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Research Article

A CORRELATION OF ULTRASONOGRAPHY GUIDED PARAMETERS TO THE CORMACK-LEHANE GRADE FOR DIFFICULT LARYNGOSCOPY AND INTUBATION

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Abstract

Background and aim: The appearance of laryngeal inlet on direct laryngoscopy is best described by the Cormack Lehane grade of laryngeal view. Difficult laryngoscopy is most commonly defined as presence of grade 3 and 4 view on laryngoscopy. Incidence of difficult laryngoscopy and endotracheal intubation ranges from 1.5% to 13%. The ultrasonographic assessment of upper airways has potential of predicting difficult laryngoscopy and has encouraging results in predicting difficult laryngoscopy in preoperative period.

Materials and Methods: The prospective observational study was conducted among 135 patients scheduled for elective surgery requiring general anesthesia and intubation. The depth of pre-epiglottis space (Pre-E), the distance from the epiglottis to the midpoint of the distance between vocal cords (E-VC) was measured ultrasonographically with neck in extended position. The primary outcome was the efficacy of Pre-E/E-VC ratio for predicting difficult laryngoscopy (Cormack–Lehane [CL] Grade 3, 4). The secondary outcome was to correlate these parameters to CL grading.

Results: Out of a 135 patients, difficult intubation was observed in 8.14%. The mean ± standard deviation (SD) of Pre-E/E-VC ratio was 0.59 ± 0.31, 0.66 ± 0.28 and 0.79 ± 0.31 for CL Grade 1, 2 and 3 respectively. Pre-E/E-VC ≤0.64 cm had sensitivity of 90.91% and specificity of 73.39% for predicting easy laryngoscopy with PPV and NPV of 3.41 and 0.12 respectively.

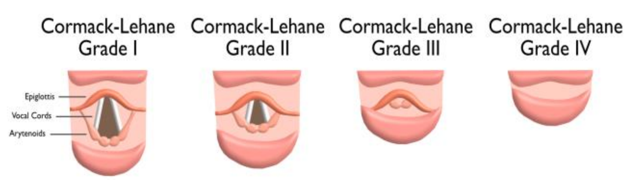
Conclusion: The ultrasonographic measurement of Pre-E/E-VC ratio is a good predictor of CL grading. The non-invasive prediction of CL grading can be precisely done by Pre-E/E-VC ratio (range: 0.13-2 corresponds to CL Grade 1; 0.29-2 corresponds CL Grade 2 and 0.28 -1.61 corresponds to CL Grade 3 respectively).

Keywords: Difficult laryngoscopy and intubation, pre-epiglottis space, epiglottis-vocal cord distance, Cormack Lehane, general anesthesia, ultrasonography

INTRODUCTION

Safe Airway management has been a challenge in anesthesiology because airway related morbidity occurs as a result of inability to anticipate difficult airway. Despite remarkable progress in the technology in this regard with a huge armamentarium to aid anesthesiologist, difficult airway (DA) remains a significant concern and airway related critical events are the leading cause of anesthesia related morbidity and mortality.[1] Unanticipated DA continues to be encountered even after airway assessment with clinical tests.[2] Incidence of difficult Laryngoscopy and endotracheal intubation ranges from 1.5% to 13%.[3] A difficult airways is the one where patient will be hard to mask ventilate or intubation is likely to fail.[3] ASA Task Force on Management of the Difficult Airway defines difficult tracheal intubation as follows: 'when proper insertion of the tracheal tube with conventional laryngoscopy requires more than three attempts or more than 10 min.[4] That definition belongs to the 1993 ASA guidelines.[5] In the 2003 updated report, the ASA Task Force has revised the old numerical definition and now defines difficult tracheal intubation simply as 'requiring multiple attempts'. Airway assessment in a patient requiring airway management should be done quickly and efficiently. One of the parameters for predicting difficult airway is the appearance of laryngeal inlet on direct laryngoscopy which is best described by the Cormack Lehane grade of laryngeal view. Presence of grade 3 and 4 view on direct laryngoscopy has been regarded as difficult laryngoscopy.[6] This is an invasive procedure that cannot be performed in an awake patient or for pre-anaesthetic airway assessments in patients with no prior history of tracheal intubation. Recently, non-invasive parameters are being primarily focused in airway assessment. Ultrasound has been successfully used for several airway-related applications. In comparison between direct visualization of airway structures and USG parameters, good correlations was found in the two modalities.[7] In recent studies, ultrasound (US) measurement of depth of the pre-epiglottis space (Pre-E)/distance from the epiglottis to the midpoint of the distance between the vocal cords (E-VC) done in the preoperative period has been shown to correlate with the Cormack–Lehane (CL) grading.[8]

There are many anatomical and clinical parameters for evaluating the feasibility of tracheal intubation. The anatomical parameter include Cormack-Lehane (CL) classification done during direct laryngoscopy whereas clinical parameters that are introduced with regard to evaluation of the patient's airway before induction of anesthesia, includes Mallampati classification, mouth-opening size, thyromental distance, neck extension, jaw protrusion and the upper-lip bite test. Among these the Cormack-Lehane classification is the one that can reliably predict a difficult intubation.[9] The Cormack-Lehane system is an invasive procedure that classifies views obtained by direct laryngoscopy into four grades based on the structures seen.[10] It was initially described by R.S. Cormack and J. Lehane in 1984.



Firure 1: Cormack-Lehane Grades for laryngeal view during direct laryngoscopy.[11]

A modified version that subdivided Grade 2 was initially described in 1998.[12]

Modified Cormack-Lehane classification.[9,13]

Grade	Description	Approximate frequency	Likelihood of difficult intubation
1	Full view of glottis	68-74%	<1%
2a	Partial view of glottis	21-24%	4.3-13.4%
2b	Only posterior extremity of glottis seen or only arytenoid cartilages	3.3-6.5%	65-67.4%
3	Only epiglottis seen, none of glottis seen	1.2-1.6%	80-87.5%
4	Neither glottis nor epiglottis seen	very rare	very likely

First published in 1984, it has since become the gold standard for airway classification in clinical practice and in airway-related research.[3,9,14,15] Although 89% of interviewed subjects claimed to know a classification to describe laryngeal view during laryngoscopy, 53% were able to name a classification. When specifically asked about the CL classification, 74% of the interviewed subjects stated to know this classification, whereas 25% could define all four grades correctly.[9]

Though various parameters are available for airway assessment, the inability to predict difficult airways is probably due to high inter-observer variability and low predictability of commonly used airway assessment screening tests.[16-17] Even though CL grading is one of the most widely used classifications for prediction of difficult intubation, one major drawback is that it cannot be applied for predicting difficulty in tracheal intubation in patients undergoing intubation for the first time. Direct laryngoscopy is simply too invasive of a technique to be used to assess and classify an airway in an awake patient.[16] However, despite careful airway assessment, direct laryngoscopy sometimes results in unanticipated poor laryngeal views.

Currently, the role of ultrasound (US) in anesthesia-related airway assessment and procedural interventions is encouraging. Ultrasound imaging is a safe, simple, painless, and non-invasive modality through which soft tissues can be visualized and identified.[16] The application of Ultrasonography (USG) is increasing exponentially over time in emergency, critical care and perioperative settings. It is increasingly being used as a powerful adjunct in airway assessment and management.

Basic Principles of Ultrasound:

History of Ultrasound:

1880: Pierre and Jacques Curie discovered about the piezoelectric effect in crystals.

1942: Karl and Dussik described ultrasound used as a medical diagnostic tool in an attempted to locate brain tumours and the cerebral ventricles by measuring the transmission of ultrasound beams through the head.

1978: P. La Grange published ultrasound application for placement of needles for nerve blocks.

1989: P. Ting and V. Sivagnanaratnam used USG to demonstrate the anatomy of the axilla and observe the spread of local anaesthetics during axillary block.

1994: Steven Kapral and colleagues explored brachial plexus blockade using B-mode ultrasound.

Sound is a wave of energy that, unlike x-rays, must be transmitted through a medium. Sound waves can be described by their frequency, wavelength, and velocity. The frequency is the number of cycles or waves that are completed every second, and the wavelength is the distance needed to complete one wave cycle. The frequency of the sound waves used in ultrasonography is well above the limit of the human ear (20,000 kHz) — usually in the range of 2 to 12 MHz (2 to 12 million Hz).[18]

The following equation demonstrates the relationship between frequency, wavelength and velocity: Velocity (m/sec) = Frequency (cycles/sec) x Wavelength.[19]

An inverse relationship exists between the frequency and the wavelength of a sound wave: higher the frequency, shorter the wave length. Higher-frequency ultrasound waves create higher-resolution images, but their shorter wavelength makes them unable to penetrate deeper tissues. Lower-frequency waves have better penetrating power, but because of their longer wavelengths, their resolution is lower.

Velocity of sound is 331 m/sec in air and 4,080 m/sec in bone.[20] Within the soft tissues of the body, it is considered to be steady at about 1,540 m/sec.[21]

Generation and formation of image in ultrasound is based on two basic principles. The first is the piezoelectric effect, which explains how ultrasound is generated from ceramic crystals in the transducer.[18] An electric current passes through a cable to the transducer and is applied to the crystals, causing them to deform and vibrate. This vibration produces the ultrasound beam. The frequency of the ultrasound waves produced is predetermined by the crystals in the transducer.

The second key principle is the pulse-echo principle, which explains how the image is generated.[22] Ultrasound waves are produced in pulses, not continuously, because the same crystals are used to generate and receive sound waves, and they cannot do both at the same time. In the time between the pulses, the ultrasound beam enters the patient and is bounced or reflected back to the transducer. These reflected sound waves or echoes, cause the crystals in the transducer to deform again and produce an electrical signal that is then converted into an image displayed on the monitor.

Transducers:

Transducers are first classified as linear or sector, according to the arrangement (array) of the crystals and the shape of the imaging field produced on the monitor. In a linear transducer, the crystals are oriented in a straight line, producing a rectangular image in which both the near and far fields are wide. Linear transducers provide superior resolution of near-field structures.

Sector transducers contain curvilinear arrays of crystals that produce a fan- or pie-shaped image with a narrow near field and wider far field, which is helpful in imaging deeper structures. These transducers have a rounded or convex curve to their surface.[23,24]

Figure 2: Ultrasound Probe.[25]

Uses of Ultrasound in Airway:

Ultrasound can visualize anatomical structures in the supra-glottis, glottis and subglottic regions.[26] Oral and nasal cavities, pharynx, larynx, and trachea are nearly completely filled with air. However, various other structures can be visualized in relation to their anatomic location. Ultrasound has been evolving as a useful device for airway assessment to predict difficult intubation.[25-27] US has become the potential first-line non-invasive airway assessment tool in anesthesia and intensive care practice.[26] US can provide dynamic anatomical assessment which is not possible by clinical examination alone. US can help in confirming the correct tracheal tube placement by dynamic visualization of the endotracheal tube insertion, widening of vocal cords.[25] In the last few years, there have been some reports and a study that described various roles of US imaging in airway management.[26] It is widely available, portable, repeatable, relatively inexpensive, pain-free, and safe.[27-28] Ultrasonography (USG) of the upper airway is capable of providing detailed anatomic information and has numerous potential clinical applications.[25,27,29-30] Airway USG can be used to predict and calculate the appropriate size (diameter) of endotracheal, endobronchial, double lumen, or guide percutaneous tracheostomy tubes.[31-32] It is also used to assess at the time of weaning from ventilator and to rule out airway related emergencies like pneumothorax.[16,33] Researchers have hypothesized that increased anterior neck soft tissue thickness could impair the forward mobility of the pharyngeal structures so, it can be measured using ultrasound and airway can be assessed.[34-35]

Sonoanatomy of Upper Airway:

Epiglottis (E) in the transverse and parasagittal views through the thyrohyoid membrane (THM) is visible as a hypoechoic curvilinear structure.[27] [figure 3 and 4]. Its anterior border is demarcated by the hyperechoic pre-epiglottic space (PRE-E) and its posterior border by a bright linear Air-mucosal interface (A–M interface). Any interface between the mucosa lining the upper airway and the air within it produces a bright hyperechoic linear appearance. Epiglottis can be easily identified in almost all individuals in the transverse plane with a varying cephalad or caudad angulation of the linear transducer. Due to acoustic shadowing by the hyoid bone, it is not easy to visualise epiglottis in the parasagittal plane. Extended submandibular sagittal view (between the hyoid bone and mentum) using a curved transducer can also identify epiglottis [Figure 5]. Identification of the epiglottis can be facilitated by tongue protrusion and swallowing, when it becomes visible as a discrete mobile structure inferior to the base of the tongue.[27]

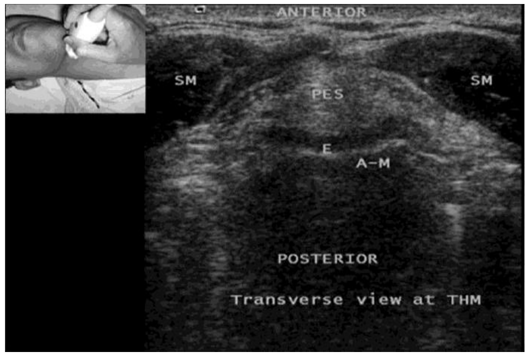


Figure 3: Transverse view at thyrohyoid membrane (THM). E = Epiglottis, A–M = Air–mucosal interface, PES = Pre-epiglottic space, SM = Strap muscles.[26]

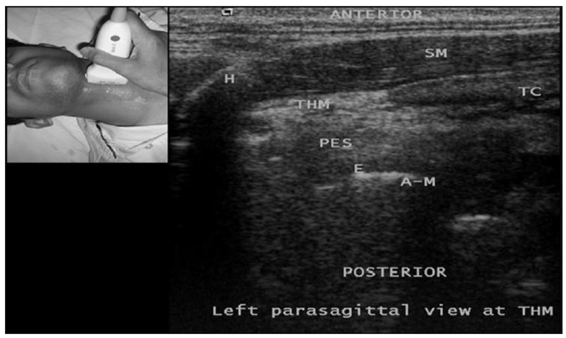


Figure 4: Left parasagittal view at thyrohyoid membrane (THM). H = Hyoid bone, SM = Strap muscles, THM = Thyrohyoid membrane, TC = Thyroid cartilage, PES = Pre-epiglottic space, E = Epiglottis, A–M = Air mucosal interface.[26]

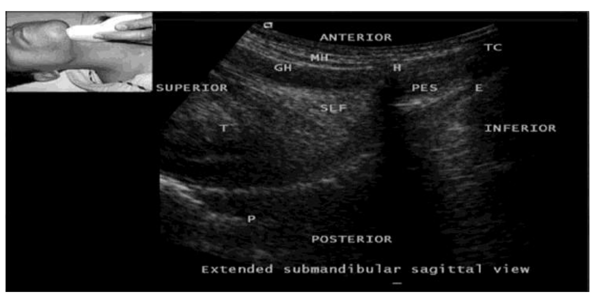


Figure 5: Extended submandibular sagittal view using a curved transducer. T = Tongue, H = Hyoid bone, E = Epiglottis, GH = Geniohyoid, MH = Mylohyoid, PES = Pre-epiglottic space, P = Palate, TC = Thyroid cartilage.[26]

Thyroid cartilage (TC) provides the best window to view the vocal cords. Vocal cords are seen forming an isosceles triangle with a central tracheal shadow. Vocal cords are delineated medially by the hyperechoic vocal ligaments (VL).[27,36] The false vocal cords (FC) lie parallel and cephalad to the true cords and are more hyperechoic in appearance [Figure 6]. During phonation, the true cords oscillate and move towards the midline when compared to the false cords, which remain relatively immobile. Vocal cord movement can be better visualised with a 3D probe with fluid interface (water bath) between the 3D probe and skin [Figure 7].

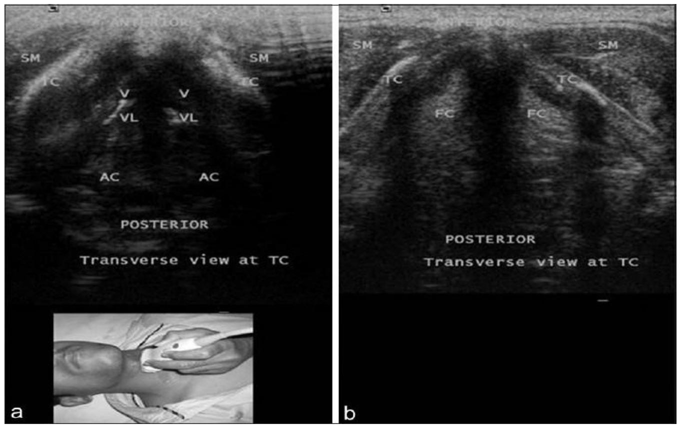


Figure 6: (a) Midline transverse view at hyoid. (b) Transverse view at cricoid cartilage. SM = Strap muscles, TC = Thyroid cartilage, AC = Arytenoid cartilage, VL = Vocal ligament, V = Vocal cord, FC = False cord.[26]

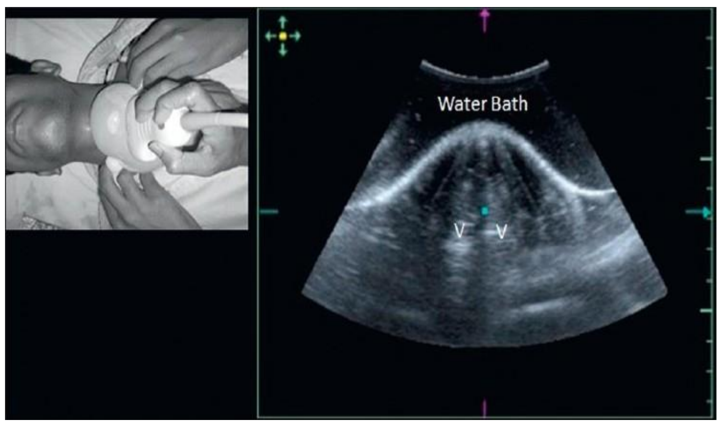


Figure 7: Vocal cords view with 3D probe with fluid interface (water bath) between probe and skin. V = Vocal cord.[26]

Airways US uses	**Comment**
Predict difficult airway	Shown to be useful in obese patient
Diagnosis airway anomalies	Can diagnose vocal cord malformation, Laryngeal stenosis, papillomatosis, maxillary sinusitis, tumor or zenker's diverticulum
Identify cricothyroid membrane	Can be useful in case emergency cricothyroidotomy is needed for oxygen insufflations by prophylactic placement of transtracheal catheter, topicalization and retrograde intubation
Estimation of gastric volume and nature of contents prior to airways management	Especially useful in the emergency cases when history is not available and emptying is variable. Cross-section at the level of antrum is reliable and nature of contents(particulate or liqiud) can be assessed
Airway related nerve blocks	Preparation of awake intubation in case of anticipated DA. Superior laryngeal and recurrent laryngeal nerve increase success and safety

Predict sleep apnea	Approximation of tongue base posterior and inferior towards the hypo pharynx correlates with airways obstruction
Predicts suitable diameter of ETT and tracheostomy tube	Prediction of ETT size especially in pediatrics to decrease tube changes.
Detect esophageal intubation	Detect esophageal intubation before ventilation is initiated and is useful in cardiac arrest situation when capnography is not reliable
Detect endobronchial intubation	A bilateral presence of lung sliding and diaphragm descend in noisy environment where it is difficult to listen to stethoscope
Localize trachea and tracheal ring interspaces for tracheostomy and PDT	Real time US improves the success and safety by identifying aberrant vessels in path and appropriate depth of insertion

Table 1: Clinical application of airway ultrasound in DA management.[37]

Role of Usg in Management of Difficult Airway:

Recognition of difficult airway is purported to be the most important factor in successful management of difficult airway. Regarding difficult airway prediction recently a lot of sonographic parameters have been suggested as useful like soft tissue thickness anterior to trachea, tongue base width, volume and cross-sectional area of tongue, thickness of lateral pharyngeal wall, hyomental distance ratio, DSHB – distance between skin and hyoid bone, DSEM – distance between skin and epiglottis and pre-epiglottis space, distance between epiglottis and midpoint of vocal cord.

Prediction of Difficult Laryngoscopy Ion Difficult Patient:

US measurement of anterior neck soft tissues helps in predicting difficult laryngoscopy in obese patients. The distance from the skin to the anterior aspect of the trachea is measured at three levels: Vocal cords, thyroid isthmus, and suprasternal notch. The amount of soft tissue at each level can be calculated by averaging the amount of soft tissue in millimeters obtained in the central axis of the neck and 15 mm to the left and right. it was found that pre-tracheal soft tissue at the level of the vocal cords is a good predictor of difficult laryngoscopy in obese patients. Patients who had more pretracheal soft tissue (28 mm) and a greater neck circumference (50 cm) at the level of vocal cords had difficulty in laryngoscopy.[34]

Role of Ultrasound in Percutaneous Dilatational Tracheostomy:

Accurate identification of anterior neck structures during percutaneous dilatational tracheostomy can eliminate potential dreaded complications like haemorrhage, tracheal stenosis, erosion into high mediastina vessels and injury to the thyroid isthmus.[38]

Assessment of the Diameter of the Subglottic Upper Airways and Prediction of Endotracheal Tube Size:

Ultrasonography has emerged as a reliable tool for assessing the narrowest diameter of the cricoid lumen (transverse diameter) compared the transverse diameter of the cricoid lumen assessed by ultrasonography and magnetic resonance imaging in healthy young adults and found it a reliable tool to assess the diameter of the subglottic upper airway. Age-dependent calcification of the laryngeal cartilages begins to occur in the third decade of life, creating an acoustic shadow, an important limitation of laryngeal ultrasonography in older patients.[31] In paediatric patients, subglottic upper airway diameter measured by ultrasonography is a good predictor of correct cuffed and uncuffed ETT sizes.[39]

Prediction of Post-Extubation Stridor:

Laryngeal ultrasonography is a useful noninvasive tool for the evaluation of vocal cords and laryngeal morphology in intubated patients. The air-column width measured by US may potentially identify patients at risk for post-extubation stridor, in whom caution should be exercised after extubation.[40-41] It was found that after cuff deflation, an air-column width of 4.5 (0.8) mm was associated with post-extubation stridor while patients who did not develop stridor had an air-column width of 6.4 (2) mm.[26]

Elective Transtracheal Cannulation and Emergency Cricothyroidectomy:

Successful location of the trachea plays an important part in managing the difficult airway for both elective and emergency cases. US imaging helps to identify the trachea prior to both elective transtracheal cannulation and emergency cricothyrotomy.[42-43] This is particularly helpful in situations where localising the trachea is difficult due to neck mass or any other swelling, for example, huge thyroid swelling, Ludwig's angina, etc.

Ultrasound Guided Upper Airway Anesthesia to Facilitate Awake Intubation:

Superior laryngeal nerve, located between the hyoid bone and thyroid cartilage, can be easily visualised on transverse ultrasonographic section across the hyoid bone. The membrane between the hyoid bone and thyroid cartilage is an isoechogenic line (with hyperechogenic air below) from both sides of the hyoid bone.[44-45]

Endotracheal Intubation, Esophageal Intubation and Double-Lumen Bronchial Tube (Dlt) Placement:

Most frequently used methods of confirmation of endotracheal intubation are auscultation of chest, end-tidal carbon dioxide detection and by oesophageal intubating devices. US imaging can visualise the motion of the diaphragm and pleura indicating lung expansion, an indirect but dynamic anatomic evidence of the correct physiologic function of the ETT in paralysed or apnoeic patients. Bilateral equal motion of the diaphragm towards the abdomen can be seen by US if the ETT is inside the trachea. Further, with intercostal ultrasonographic view at the lung–chest wall interface, "to-and-fro" movement of the pleura synchronised with ventilation (lung-sliding sign) can be visualised.[46,47,48]

Oesophageal intubation will result in an immobile or paradoxical state of the diaphragm. Ventilation through oesophageal-positioned ETT can also result in a paradoxical motion of the diaphragm, in which the diaphragm moves towards the chest due to increased intra-abdominal pressure as a result of distension of stomach caused by the positive pressure ventilation.[26,49]

Endobronchial intubation also can be diagnosed by movement of the diaphragm and presence of lung-sliding sign on the ventilated lung (endobronchial) and absent or restricted movement of the diaphragm and absence of lung-sliding sign on the contralateral side (non-ventilated lung).[26,50]

Cuff inflation with saline instead of air to detect position of the ETT in case of an already trachea-intubated patient has been described.[46,36,51] The authors suggested that a longitudinal view combined with a slight to-and-fro motion could improve visualisation. They concluded that this technique was beneficial particularly in pregnant women or patients receiving frequent chest radiographs to monitor ETT position.

Real-time characteristic ultrasonographic findings of the normal paediatric airway during tracheal intubation have been described using the following criteria: 1) identification of the trachea and tracheal rings, 2) visualisation of vocal cords, 3) widening of glottis as the tracheal tube passes through, and 4) tracheal tube position above carina and demonstration of sliding sign after manual ventilation of the lungs. The authors conclude that US of the paediatric airway can be easily used to assess correct tracheal tube position and to detect oesophageal intubation.[52-53]

Predicting the size of a left double-lumen bronchial tube: Measurement of the outer tracheal width by US can be a useful method for predicting the diameter of left main bronchus and for selecting a left-side double-lumen bronchial tube. The authors found a strong correlation between tracheal widths as measured by US and tracheal width and left main bronchus width as measured by computed tomography (CT).[39,40,54]

Detection of Laryngeal Mask Airway Position:

Ultrasonography has been used to confirm the position of the laryngeal mask airway (LMA) cuff. Proper cuff position to seal the larynx is required for adequate ventilation through the LMA. The LMA cuff was inflated with fluid and the position of the LMA cuff was seen by US from the lateral approach. If the LMA was not visualised by US equally on both sides of the larynx, it can be subsequently repositioned correctly.[55,38]

Diagnosis of Upper Airway Pathology:

Maxillary sinusitis can be detected before planning for nasal intubation.[48,56-57]

Assessment and diagnosis of inflammatory conditions of the upper airway like epiglottitis, presence of mucosal swelling and vocal cord function have also been assessed using an US.[58-59]

The scope of US application in anesthesia has widened considerably. A sound knowledge of the sonoanatomy of the upper airway can help the anaesthetist to use US in many airway-related conditions. Transverse and parasagittal views can help diagnose supraglottic, glottic and infraglottic airway conditions and aid the anaesthetist in airway management.[26]

Limitation of Sonography:

Its use is dependent on operator skills and requires training and has a steep learning curve. A high level of physical agility and knowledge of appropriate sonoanatomy is required to become proficient in its use.

LITERATURE REVIEW

Gupta D et al did a study in 2012 regarding "Ultrasonographic modification of Cormack Lehane classification for pre-anesthetic airway assessment." It was observed that there was a correlation of the distance between the epiglottis and the vocal cords (E-VC) with the Cormack Lehane Grading; correlation was strong negative with regression coefficient of -0.966 (95% CI -1.431 to -0.501; p = 0.0001). Subsequently, the correlation of the pre-epiglottis space (Pre-E) with the Cormack Lehane Grading was strong in positive direction with regression coefficient of 0.595 (95% CI 0.261 to 0.929; p = 0.0008). Finally the ratio of Pre-E and E-VC distances with the Cormack Lehane Grading had the strongest positive correlation with regression coefficient of 0.495 (95% CI 0.319 to 0.671; p < 0.0001).[16]

Sussan Soltani Mohammadi et al did a study regarding "Usefulness of Ultrasound View of Larynx in Pre-Anesthetic Airway Assessment: A Comparison with Cormack-Lehane Classification during Direct Laryngoscopy". It was observed that correlations between the pre-epiglottic space (Pre-E) and Cormack-Lehane grades I, II, and III were weak. Correlations between the distance from the epiglottis to the vocal cords (E-VC) and Cormack-Lehane grades I, II, and III were also weak. The Pre-E/E-VC ratio for correlations between the sonographic view and laryngoscopy had 87.5% sensitivity and 30% specificity. There was no correlation between Mallampati class and the Pre-E/E-VC ratio (P = 0.566).[8]

Shelly Rana et al did a study regarding "Point-of-care Ultrasound in the Airway Assessment: A Correlation of Ultrasonography-Guided Parameters to the Cormack-Lehane Classification". The prospective observational study was conducted on 120 patients scheduled for elective surgery requiring general anesthesia and tracheal intubation. Difficult intubation was observed in 12.5% of patients. The mean ± standard deviation (SD) of Pre-E/E-VC ratio was 1.33±0.335, 1.62±0.264 and 1.87±.243, 2.22±.29 for CL Grade 1, 2, 3, and 4 respectively. Pre E/E-VC ratio of more than 1.77 cm had 82% sensitivity, specificity 80%. Conclusion with, the sonographic measurement of the Pre-E/E-VC ratio is a better predictor of CL grading.[6]

Vishal koundal et al did a study at 2019 regarding "The Usefulness of Point of Care Ultrasound (POCUS) in Preanaesthetic Airway Assessment". Utilising receiver operating curves, cutoff value of HMDR (hyomental distance ratio) for predicting difficult laryngoscopy was ≤1.0870 with sensitivity of 65%, specificity of 77%. The cutoff value, sensitivity and specificity for Pre-E/E-VC were ≥1.785, 82.8% and 83.8%., respectively. The strong positive correlation of Pre-E/E-VC, DSEM, and moderate negative correlation of HMDR makes these ultrasound parameters reliable predictors for difficult laryngoscopy.[60]

Navin K Yadav et al did a study in 2019 regarding "Ultrasound Measurement of Anterior Neck Soft Tissue and Tongue Thickness to Predict Difficult Laryngoscopy - An Observational Analytical Study". A significant difference was observed in the ultrasound parameters between the easy and difficult laryngoscopy (*P*-value = 0.001). Sensitivity and specificity to predict difficult airway was 69.6% and 77% for tongue thickness, 68% and 73% for the skin to hyoid bone distance in a neutral position and found to be higher than clinical parameters. The ultrasound measurements of soft tissue thickness of anterior neck and tongue thickness along with the clinical assessment of airway can be useful in predicting difficult laryngoscopy.[61]

Stefano falcetta et al did a study regarding "Evaluation of Two Neck Ultrasound Measurements as Predictors of Difficult Direct Laryngoscopy: The mDSE cut-off value of 2.54 cm (sensitivity 82%, specificity 91%) and the pre-epiglottic area cut-off value of 5.04 cm (sensitivity 85%, specificity 88%) were the best predictors of a Cormack-Lehane grade at least 2b at direct laryngoscopy and of difficult intubation. The cut-off value of mDSE showed greater sensitivity in female patients (94 vs. 86%) and greater specificity in male patients (92 vs. 83%). No correlation was found between difficult laryngoscopy and ultrasound assessments at the level of the vocal cords. It was concluded that, airways ultrasounds might be considered as a predictor of restricted/difficult laryngoscopy and unpredicted difficult intubation.[62]

Srikar Adhikari et al did a study in 2011 regarding "Pilot Study to Determine the Utility of Point-Of-Care Ultrasound in the Assessment of Difficult Laryngoscopy". Clinical screening tests did not correlate with US measurements, and US was able to detect difficult laryngoscopy, indicating the limitations of the conventional screening tests for predicting difficult laryngoscopy.[63]

Aruna Parmeswari et al did a study in 2017 regarding "Correlation between preoperative ultrasonographic airway assessment and laryngoscopic view in adult patients: A prospective study". It was concluded that, the skin to epiglottis distance, as measured at the level of the thyrohyoid membrane, is a good predictor of difficult laryngoscopy. When combined with the modified Mallampati classification, the sensitivity of the combined parameter was found to be greater than any single parameter taken alone.[64]

Bryant Ittiara et al did a study in 2011 regarding "Ultrasound Assessment of Airway: A Correlation Study with Cormack Lehane Classification".Among the parameters assessed by the ultrasound, the bigger value of the distance between the epiglottis and vocal cords (E-VC) predicts lower Cormack Lehane grade and easier airway; and the bigger value of pre-epiglottis space (Pre-E) predicts higher Cormack Lehane grade and hence more difficult airway.[65]

Riad et al. did a study in 2016 regarding "Neck circumference as a predictor of difficult intubation and difficult mask ventilation in morbidly obese patients". Multiple logistic regression analysis showed that neck circumference more than 42 cm ($P = 0.044$) and BMI more than 50 kg m^{-2} ($P = 0.017$) were independent predictors of difficult intubation. Male sex ($P = 0.004$) and BMI more than 50 kg m^{-2} ($P = 0.031$) were independent predictors of difficult mask ventilation.[66]

Francesco Alessandri et al did a study in 2018 regarding " Ultrasound as a new tool in the assessment of airway difficulties". It was observed that, mean (SD) of minimum distance from the hyoid bone to skin surface (DSHB) was 0.88 (0.3) cm in the easy mask ventilation group, 1.4 (0.19) cm in difficult mask ventilation (DMV) group.[67]

Bi-Xin Zheng et al did a study in November 2019 regarding " Ultrasound for predicting difficult airway in obstetric anesthesia". Multiple logistic regression analysis were performed to determine independent predictors of difficult intubation. The study outlined in this protocol will explore the possibility of ultrasound for predicting difficult airway in obstetric anesthesia. This may provide new insight into the practice of airway management.[68]

Cristina Petrisor et al did a study in 2019 regarding "Preoperative difficult airway prediction using suprahyoid and infrahyoid ultrasonography derived measurements in anesthesiology". Study gives conclusion that Anesthesiologists have many available US-derived parameters, which could provide additional information regarding airway anatomy during the preoperative airway evaluation. These could serve as potential screening parameters for a difficult laryngoscopy/difficult airway.[69]

Jacek A Wojtczak et al did a study in 2012 April regarding "Submandibular sonography: assessment of hyomental distances and ratio, tongue size and floor of the mouth musculature using portable sonography". They conclude that sonography allows bedside measurements of the hyomental distance ratio and tongue size in morbidly obese patients. Preoperative assessment of the hyomental distance ratio may predict difficult laryngoscopy resulting in difficult intubation.[70]

Pawel Andruszkiewicz et al did a study in 2016 regarding "Effectiveness and Validity of Sonographic Upper Airway Evaluation to Predict Difficult Laryngoscopy". The diagnostic validity profiles showed poor sensitivity (9.1%-42.9%) and positive predictive value (4.5%-66.7%), but good specificity (71.8%-97.7%) and negative predictive value (87.1%-94.5%). So this study conclude that sonographic predictors may help identify patients with difficult laryngoscopy.[71]

Justin S Fulkerson et al did a study in 2017 June regarding "Ultrasonography in the preoperative difficult airway assessment". Significance for sonographic prediction of difficult laryngoscopy occurred at three locations: hyomental distance [52.6 ± 5.8 mm ($p < 0.01$)], anterior tissue at the hyoid bone [16.9 mm (95 % CI 11.9-21.9) and 15.9 ± 2.7 mm ($p < 0.0001$)] and the thyrohyoid membrane [34.7 mm (95 % CI 28.8-40.7) and 23.9 ± 3.4 mm ($p < 0.0001$) and 28.25 ± 4.43 mm ($p < 0.001$)]. The vocal cords and sternal notch levels had conflicting significance. Limitations include the heterogeneous populations and lack of standard scanning protocols.[72]

Harith Daggupati et al did a study in 2020 March regarding "Development of a scoring system for predicting difficult intubation using ultrasonography". A score named MSH was constructed, which included mentohyoid distance, mandibular subluxation and head extension. Then, skin to epiglottis distance (SED) was added to the MSH (mentohyoid distance, mandibular subluxation and head extension) score to form another new score named U_{SED}-MSH. Both scoring systems were compared under the receiver-operating characteristic curve and area under the curve (AUC) were calculated. Difficult intubation was observed in 62/310 patients (20%). The AUC for U_{SED}-MSH score was greater than the MSH score (0.93, 95% CI [0.89-0.97] vs 0.76, 95% CI [0.69-0.84] with P value <0.001. U_{SED}-MSH score had higher sensitivity (93.6% vs 59.7%) and lower specificity (85.9% vs 91.1%) with similar positive predictive value (62.7% vs 62.4%) in comparison with MSH score.[73]

Chao Ji et al did a study in 2018 March regarding "Diagnostic accuracy of radiology (CT, X-ray, US) for predicting difficult intubation in adults: A meta-analysis". The results indicated that the diagnostic value of CT, X-ray and US was much better than that of modified Mallampati score. Ultrasound had diagnostic indices and the area under curve similar to those of CT and X-ray in predicting difficult airway.[74]

Bruno Marciniak et al did a study in 2009 regarding "Airway management in children: ultrasonography assessment of tracheal intubation in real time". This study describes characteristic ultrasonographic findings of the pediatric airway during tracheal intubation. It suggests that ultrasonography may be useful for airway management in children.[52]

Sandra Werner et al did a in 2007, "Pilot study to evaluate the accuracy of ultrasonography in confirming endotracheal tube placement". This was a prospective, randomized, controlled study. Eligible patients were adults undergoing elective surgery requiring intubation. Exclusion criteria were a history of difficult intubation, abnormal airway anatomy, aspiration risk factors and esophageal disease. Thirty-three patients were enrolled. After induction of anesthesia and neuromuscular blockade, the anesthesiologist placed the endotracheal tube in the trachea and esophagus in random order with direct laryngoscopy. Two emergency physicians, blinded to the order and performance of the intubations, independently recorded the location of the endotracheal tube according to the real-time ultrasonographic image. For each physician, the sensitivity for identifying the first intubation as tracheal was 100% (95% CI 77% to 100%) with a specificity of 100% (95% CI 82% to 100%).[47]

Data Collection Method:

After approval by the institutional review committee (IRC) and obtaining informed consent, prospective and observational study was carried out on among patients in the age group of 18–70 years of either gender, scheduled for elective surgery and requiring general anesthesia with direct laryngoscopy and endotracheal intubation at KUSMS Hospital. The patients with interincisor gap <3 cm, edentulous patients, and patients with head and neck anatomical pathologies with restricted mobility that might have an unpredictable effect on the US assessment of the airway were excluded from the study. Patients having altered level of consciousness, inability to follow commands were also excluded from the study.

The routine airway assessment including mouth opening, Mallampati scoring, thyromental distance, and neck movements, was done during the pre-anesthetic assessment. Along with airways assessment, routine pre-anesthetic check-up was done including vitals (mainly systolic blood pressure, diastolic blood pressure and heart rate) and systemic assessment like cardio vascular system, respiratory system and central nervous system. The patients not meeting inclusion criteria were excluded from the study and the enrolled patients underwent sonographic assessment of airways in the preoperative holding area.

In the pre-anesthetic room, after fully explaining the procedure to the patients, with the patients lying supine or in a sitting position and active maximal head-tilt/chin lift, the sonographic assessment was done. High frequency linear probe of 5-12 Hz of Mindray Z26 model was placed in the submandibular area, transversely in the midline. Without changing the position of the probe, the linear array of the US probe was rotated in the transverse planes from cephalad to caudal, until simultaneous visualization of the epiglottis and posterior part of vocal folds with arytenoids were observed on the screen. Thereafter, following measurements were obtained with the oblique-transverse US view of the airway (a) distance between epiglottis and midpoint of vocal cord (E-VC), (b) Pre-Epiglottis space (Pre-E).

The patients were then taken to the operating room and the standard general anesthesia procedure was performed as per the discretion of the attending anesthesiologist and as per standard of care. All base line vitals were monitored and patient was induced with Propofol (1-2 mg/kg), Fentanyl (1.5-2.5 mcg/kg) with Vecuronium (0.1 mg/kg) as a muscle relaxant. The patients were induced and intubated by a senior anesthesiologist with >1 year of experience post-qualification and was blinded to the findings of preoperative ultrasonographic airway assessment. Direct laryngoscopy was performed using a Macintosh blade and the CL grade noted without external laryngeal manipulation. The CL classification: Grade 1: visualization of the entire laryngeal aperture; Grade 2: visualization of parts of the laryngeal aperture or the arytenoids; Grade 3: visualization of only the epiglottis; Grade 4: visualization of only the soft palate. The laryngoscopy was classified as easy (CL Grade 1 and 2) or difficult (CL Grade 3 and 4). The trachea was intubated with appropriate sized endotracheal tube and confirmation done with auscultation and waveform capnography. After confirmation of endotracheal tube placement, anesthesia was maintained with oxygen and inhalational agent under mechanical ventilation.

DISCUSSION

The currently available non-invasive screening tests for airway assessment during pre anesthetics examination are mouth opening, Modified mallampati classification, thyromental distance assessment, atlanto-occipital extension, jaw protrusion, and the upper lip bite test. However, these screening tests alone or in combination not necessarily correlate with the CL grading during direct laryngoscopy, due to low predictive value.[75]

Therefore, non-invasive screening test to predict the difficult laryngoscopy and intubation with greater accuracy in the preoperative period is the need of the hour. Encouraging results have been obtained in few studies, utilizing the ultrasound (US) as a direct predictors for the assessment of airway in the preoperative period.[16,70]

In our study, maximum individuals had ASA grade I, mallampati grade I and CL grade I. Whereas, among the grading used for airway evaluation, ULBT grade was also evaluated and maximum individuals reported to have ULBT grade II.

Regarding the utilization of sonographic guided Pre-E/E-VC ratio to CL classification in present study, the values of Pre-E/E-VC ratio are (mean ± SD: 0.59 ± 0.31) for CL grade I, (mean ± SD: 0.66 ± 0.28) for CL grade II and (mean ± SD: 0.79 ± 0.31) for CL grade III respectively. This study does not encounter patient with CL grade 4 (P = 0.005). In the study by Reddy et al.[76] the value of mean ± SD of Pre-E/E-VC ratio were (1.09 ± 0.38), (1.28 ± 0.37) for CL Grade 1 and 2, whereas for CL Grade 3, it was (1.29 ± 0.44). Also in the study, the authors did not encounter patient with CL 4. Similarly, in the study by Rana et al.[6] The mean ± standard deviation (SD) of Pre-E/E-VC ratio was (1.33 ± 0.335), (1.62 ± 0.264), (1.87 ± 0.243) and (2.22 ± 0.29) for CL Grade 1, 2, 3, and 4, respectively.

The cut off value of Pre-E/E-VC for predicting difficult laryngoscopy was ≥1.77 with sensitivity of

82% and specificity of 80% in previous study done by Rana et al.[6] Another study done by Koundal et al. showed, cut off value of Pre-E/E-VC for predicting difficult laryngoscopy was ≥1.785 with sensitivity of 82.8% and specificity of 83.8%, whereas in the present study, the cut off value for Pre-E/E-VC was ≤0.64 with sensitivity of 90.91% and specificity of 73.39% for predicting easy laryngoscopy. In the review article by Justin et al.[72] including 10 studies determining CL grade correlation with sonographic predictors of difficult airways, 114 of the 681 total subjects had difficult laryngoscopies (16.8%), whereas in present study determining CL grade correlation with sonographic predictors of difficult airways, 11 of the 135 total subjects had difficult laryngoscopies (8.14%).

In the study by Gupta et al.[16] the predictability of the grade was Pre-E/E-VC ratio 0-1 corresponded to grade I; 1-2 corresponded to CL grade II and the ratio between 2 -3 corresponded to CL grade III, whereas in present study, the predictability of the grade was Pre-E/E-VC ratio 0.13-2 corresponded to grade I; 0.29-2 corresponded to CL grade II and the ratio between 0.28 -1.61 corresponded to CL grade III. The difference may be contributed to difference in the study population involved.

From the above observation, a correlation of age and body weight with CL grading might suggest an anticipation for a higher grade of laryngoscopic finding and a difficult intubation. In the study by AM Hekiert et al. weight has also been identified as a predictor of difficult laryngoscopy.[77]

CONCLUSION

We conclude that ultrasonographic parameters should be incorporated in pre-anaesthetic evaluation of airways by virtue of its better accuracy and correlation in predicting CL grading. The good predictive value of USG measured parameters ensure reliability of these variables in detecting difficult laryngoscopy.

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