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Review Article

A Comprehensive and Analytical Review of the Airway Pathology, Assessment, and Management

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ABSTRACT

The human airway has since long remained a subject of debate and controversies; thus, to arrive at a subtle and acceptable solution, airway assessment tests, innovative techniques, and devices have been introduced to solve the enigma. Although human endeavors have made significant advances since time immemorial, the difficult airway still poses a major challenge even in the best of hands and the best centers.

Inhale the constellations, pure and white,
let galaxies swirl in every breath,
A cosmic waltz defying death.

Eric Daniel Fjelde Ondrieko

Introduction

Difficult airway (DA) remains challenging in clinical practice, and repeated intubation attempts usher in a plethora of adverse events such as brain damage and death [12]. Tracheostomy can be traced back to ancient Egyptian and Indian civilizations [3-4].

Alexander used the tip of his dagger to make a tracheal incision in a soldier who was suffocating [5]. Whether it is a myth or a real historical version is not clear. Antyllus described a tracheostomy as a horizontal incision between two tracheal rings to bypass airway obstruction [6].

Although it is beyond our comprehension to unveil all the information about the human airway, nevertheless, an attempt has been made to bring to lime light the advances made in the past coupled with the latest innovative techniques and appliances introduced in overcoming the highly dreaded entity of the DA.

Discussion

To give full justice and unveil the subject of DA, the discussion section has been split and discussed under separate subheadings as follows:

A. A Running History of the Airway

Except Rhazes, who is said to have performed a tracheostomy, other medieval Islamic physicians did not perform it. Again, it is doubtful whether Albucasis ever performed a tracheostomy, but he treated a maid who had cut her throat and the windpipe with a knife by exploring the wound and suturing it. Another physician and a stalwart of medicine from the Islamic world performed a

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tracheostomy on a goat [7]. There is also no evidence in the contemporary literature that Galen ever performed a tracheostomy on humans. Asclepiades is being credited as the originator of the tracheostomy. Antyllus, who lived in the second century, was the next to perform a tracheostomy. After a lapse of fourteen centuries, there were no substantial advances. Before 1800, only 50 tracheostomies were performed. The technique was popularized by Trousseau with his landmark experiences with 200 diphtheria patients [8]. Then came a new era when William Macewen relieved airway obstruction by passing an oral tube into the trachea [9], and Joseph O'Dwyer blindly used a metal tube in the trachea to relieve airway obstruction in children suffocating from diphtheria [10]. The O'Dwyer tube system comprised a flexometallic endotracheal tube with a matching introducer to conduct blind insertion [11]. Later in 1855, Manuel Garcia performed autolaryngoscopy through the use of a dental mirror together with another mirror to direct sunlight into his mouth and thus allowed him to see his larynx and trachea [12]. Years later, in 1941, Robert Miller introduced his straight laryngoscope blade, followed shortly in 1943 by Robert Macintosh's new innovation, a curved blade, which made a tremendous breakthrough in airway management. Bannister and Macbeth introduced the concept of axes of alignment in 1944 [15]. The traditional sniffing position (SP) is recommended for direct laryngoscopy with the Macintosh laryngoscope [14]. It is believed that it provides the best optical visualization and the axes of alignment [15], which not only provided an acceptable rationale for SP but was in fact the basis for its introduction. However, a controversy persists regarding the best head and neck position for glottis visualization and endotracheal intubation, as propounded by Adnet et al. [16].

B. Airway Pathology and Its Inherent Risks in Airway Management

The sphincteric protective function is the oldest phylogenetic function of the larynx, which has evolved and developed from aquatic amphibian predecessors. The constrictor mechanism of the larynx imparts it an effective and rapid closure that prevents food, liquid, and other foreign material from entering the lower airway. Apart from that, the vocal cords have a vibratory effect on the expiratory air column and produce a sound used in voice production. An endotracheal tube passed through the larynx inevitably interferes with all these laryngeal functions. Thus, as a result, the intubated patient experiences loss of voice and possible aspiration of foreign material into the airway. Foreign material such as secretions that are aspirated may trickle down into the lungs, causing atelectasis and infection and, if not noticed or timely treated may end up in death. The presence of an endotracheal tube also prevents the production of an adequate cough, thus potentiating the aforementioned complications. Patients in the intensive care unit are especially prone to developing such complications if vigilant and timely care and toilet of the airway are not performed. Malignancies in the upper airway that include the base of the tongue, nasopharynx, pyriform fossa, epiglottis, or vocal cords will usually require a surgical airway such as a tracheotomy or cricothyrotomy. It is recommended that in such situations, intubation should only be attempted in the presence of a surgeon because malignancies in these locations make intubation not only difficult but also able to lead to profuse bleeding, as the tumors are highly fragile. Sedatives, respiratory depressants, and muscle relaxants should altogether be avoided. Fiberoptic intubation can be particularly dangerous due to the tumor's fragility, especially if it is already bleeding. Simultaneously, the distortion of the airway anatomy can significantly hinder the visualization of the glottis aperture. Furthermore, in patients who are not cooperative or are in respiratory distress, fiberoptic intubation for securing the airway should be avoided [17]. Studies have indicated that there is no survival benefit in performing emergency laryngectomy for patients with carcinoma of the larynx. Such patients should preferably undergo tracheotomy and their elective procedure postponed to another date [18-19]. It appears that for patients in distress and who cannot lie supine for tracheostomy, stab cricothyrotomy can be life-saving. For lesions in the distal airway, intubation and tracheostomy are essentially useless to alleviate the distressing symptoms. On the contrary, a rigid bronchoscope has been found to be of help in patients with central airway obstruction. The rigid bronchoscope can relieve the obstruction due to a blood clot or fragments of the tumor. The bronchoscope can keep the airway open if the lower airway obstruction is from an extrinsic cause [20]. The rigid bronchoscope not only provides a secure patent airway permitting excellent and reliable control of oxygenation but also, at the same time, creates a channel through which several instruments can be passed. As far as the children are concerned when they present with acute airway obstruction, endotracheal intubation is the preferred option even in an emergency situation. They should preferably be intubated while being awake and breathing spontaneously, because once the breathing is lost because of drugs, a DA scenario may set in [17].

C. Airway Assessment Tests

It is important that we should make an effort to identify both anatomical difficulties and physiological difficulties, as both are of value in preventing any unanticipated airway difficulties. Numerous airway assessment tests have been proposed to identify a

potentially difficult airway (DA), but since these tests lack high sensitivity (Se), caution should be exercised when interpreting their results. Some of the tests have high false positive (FP) values, which impel us to take extra precautions in terms of variability of various tools and gadgets, etc., but it is a high false negative (FN) value that should be feared most because that could entail disastrous repercussions.

Customarily, patients with a potential DA are those with a modified Mallampati class (MMC IV) (Figure 1) [21], an interincisor distance (IID) < 4 cm [22-23], a thyromental distance (TMD) < 6 cm [24], buck teeth, a body mass index (BMI) > 30 kg/m² [25], poor dentition, and an upper lip bite test (ULBT) > 2, (Figure 2) [26].

Figure 1- Schematic classification of the pharyngeal structures based on Samsoon and Young's modification of the original Mallampati classification.

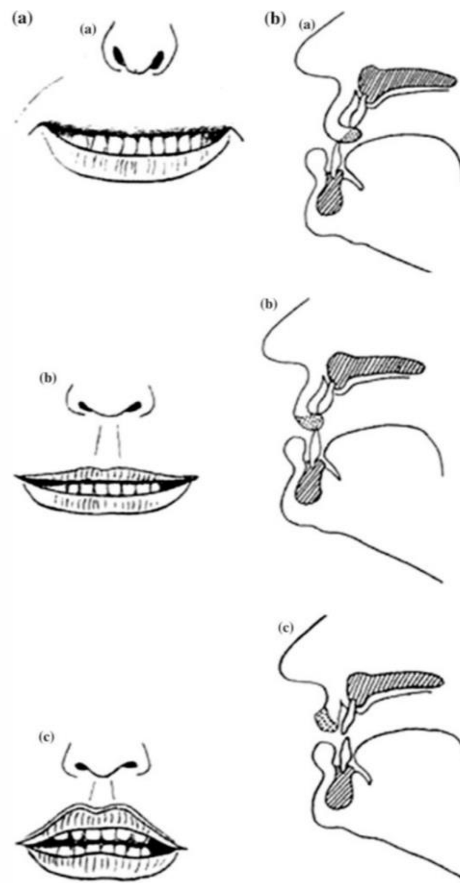

Figure 2- Frontal and lateral views of the upper lip bite test (Reproduced from Khan et al.) A comparison of the upper lip bite test (a simple new technique) with modified Mallampati classification in predicting difficulty in endotracheal intubation: a prospective blinded study. Anesthesia and Analgesia 2003; 96: 595–9 by permission. (Copyright 2003, Philadelphia, Lippincott Williams and Wilkins).

(Figure 1) [21] Class I: Soft palate, fauces, entire uvula, and anterior and posterior pillars visible Class II: Soft palate, fauces, and uvula are visible. Class III: Soft palate and base of uvula visible Class IV: Only hard palate visible Classes I and II were considered predictive of easy intubation, whereas Classes III and IV were considered predictive of difficult intubation.

(Figure 2) [26] 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. Classes I and II were considered predictive of easy intubation, and Class III was considered predictive of difficult intubation [26].

In addition to the existing airway assessment tests, American Society of Anesthesiologists (ASA) guidelines also recommend the ratio of neck circumference to TMD, the ratio of height to TMD, hyomental distance, and the use of ultrasound for airway assessment [27].

Unfortunately, all the available tests of investigation have relatively low Se and high variability. The ULBT has shown favorable diagnostic accuracy (Ac) and seems to be a reliable predictor of difficulty (28). Again, among the assessment tests, the ULBT was both of value in predicting difficulty using direct laryngoscopy and difficult mask ventilation [26,29-35].

D. Virtual Endoscopy

Endoscopic airway examination has been recommended to avoid the risks that may be encountered in case of difficulty [36]. Virtual endoscopy is indispensable, which entails computed tomographic images, thus enhancing our knowledge about any airway pathology that may be missed by other available tests [37].

E. Ultrasound Examination

Ultrasound examination is also being of value in the assessment of the airway as it predicts airway thickness and the distance of the skin to the epiglottis (DSE). It has been shown that a tongue thickness of greater than 6.1 cm and a DSE > 2–2.5 cm can both serve as independent predictors of difficult laryngoscopy [38,39]. Ultrasound assesses the anatomy of the neck and airway and identification of the cricothyroid membrane during emergency situations [40-41].

F. Devices and Innovative Techniques

The supraglottic airway devices (SADs) have served to achieve tracheal intubation using a flexible bronchoscope. However, it should be remembered that an IID of at least 2 cm is required to insert a laryngeal mask airway [31]. Also recommended are non-invasive ventilation (NIV) or high-flow nasal oxygenation (HFNO) in high-risk patients to increase oxygen reserves. Apnoeic oxygenation can be achieved by increasing the flow rate to 15 L/min through a nasal cannula. During the apnoeic state, an inspired oxygen concentration (FiO_2) of almost 100% can be achieved using this method, which can be of benefit in managing the difficult airway [42-43].

For all purposes and intents, the indirect laryngoscopes provide better laryngeal views compared with the widely used Macintosh laryngoscope and thus are associated with negligible dental trauma. As the endotracheal tube (EET) is self-geared to the glottis while using the Airtraq, apparently few psychomotor skills are involved in its acquisition [44]. In a manikin study [45], GlideScope, McGrath, and Airtraq laryngoscopes were compared with the direct laryngoscope using a Macintosh blade. In this study it was found that the time taken to place the ETT was shorter for the Airtraq than the Glidescope and McGrath.

G. Multivariate or Composite Variables and Airway Risk Indexes

It appears that the DA is a Pandora's box and represents a composite of many factors interacting to make the process of endotracheal intubation difficult. Because of the low occurrence of difficult intubation, it is exceedingly difficult to predict it with reasonable Ac. The setback in most of the tests has been their Se, Sp, positive, and negative predictive value to allow accurate prediction of the possibility of difficult intubation. The combination of the tests has not improved the various attributes to improve Ac [34].

The anatomical indexes associated with the Mallampati score failed to improve Se and PPV [46]. Similarly, the Mallampati score, TMD, and cervical immobility were found to have little value in predicting DA [47]. Merah et al. [48] found a Se and Sp of 85% and 98%, respectively, when using a combination of Mallampati 3 or 4, an IID of 4 cm or less, and a TMD of 5 cm or less for predicting difficult intubation. Shiga et al. [49], in a meta-analysis, evaluated the Mallampati score, TMD, SMD, IID (mouth opening), and the Wilson risk score for predicting difficult intubation.

All the tests showed poor to moderate discriminative power when used alone. However, the most powerful combination was the Mallampati score and the TMD in this study. Patients may inadvertently phonate during the Mallampati test and thus increase false positives. It may be of value as part of a multivariate model for the prediction of difficult laryngoscopy and intubation [35].

A disadvantage of the MMC is that phonation may erroneously show a lower class and thus a false negative impression, which could be disastrous [50]. Other studies have also come up with different results, but no tentative results could be obtained. Accurate preoperative predictions cannot be achieved using the available

quantitative tests, as these tests lack sufficient sensitivity (Se) and specificity (Sp), leading to a low positive predictive value (PPV) for any individual test [51].

Krobbuban et al. [52], using a multivariate analysis, found that tests using neck movement ≤80%, a Mallampati class 3 or 4, and the ratio of height to TMD (RHTMD = Height (cm)/TMD (cm)) > 23.5 cm were the major factors for predicting difficult direct laryngoscopy. Scoring systems such as the intubation difficulty scale (IDS) and the airway difficulty score (ADS), which include multiple variables, are still subject to scrutiny [53-54].

Numerous studies have introduced multifactorial indexes [55-58], but they entail time to execute and, moreover, do not add much to our knowledge about the DA. They may be of academic value. We need a test that is quickly performed and does not have any inter-observer variability. Most of the tests and the risk scoring models are of a quantitative nature, whereas the ULBT is of a qualitative nature, thus giving it a degree of superiority compared to the other available tests. An added benefit of ULBT is that it assesses a combination of back teeth and subluxation simultaneously [26]. A combination of ULBT and other tests failed to show any superiority to the ULBT alone regarding Sp and also did not enhance PPV, NPV, Ac compared to those obtained with the ULBT as the sole test.

However, a combination of the sternomental distance (SMD) and ULBT improved the Se of ULBT when compared with the latter alone [31]. While comparing the labio-mandibular morphology with cervico-mandibular morphometry in order to test whether the ULBT had a positive correlation with hyomandibular distance (HMD), thyrosternal distance (TSD), and mandibular length (ML), a significant agreement was found between the ULBT, HMD, and ML and the laryngoscopic view, but no such agreement was found between the TSD and the laryngoscopic view [32]. The incidence of difficult intubation (DI) varies between studies, ranging from 0.05 to 18% [58-59]. DI has commonly been defined as repeated attempts at intubation, the use of a bougie, or other intubation aids, but the widely used grading is that of Cormack and Lehane [60], which describes the best view of the larynx visualized at laryngoscopy (Figure 3). This grading is universally abbreviated as the Cormack-Lehane grading (CLG), which has played a significant role in the execution of most research studies.

CLG is widely used to assess the glottis view as appears in (Figure 3). Grade I: Most of the glottis is visible. Grade II: Only the posterior part of the glottis and epiglottis are visible. Grade III: Only the epiglottis is visible. Grade IV: Neither the epiglottis nor the glottis is visible.

Conclusion

Having said that, a subtle and logical conclusion is hard to make regarding forecasting a difficult airway well in advance. To grasp the salient features in clinical research is to demarcate between prediction, probability, prophecy, and forecast.

The distinction between probability and prediction is that the former is built on a collection of data and ranges from exceedingly improbable to incredibly likely, whereas the latter is essentially based upon knowledge or experience of forecasts. A prediction customarily is a rigorous, quantitative statement, forecasting what could be observed under specific conditions, whereas a forecast, on the other hand, is definitive and will either be correct or wrong. Predictions that are not based on solid facts cannot be believed.

In the movie Matrix, the Oracle can see the future because of its powers to speak the prophecies of Apollo.

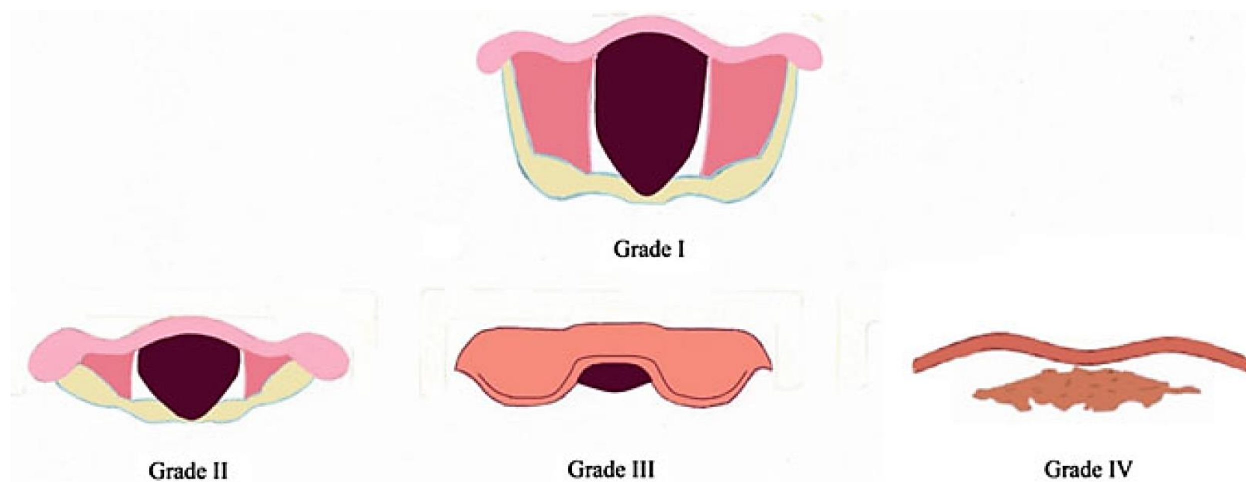

Figure 3- Schematic Cormack-Lehane Grading of the laryngoscopic views. Grade I: Most of the glottis is visible. Grade II: Only the posterior part of the glottis and epiglottis are visible. Grade III: Only the epiglottis is visible. Grade IV: Not even the epiglottis is seen.

However, the reason the Oracle could forecast the future is that the machines kept the humans blissfully unaware, thus creating a virtual reality created by the often-used word "artificial intelligence." Nostradamus, a French astrologer, made predictions about the future, some of which turned out to be true. We neither have the Oracle's powers to predict the future nor Nostradamus's wisdom to make predictions about it; thus, as clinicians, we should use predictions that involve using statistical models to estimate the value of a dependent variable based on one or more independent variables. It could either be interpolation, which is based on observed data, or extrapolation, which forecasts beyond observed data. To be honest, at present a perfect airway tool does not exist; thus, an unanticipated difficulty will continue to occur.

Thus, it is pragmatic to use multiple tests in predicting difficulty in airway management rather than using a single test in isolation. Future trends of airway management would definitely include the role of artificial intelligence in the recognition of the dreaded scenario of an unanticipated difficult airway.

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