabling a more accurate assessment of head extension than any other subjective assessment and avoiding the need for radiological examination which in fact is an infringement on patient's safety. Ramadhani et al. [50] have shown that SMD had a high Se and Sp for predicting DL. Contrary to their observations in which they concluded that SMD was not affected by age, Turkan et al. [51] found that the SMD measurements were affected both by age and sex. Sava et al. [30] found that the SMD, a positive objective indicator of head and neck mobility, was the best of the five preoperative tests.

Wilson's Risk-Sum Score

Wilson et al. [49] used weight, head and neck movement, jaw movement, receding mandible and buck teeth and suggested a risk-sum in their prospective study to assess the prediction of DL. This score had a se of 42 % and a sp of 95 % when a risk-sum of 2 or more was considered to be a predictor of DL. Compared to the Mallampati test, the Wilson's score had minimal inter observer variation. It had a false positive rate of 12 % and surprisingly combining it with the Mallampati score increased false positives [28].

Head and Neck Movement

The head and neck movement is measured as described by Wilson et al. [49] by asking the patient to fully extend the head and neck. The range of motion from full extension through full flexion was categorized as >90°, 80–90°, or <80°. Body weight is categorized as <90, 90–110 or >110 kg [28, 49]. Tse et al. [39] found that a head extension angle ≤80° to predict DI had a Se of 8 % and a PPV of 21 %. Thus it cannot be used as a reliable test in the prediction of DI. However if there is no limitation in head extension, there would be no intubation difficulty meaning that the test has high Sp and NPV thus providing reassurance that negative results indicate truly easy endotracheal intubation. The test described by Bellhouse and Dore [2] estimates the angle traversed by the occlusal surface of the maxillary teeth when the occipito-atlanto-axial (OAA) complex is fully extended. The test is based on the erroneous assumption that separate movements of the OAA complex and the sub-axial regions are possible. In half of the subjects, a more than 10° subaxial extension occured despite attempts to move the neck as little as possible [52]. The Bellhouse

test evaluates an overall extention of the cervical spine and may fail to detect a pathology of the OAA complex if the subaxial excursion is not impeded.

Obesity and Body Mass Index

The impact of obesity on DI has also not been settled. Juvin et al. [53] found that DI was more common among obese than non obese patients while using the scale proposed by Adnet et al. [54], Brodsky et al. [43] on the contrary concluded that neither absolute body weight nor body mass index(BMI) was associated with intubation difficulties. The controversy widens further when others regard an increase in BMI above 30 kgm^2 as contributive to DI [10, 49, 55]. Contrary to the multifactorial system proposed by Wilson et al. [49] which postulates that greater the degree of obesity, greater is the degree and probability of difficulty, Voyages et al. [55] consider that morbid obesity should not be considered to be a more serious factor than moderate obesity (BW95–110 and >110kg). None the less, their recommendation is to opt for an elective awake intubation whenever obesity is accompanied by an inability to see the posterior pharyngeal wall.

Upper Lip Bite Test

The upper lip bite test (ULBT) introduced as a simple beside test by Khan et al. [56] was based on the hypothesis that as the range and freedom of mandibular movement and the architecture of the teeth had pivotal roles in facilitating laryngoscopic intubation, they hypothesized that the ULBT could serve as a predictor of DI. While performing the test, the patient is asked to take a bite of the upper lip with the lower incisors as far as possible and different classes are assigned as under: class 1, the ability of the patient to take a bite well above the vermilion line; class II, the patient fails to obliterate the vermilion line with the bite; class III, the lower incisors fail to reach the upper lip leaving a distinct gap between the upper and lower lips (Fig. 2.3). In the maiden study by Khan et al. [56] where in the ULBT was compared with the MMT in predicting difficulty in endotracheal intubation, they found that the ULBT showed significantly higher Sp and accuracy (Acc) than the MMT. The Se, positive and negative predictive values between the two tests however did not reveal any significant differences. Hester et al. [57] again found that the ULBT was superior to the MMT in terms of Sp and Acc in predicting DI (97 Vs. 75, 90 Vs. 64). Contrary to Khan et al.'s [56] findings which showed no differences between the two assessments regarding Se, PPV, and NPV, Hester et al. [57] found that the ULBT was superior to MMT in all measures (Se 55 Vs. 11, PPV 83 Vs. 9, NPV 90 Vs.79). They also found a strong correlation between ULBT and Cormack–Lehane scale ($r = 0.512$; $p < 0.001$), but no significant correlation was found between the ULBT and MMT. The ULBT could correctly predict DI 83 % of the time where as the

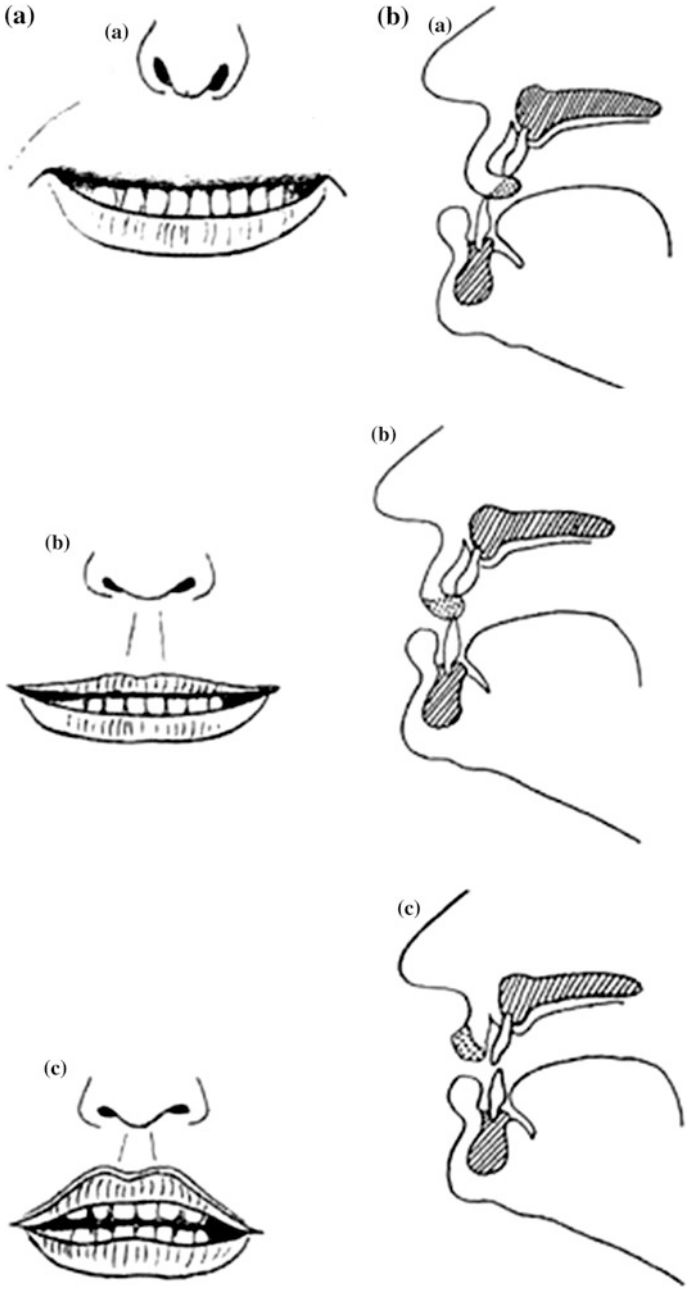

Fig. 2.3 **a, b**: Frontal and lateral views of the upper lip bite test (Reproduced from from Khan et al. A comparison of the upper lip bite test (a simple new technique) with modified Mallampati classification in predecting difficulty in endotracheal intubation: a prospective blinded study. Anesthesia and Analgesia. 2003; 96:595–9 by permission. (Copyright 2003, Philadelphia, Lippincott Williams and Wilkins)

MMT predicted DI only 9 % of the time. In the study by Tremblay et al. [58] the areas under the ROC curves confirmed that CLG during direct laryngoscopy and upper lip bite score were the most discriminating factors. They found out that poor glottic visualization during direct laryngoscopy and high upper lip bite score are the best predictive factors for challenging intubation with glidescope video laryngoscope. In the trial by Eberhart et al. [59] 11 % of a series of 1425 consecutive patients had to be excluded because the ULBT could not be applied to evaluate edentulous patients, and found out that both ULBT and the MMT are poor predictors for DL when used as single preoperative beside screening tests.

The ULBT simultaneously evaluates buck teeth and mandibular subluxation thus enhancing its value as a predictive test for for DI. Limited mandibular protrusion has been associated with both DI using direct laryngoscopy and difficult mask ventilation [56, 59, 60]. A high ULBT score was found to have a direct correlation with difficult mask ventilation as depicted by its high Se and odds radio [61]. The search for a predictive airway test that has the ease of applicability, reliability and accuracy of prediction(discriminating power) continues. The ULBT seems to meet all these quality factors. Increased inter observer reliability compared with the Mallampati score may be another major advantage of the ULBT.

Radiological Measurements

Cass and James [62] referring to the causes of intubation in their cases enumerated them after x-ray findings as under: (1) short muscular neck with a full set of teeth, (2) receding lower jaws, (3) obtuse mandibular angles, (4) protruding upper incisors, (5) relative overgrowth of the premaxilla, (6) poor mobility of the mandible due to temporo-mandibular arthritis or trismus, (7) large mandible, (8) short descending ramus of the mandible, (9) high arched palate associated with a long narrow mouth (resulting in less space between the angles of the mandible posteriorly), (10) increased alveolar-mental distance, necessitating wider opening of the mandible during direct laryngoscopy. They suggested that the angle of the mandible and the distances from the upper incisors to the posterior border of the ramus of the mandible, from the alveolar margin to the lower border of the mandible can be of significance in predicting DI. This case series reflect that x-rays had been employed more than half a century back to get a clue to the causes of DI, and this armamentarium is used even today to clinch the diagnosis in difficult cases of airway management.

White and Kander [63] while comparing normal and DI groups rated an increase in the posterior depth of the mandible as the most important factor hindering displacement of the soft tissues by the laryngoscope blade. Other factors contributing to DI were cited as an increase in the anterior depth of the mandible, a reduction in the distance between the occiput and the spinous process of C1, the C1–C2 inter-spinous gap and reduced mobility of the mandible associated with temporo-mandibular joint arthritis or trismus. These abnormalities could be elucidated by radiographs obtained in both case and control patients.

Karmath and Bhatt [64] construed that effective mandibular length to posterior mandibular depth ratio of less than 3.74 cm was associated with DI. This finding corroborates with that of White and Kander's [63] observations. Eversince the advent of endotracheal anesthesia, cases of DL and DI started appearing in the literature and a global search in predicting difficult cases made an unprecedented spiral rise. Since an access to anatomical landmarks of the mandible, neck and occiput was only possible through x-ray examinations, researchers resorted to roentgenographic studies to measure the different anatomical distances which they presumed and rightly presumed in playing a pivotal role in DI. Owing to the indispensible role of the mandible in relation to DI, the mandibular configuration has since been analyzed using roentgenography of lateral views of mandible in innumerable studies [2, 62–65].

Mandibulohyoid distance (MHD) has been found to be a determining factor in predicting DI by Chou and Wu [41]. In another study, Chou and Wu [65] suggested that a short mandibular ramus or a relatively caudal larynx could predispose problems in visualization of the larynx with a rigid laryngoscope, and also confirmed that the distance from the occiput to the spinous process of the atlas was an important determinant of a difficult airway. Turkan et al. [41] stated that HMD was the only morphometric measurement that was unaffected by age. While performing the Bellhouse test [2], the subaxial extension occurred independently of the degree of OAA extension, and thus the OAA complex capacity was overestimated by the degree of subaxial extension and was not always accurately evaluated. To overcome these problems of obtaining an erroneous impression from the Bellhouse test [2], radiographic examination could be of a potential value as the only method to make the distinction. Lateral neck radiographs in the neutral position and the extreme of head extension are useful as one of the preoperative airway assessment tests [52]. They also help in determining alternative techniques for airway management when tracheal intubation with a conventional laryngoscope fails [66]. However, radiological measurements have not been found to be successful for the prediction of DI as mentioned by McIntyre [67] and Randell [29]. Furthermore, radiographic studies incur a radiation threat which albeit small but still is an infringement on patient's safety.

Composite Variables or a Combination of Predictors

An effort has been made in the recent past by providing composite variables in improving screening for DI but the addition of variables also failed to increase the Se owing perhaps to the innumerable factors involved in DI. Some improvement in Se was observed but at the expense of Sp which showed a decline.

The Airway Difficulty Score (ADS) proposed by Janssens et al. [44] represents the sum of the points for five criteria of difficult intubation i.e., TMD, Mallampati class, MO, neck mobility and upper incisors whether normal, absent or prominent. For each variable, a score ranging from 5 to 15 is subscribed, and a total score ≥ 8 is declared as a potentially DI. When compared with the intubation difficulty scale

(IDS), they found a 85.7 % Sp, 75 % Se, 98.7 % NPV and a 18.6 % PPV. The use of anatomical indexes associated with the Mallampati score failed to improve Se and PPV [35]. Tse et al. [39] found that Mallmpati score, TMD and cervical mobility were of little value in predicting a difficult airway. The investigator at present is at crossroads as to which predictors should be pursued in future studies since clinical anatomical predictors so far have failed to improve our insight in anticipating a difficult airway. Bilgin et al. [47] found the Wilson risk sum to have the highest Se and NPV among the three tests i.e. Mallampati test, Wilson risk sum and TMD. Oates et al. [28] found that both the Wilson risk sum and the Mallampati test failed to predict as many as 58 % of difficult laryngoscopies.

In an obstetric population, Gupta et al. [68] found a Se of 100 % and a Sp of 96 % when using a combination of Mallampati and the Wilson's scores. Merah et al. [69] could find a Se and Sp of 85 % and 95 % respectively when using a combination of Mallampati 3 or 4, IIG of 4 cm or less, and TMD of 6.5 cm or less for predicting DI.

In an effort to arrive at the best results in predicting DI, it has been suggested that evaluation of the tests be combined, but Tse et al. [39] found that using an oropharyngeal class 3, a TMD ≤7 cm, a head extension angle ≤80° or any combination of these factors failed to predict DI reliably. The combination of all these tests had the lowest Se. The PPV again had been low in predicting DI when the tests were used alone or in combination. A TMD ≤7 cm had a Se of 32 %, a Sp of 80 % and a PPV of 20 %, where as an oropharyngeal class 3 had a Se, Sp, PPV and NPV of 66, 65, 22 and 93 % respectively.

A combination of oropharyngeal class 3, and a TMD ≤7 cm had a Se of 21 % and a PPV of 28 % thus showing no improvement. Surprisingly, Frerk [48], reported that assignment to oropharyngeal class 3 or 4 had a Se of 81.2 % and a Sp of 81.5 %, and in the same vein reported still high figures of 81.2 and 97.8 % when using the oropharyngeal class 3 or 4 and a TMD ≤7 cm together. Tse et al. [39] however reported high NPV for all the tests alone and their combinations thus providing reassurance that negative results indicate truly easy intubation. Scoring systems such as the IDS [54], and the ADS [45], which include multiple variables are still subject to scrutiny to serve as methods of airway assessment.

El-Ganzouri et al. [42] concluded that application of the multivariate composite airway risk index stratifies the degree of difficulty encountered in visualizing the laryngeal structures better than any of the individual airway assessment criteria used to derive it. Although the Se and Sp are above 90 % for most patient groups, the predictive value is still limited. Arne et al. [25] describe a multivariate risk index for difficulty in intubation which has a high Sp, an improved Se compared to previous studies and minimal detection failure of difficult tracheal intubation thus minimizing false negatives. Despite promising characteristics, the only drawback of this study is that it performs poorly for PPV (30–50 %) which implies that DI is falsely predicted in 2 of 3 patients or 1 of 2 patients. This may result in more time expended or use of extra manoeuvres. Karkouti et al. [70] in their model found that MO, chin protrusion and atlanto-occipital extension had a Se of 86.8 % and a Sp of 96.0 % in predicting difficult tracheal intubation. In the ongoing search for a better

predictor of DI, Schmitt et al. [71] found that the ratio of height to TMD (RHTMD = Height (cm)/TMD(cm) had a better predictive value than the TMD. ≥25 cm can be used to predict difficult laryngoscopies in white men and women and suggested that it might not apply to other races. Krobbuaban et al. [72] using a multivariate analysis found that the tests using neck movement ≤80°, a Mallampati class 3 or 4 and RHTMD ≥23.5 were the major factors for predicting DL. This study was conducted on Thai patients suggesting that the RHTMD was equally applicable to other races and not exclusively restricted to the white race as upheld by Schmitt et al. [71].

In evaluating different multivariate models, Naguib et al. [73] found that their model had the highest Se compared to that of Arne et al. [25] and Wilson et al. [49] but the Sp of the models described by Arne et al. [25] and Wilson et al. [49] was significantly higher. The new prediction model described by Naguib et al. [73] considers the TMD, Mallampati score, IIG, and height. This model in which the TMD, IIG and height were measured in centimeters and Mallampati score as 0 or 1 had a high Se (82.5 %) and an equally high Sp (85.6 %).

A meta-analysis by Shiga et al. [75] evaluated beside tests for predicting DI, including the Mallampati classification, TMD, SMD, MO and the Wilson risk score. All these tests had poor to moderate discriminative power when used alone. In this study, the most powerful combination was the Mallampati classification and the TMD.

Another systematic review with a total of forty two studies enrolling 34,513 patients demonstrated that when used alone, the Mallampati class is insufficient to predict a DI. Accurate preoperative prediction cannot be realized with the available quantitative tests, which lack in Se and Sp, resulting in a low PPV for any single test [23].

In a study by Khan et al. [76] a combination of ULBT and the other tests did not show any superiority to the ULBT alone with regards to Sp and also did not enhance PPV, NPV and accuracy compared with those obtained with the ULBT alone. A combination of SMD and ULBT only improved the Se of ULBT when compared with the latter alone.

In another study, Khan et al. [77] compared the labiomandibular morphometry with cervico mandibular morphometry in order to test whether ULBT had a positive correlation with HMD, thyrosternal distance and the mandibular length. A significant agreement was found between the ULBT, HMD and mandibular length and the laryngoscopic view but no such agreement was found between thyrosternal distance and the laryngoscopic view. A stepwise increase in grade III and IV CLG was seen as the ULBT class showed a rise from I to II, and from II to III. A similar cascade of laryngoscope view was noted as the mandibular length and the HMD decreased from their predetermined values of 3.5 and 9 mm respectively. It can be concluded from this study that as the thyrosternal distance does not take into account the state of the oropharynx, thus it fails to be of help in predicting airway difficulty.

Common Limitations of the Test Parameters

The rate of difficult airway in the normal population has been estimated to be around 1:3000 [27]. With this rate, it is impossible for all the tests to be critically appraised in those patients, who truly have difficult airways. The skewed patient population under-represented in the difficult airway range makes the data collected for every tested parameter totally inadequate to represent the risk group concerned.

Whilst so much effort has been put into looking for the panacea of the problem, it must be acknowledged that the difficult airway probably represents a composite sum of many processes and factors interacting to make the process of intubation difficult. These result in the failure to find a truly representative method to predict a difficult intubation.

Conclusion

One of the most important challenges in using SMD, TMD, and IIG is the quantitative nature of these tests [76] whereas the classification of patients based on the ULBT is of a qualitative nature, making differentiation of class easy and precise. Moreover, the differences between the ULBT and the other tests are those between continuous and discrete variables. Thus, the ULBT is associated with the least inter observer variability, which adds to its advantage as an airway assessment test. Risk indexes again have been developed based on quantitative evaluations. Wilson et al. [49] developed a risk scoring system based on body weight, head and neck movement, jaw movement, and the presence or absence of mandibular recession and protruding teeth. The Naguib model [73] also considers quantitative variables such as TMD, Mallampati score, IID and height. The El-Ganzouri multivariate risk index combined and stratified seven variables derived from parameters and observations individually associated with DI [42].

Many researchers have delved deep into the matter by comparing different airway assessment tests but it is difficult to comprehend as to what degree this parallel and such comparisons are possible and fair.

Because of the very low occurrence of DI, it is exceedingly hard to predict it with a reasonable accuracy. Many investigators have expatiated on this subject extensively in order to find a panacea for the problem, but let us not forget that the causes of a difficult airway are usually infinitively more complex and more various than we are in the habit of explaining them afterwards, and are seldom clearly outlined. What I am leading up to is an earth shattering conclusion that it is beyond our intellect and comprehension to guess our way to the truth of very many things about the human airway.

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