Chapter

Title: Ultrasound (US) Imaging Use in the Management of the Difficult Tracheal Intubation

Ajay Singh, Ankita Dhir, Shiv Lal Soni, Rekha Gupta, Naveen B. Naik, Kashish Garg, Venkata Ganesh and Narender Kaloria

Abstract

The ultrasound has been in clinical use since the early 1900s, but its use in the airway has not been published extensively so far. Combining the skills of USG with thorough knowledge of regional anatomy can prove to be a boon to improving the quality of care being delivered to patients. Preoperative use of USG at different levels of the neck combined with the risk assessment methods can help to organize predictors of difficult airway and difficult laryngoscopy. Basic comprehension of USG physics, transducer selection, and probe orientation and a better understanding of airway anatomy contribute to the accuracy of ultrasound interpretation. In day-to-day practice, there is a potential for failed tracheal intubations followed by failure of gaining adequate access to the airway, thus posing challenges to anesthesiologists. Besides predicting difficult airway, USG provides an incentive to properly place an endotracheal tube (ETT) to an adequate depth, estimation of the size of ETT particularly helpful in children and obese, laryngeal mask airway (LMA) confirmation, surgical airways, and post-extubation stridor assessment and thus prevents the risk of reintubation. With the promising and increasing number of evidence exists, there is potential for incorporation of upper airway USG into further standard of care assessment, monitoring, and imaging modalities.

Keywords: airway, predictors, ultrasonography

1. Introduction

The difficult airway has been defined as "the clinical situation in which a conventionally trained anesthesiologist experiences difficulty with face mask ventilation or difficulty with tracheal intubation or both." Failure to assess or identify a difficult airway and not make an organized plan for the management of the airway may lead to a poor outcome. Assessment of the airway goes beyond bedside clinical tests and should emphasize the identification of problems during each step of airway management [1]. This should involve the proper assessment of variations in anatomy, various airway pathologies, and the previous approach used in prior cases. These variable factors play decisive role in determining the success of any equipment or technique or adjunct used and most importantly incorporate the skill and knowledge of anesthetist about various techniques and equipment.

2. Incidence

The incidence of difficult airway can range between 5.8 and 20% according to previous studies [2–5]. This high incidence is probably because of various definitions of difficult airway either using the Intubation Difficulty Scale or the modified mallampati (MMP) grading. None of these studies, however, have reported ultrasound measures consistently.

3. Assessment of difficult airway

3.1 Clinical history

It is important to start by reviewing the previous medical records regarding airway management and whether there was any difficulty faced and how it was handled. It can be very informational to communicate with the previous anesthesia team regarding the airway management, if their anesthesia chart reflected any difficulty. Proper documentation of the airway management is important, including techniques that were and were not successful. All of this is of value if there is no worsening or new-onset airway pathologies. This information should be recorded in all cases irrespective of difficult airway for the benefit of future colleagues.

In your preoperative examination, there are many medical conditions that have been associated with an increased risk of difficult intubation and airway management. In progressive disorders such as chronic rheumatoid arthritis, chronic ankylosing spondylitis, and chronic diabetes mellitus, disease involvement of the airway or neck joints should be ruled out. Rare syndromes such as Pierre-Robin syndrome, Klippel-Feil syndrome, and Treacher Collins syndrome are often associated with difficult airways. History of recent acute respiratory tract infections has increased incidence of laryngospasm and bronchospasm especially in children

A STOPBANG questionnaire should answered by all patients prior to anesthesia, to assess the potential risk for obstructive sleep apnea (OSA). Patients with diagnosed OSA are at increased risk for difficult airway management.

Any new-onset airway pathology or worsening pathology must be documented as it will require entirely different approach to manage.

Patients presenting with a retrosternal goiter should be evaluated for signs and symptoms suggestive of tracheal compression or recurrent laryngeal nerve compression such as the degree of hoarseness or voice change and its progression and stridor. Also underlying esophageal compression resulting in drooling of secretions, dysphagia, and ability to lie supine should be documented. It should also be documented in what position symptoms are relieved.

The trauma patient with any airway injury requires a thorough evaluation. Assessment should focus on the swelling and its onset, associated pain and trismus, and time since injury. In case of chemical and thermal burns, careful assessment should be done as mucosal edema can develop rapidly and progress very fast. Difficult airway is 10 times more commonly encountered in intensive care unit and emergency area [6].

3.2 Clinical assessment

The airway assessment should start with direct observation for obesity, bearded face, pregnancy, prominent breasts, and visible external signs of head and neck disease such as large thyroid mass or Ludwigs angina. There are specific tests to predict a difficult airway; however, there is no ideal airway assessment tool due to lack of statistical predictive power of individual airway tests. These tests, however, should alert us for the potential of a difficult airway so that appropriate measures can be taken beforehand for patient safety.

3.2.1 Clinical airway examination

- Inter-incisor distance commonly measured by mouth opening: Less than 3 cm distance is usually taken as non-reassuring sign. However, some supraglottic airway devices (SADs) such as supreme laryngeal mask airway (LMA) require <2 cm mouth opening and certain videolaryngoscope (VL) blades require barely 1.8 to 2 cm for laryngoscope insertion.

- The modified mallampati (MMP) classification: MMP is used to assess the ratio of the tongue size with oropharyngeal cavity size. The patient is examined in the sitting position, with their mouth wide open and maximal tongue protrusion. It scores from 1 to 4 based on the anatomy. Class 3 MMP (soft palate and base of uvula visible) and Class 4 MMP (only hard palate visible) are indicators of difficult mask ventilation (DMV) and difficult laryngoscopy (DL); however, they are associated with poor positive predictive value (PPV) and inter-observer reliability if used alone.

- Patil test, also known as thyromental distance (TMD): measured from the upper border of thyroid cartilage to lower border of jaw with the head extended. TMD of <6.5 cm is considered an increased risk for difficult laryngoscopy.

- Sterno-mental distance (SMD), known as Sava test: measured from the notch of the manubrium sterni to the lower border of mandible with the head in extension position. Less than 12.5 cm of SMD has been associated with a difficult laryngoscopy. For measuring these distances, use of ruler or measuring tape is better than fingerbreadths as they are more reliable and accurate.

- The neck circumference to TMD ratio of more than 5.0 is considered as an improved predictor of a difficult airway. The ratio of patient height to TMD, known as RHTMD, is also said to be a good predictor of difficult airway [7].

- To assess temporomandibular joint function, upper lip bite test and jaw protrusion are done. It takes into account prognathic ability of temporomandibular joint and prominence of maxillary teeth. Attention should be given to dentition, loose teeth, artificial dentures, and single maxillary incisors.

- Range of neck movements should be assessed to ensure whether the patient is able to do the classic "sniffing position" (flexion at cervical spine and extension at atlanto-occipital joint) for adequate mask ventilation and laryngoscopy along with proper position for tracheostomy, if required in an emergency.

- The cricothyroid membrane should also be identified in a patient with a potential difficult airway, in case of an emergent need to do a cricothyrotomy.

- Assessment of submandibular space is also useful as compliance of tissue alters due to neck infection, irradiation, or burns, and this can result in difficulty in tongue displacement into the submandibular space during laryngoscopy [8].

- Tissue compliance can be examined by tongue protrusion by patient. Decreased tongue mobility demonstrates decreased compliance.

3.3 Predictors of difficult mask ventilation (DMV)

The incidence of DMV ranges between 5 and 5.8% of all general anesthetics [9]. There are several predictors for DMV.

- One of the mnemonics that can be used to evaluate for a potential DMV is OBESE (Obesity, Beard, Elderly (>55 year), history of snoring, and edentulous mouth).

- Modified mallampati class 3 or 4, limited jaw protrusion, and male sex are the important risk factors.

- History of neck irradiation is an important predictor of impossible mask ventilation situation, defined as ineffective patient ventilation despite usage of various adjuncts, neuromuscular blockade, and multiple healthcare providers. This occurs because neck irradiation causes noncompliant tissue fibrosis involving the airway. Obesity and BMI both are not useful predictors; however, they are marker for increased aspiration risk and poor oxygen reserve due to reduced functional residual capacity. The real body fat distribution is important to predict a difficult airway. Airway collapsibility is increased by fat deposition in the parapharyngeal tissues, which predisposes to OSA [8]. This pattern is more commonly seen in male pattern obesity where fat is more often deposited around neck and upper torso. The increased fat deposition around neck can cause airway narrowing.

3.4 Predicting difficulty in airway instrumentation

. Assessment of the nasal passages should be done for nasopharyngeal airway insertion in case of nasal intubation, upper airway obstruction, or failing airway management as a rescue adjunct. Nasotracheal instrumentation can lead to trauma and epistaxis. So prior doing this, patency of nostrils, any presence of septal deviation, polyps, etc., should be looked for to avoid complications and increasing overall difficulty. Presence of clotting disorders or basal skull fractures should be warranted prior to nasal instrumentation.

Restricted mouth opening limits the insertion of almost all devices. So inter-incisor gap should be assessed so that appropriate oral devices can be used electively or in emergency situation. SADs and thin VL blades require mouth opening of < 3 cm, whereas Macintosh blade requires 3 cm inter-incisor gap. In patients with restricted mouth opening, the anesthesia team should have full knowledge of the pros and cons of the VL devices over the fiber optic technique. A high arched or narrow palate can reduce blade space in the oropharynx. Large breasts and barrel chests can pose difficult laryngoscope insertion; however, "ramp" position and appropriate device selection such as polio blade come as rescue. Indirect laryngoscopy can be fruitful in cases with relative or absolute retrognathia and restricted neck extension [10]. Cricoid pressure is an important part of rapid sequence induction; however, it can reduce optimal glottis visualization; however, in case of a difficult airway or difficult SAD insertion, cricoid pressure can be withdrawn under direct vision for improved glottis visualization or ease of SAD insertion, respectively.

Surgical airway such as cricothyrotomy or emergency tracheostomy are kept as a rescue in "can't intubate, can't ventilate" (CICV) situation. In patients with complex head and neck surgery or in anticipated emergency airway obstruction, the surgical airway is kept as rescue technique during the induction of anesthesia [8]. A difficult airway is anticipated in patients having history of neck radiation, obesity with fat deposited around anterior neck, thyroid mass or neck mass with or without deviation of trachea, previous tracheostomy, short neck, restricted neck flexion, and extension deformities. It is difficult to identify anatomical landmarks in young children and female patients. So in these patients with anticipated difficulty, anatomical landmarks should be marked with ultrasound assistance preoperatively.

3.5 Predictors of difficult laryngoscopy

A traumatic laryngoscopy can result in failure to secure the airway or unanticipated difficulty. The first attempt should always be the best attempt, particularly in cases of difficult airway so that strategies can be formulated with best available facilities.

Anatomical factors such as prominent incisors, retrognathia, macroglossia, and small inter-incisor gap affect insertion of the laryngoscope and alter the final view achieved by line of sight approach [8]. Short TMD and SMD are the indicators of an anterior larynx relative to line of sight. Due to in proportionate tongue and oral cavity relationship, modified mallampati class 3 or 4 are the good predictors of DL. Limited neck extension because of increased pretracheal tissue, large occiput, or large neck circumference has been associated with a difficult airway as it causes difficulty to achieve sniffing positioning [10]. Diseases such as lingual tonsil hyperplasia, epiglottitis, and Ludwig's angina are the important predictors of difficult or impossible laryngoscopy.

There are several factors predicting compliance and volume of submandibular tissue such as TMD, temporomandibular joint dysfunction, difficulty in mandibular protrusion, relative tongue volume, and retrognathia. These factors alter tongue displacement into submandibular tissue during laryngoscopy influencing the glottis visualization. Disease affecting the airway such as tumor or pharyngeal adipose tissue deposits also makes the laryngoscopy difficult [10].

3.6 Predictors of difficult intubation

A reduced oropharyngeal space may lead to difficult endotracheal tube manipulation. Endotracheal tube (ETT) size and suitability for awake fiberoptic technique should be assessed for specific pathologies such as vocal cord palsy, laryngeal tumors, and subglottic stenosis [8]. Stridor with or without respiratory distress is an important symptom of these pathologies and should alert the anesthetist. Whether any further investigations are required depend on the onset of stridor and its progression and association with respiratory distress.

3.7 Predicting a difficult extubation

Extubation is extremely important in the airway management. In 2012, The Difficult Airway Society has published extubation guidelines highlighting extubation as an important step in patient management. Laryngeal edema causing airway obstruction is the most common cause of early postoperative reintubation. Many factors influence postoperative airway management and includes traumatic intubation, effects of residual general anesthetic drugs, opioids, inadequate reversal of muscle relaxants, or local anesthetized airway. The residual effect of these agents on respiratory drive and airway reflexes should be ruled out [11]. There are more chances of early desaturation and postoperative airway complications in patients having obesity. Patients undergoing head and neck surgery, airway surgery, having Trendelenburg or prone positions, and prolonged intubation should be assessed carefully prior to extubation.

4. Role of ultrasonography in the upper airway evaluation

Point of care ultrasonography (US) has emerged as a novel, simple, portable, noninvasive tool that can be used for airway assessment and management. It plays a pivotal role in the quick assessment of the airway anatomy in emergency areas and the operation room. With the help of US, upper airway imaging can be used for subglottic stenosis detection, prediction of difficult intubation, verification of ETT placement, percutaneous tracheostomy, cricothyroidotomy, post-extubation stridor evaluation, and preoperative determination of pediatric ETT size and double-lumen endobronchial tube (DLT) size [11].

The basic principle behind US image formation by rarefaction needs to be understood clearly for better interpretation of images. Knowledge of US transducer types and its orientation and relevant airway anatomy are important for proper evaluation.

5. Patient position for ultrasound airway assessment

Optimal supine sniffing position is achieved by placing a pillow under the occiput to achieve optimal neck flexion and head extension. The presence of air makes it difficult to visualize deeper structures because of poor medium. Comet tail and reverberation artifacts are produced by intraluminal air [8]. Bone structures such as ramus of mandible, mentum, hyoid bone, and sternum appear as bright hyperechoic linear structures with a hypoechoic acoustic shadow beneath it. Cartilaginous structures such as thyroid and cricoid cartilages appear as homogeneous hypoechoic [10]. Muscle and connective tissues appear as heterogeneous striated and hypoechoic. Fat and glandular structures appear as homogeneous and mildly to strongly hyperechoic when compared with adjacent soft tissues, depending on the fat content. Air-mucosa (A-M) interface appears as bright hyperechoic linear structure.

6. Applications of ultrasound in airway evaluation

6.1 Ultrasound-guided assessment of the subglottic upper airway diameter and prediction of endotracheal tube size

US has emerged as a reliable tool for assessing the narrowest diameter of the cricoid lumen (transverse diameter). In third decade of life, calcification of the laryngeal cartilages begins to occur because of age factor which creates an acoustic shadow. This limits the use of US in older patients. US-guided subglottic airway diameter measurement is a better indicator of appropriate size of cuffed and uncuffed ETT in pediatric patients.

6.2 Ultrasound measured tongue thickness and difficult intubation

Tongue thickness, measured by US, (**Figure 1**) greater than 6.1 cm, has been shown to be an independent predictor of difficult intubation with 75% sensitivity and 72% specificity. A ratio of tongue thickness to thyromental distance greater than 0.87 has an 84% sensitivity and 79% specificity for predicting difficult tracheal intubation [12].

6.3 Ultrasound-guided prediction of difficult laryngoscopy in the obese patient

US-guided anterior neck soft tissue thickness measurement predicts difficult laryngoscopy. The measurement is done from skin to the anterior aspect of trachea at three levels: vocal cord, thyroid isthmus, and suprasternal notch. Soft tissue thickness at the vocal cords level is a better predictor of difficult laryngoscopy in obese patients. Soft tissue at each level can be calculated by averaging the soft tissue thickness in millimeters obtained in the central axis of the neck and 15 mm to the left and right pretracheal soft tissue. Patients having neck circumference of 50 cm

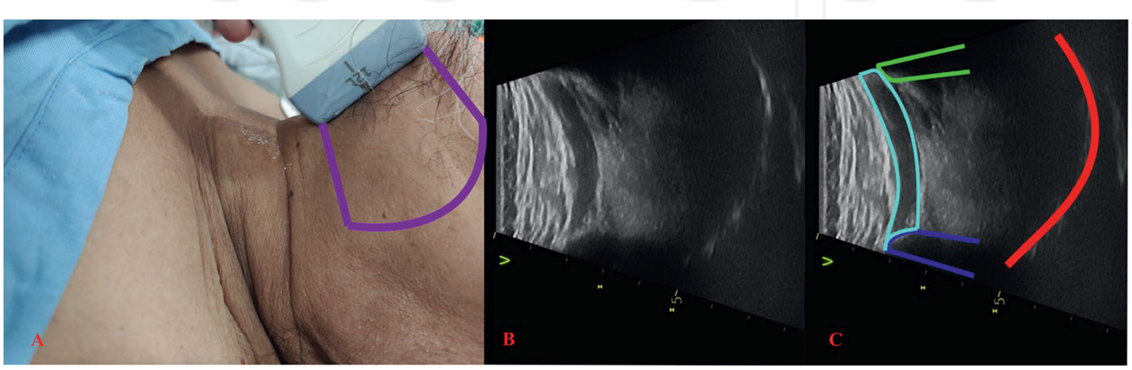

Figure 1.
(A) Photograph showing probe placement and zone of insonation (area within purple boundary); (B & C) ultrasound image showing mylohyoid (sky blue), mandible (green), hyoid (dark blue), and dorsal surface of tongue (red).(image credits: Author Dr Venkata Ganesh).

and pretracheal soft tissue thickness of 28 mm at vocal cords level have difficulty while doing laryngoscopy [13].

6.4 Ultrasound-guided prediction of post-extubation stridor

In intubated patients, assessment of vocal cords and larynx morphology by US helps to predict post-extubation stridor. US-guided air-column width measurement identifies patients at higher risk for post-extubation stridor so that appropriate measures can be taken after extubation. A reduced laryngeal air column width difference or ratio (pre-intubation vs. pre-extubation values, with the ETT cuff deflated) has been shown to be a good predictor of post-extubation stridor [14, 15] . **Figure 2** demonstrates measurement of air column width with the cuff deflated.

6.5 Ultrasound-guided emergency cricothyrotomy and elective transtracheal cannulation

For securing surgical airways, identification of the exact location of the trachea is very important to manage the difficult airway in both elective and emergency scenario. With the help of US, the trachea can be visualized before both emergency cricothyrotomy and elective transtracheal cannulation. A visual guide to identify airway-related structures is presented in **Figures 3** and **4**. This is useful in anticipated difficult airway such as neck swelling, thyroid mass, and Ludwig's angina where localization of trachea is difficult.

6.6 Ultrasound-guided airway blocks to facilitate awake intubation

For performing upper airway blocks in fiberoptic bronchoscopy, US plays an important role. It helps to identify superior laryngeal nerve (SLN) for SLN block. SLN running between thyroid cartilage and hyoid bone can be easily seen on transverse US

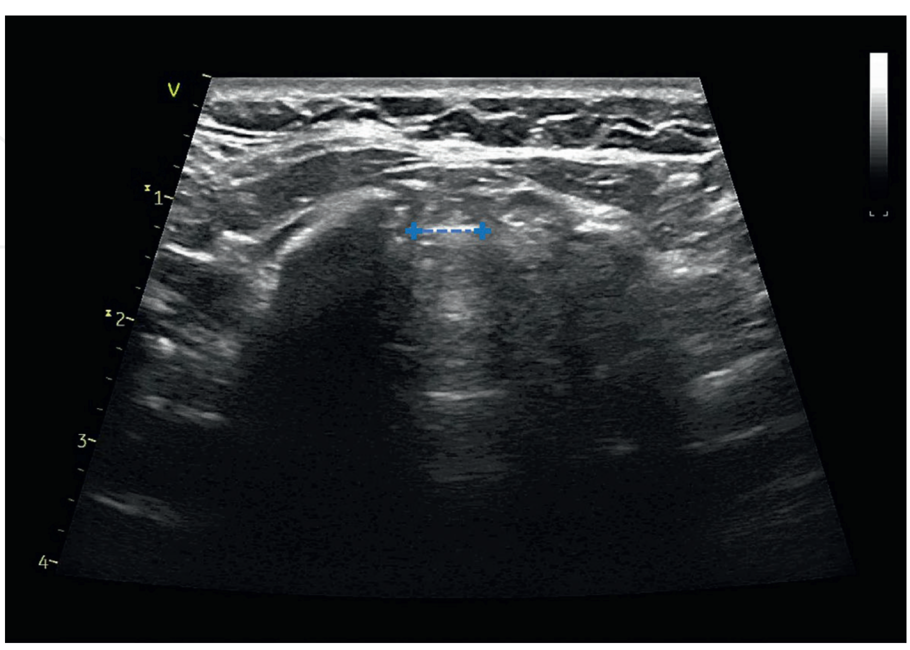

Figure 2.
Measurement of laryngeal air column (US probe placed transverse across the trachea). The length of the blue dashed/discontinuous line is the width of the air column (image credits: Author Dr Venkata Ganesh).

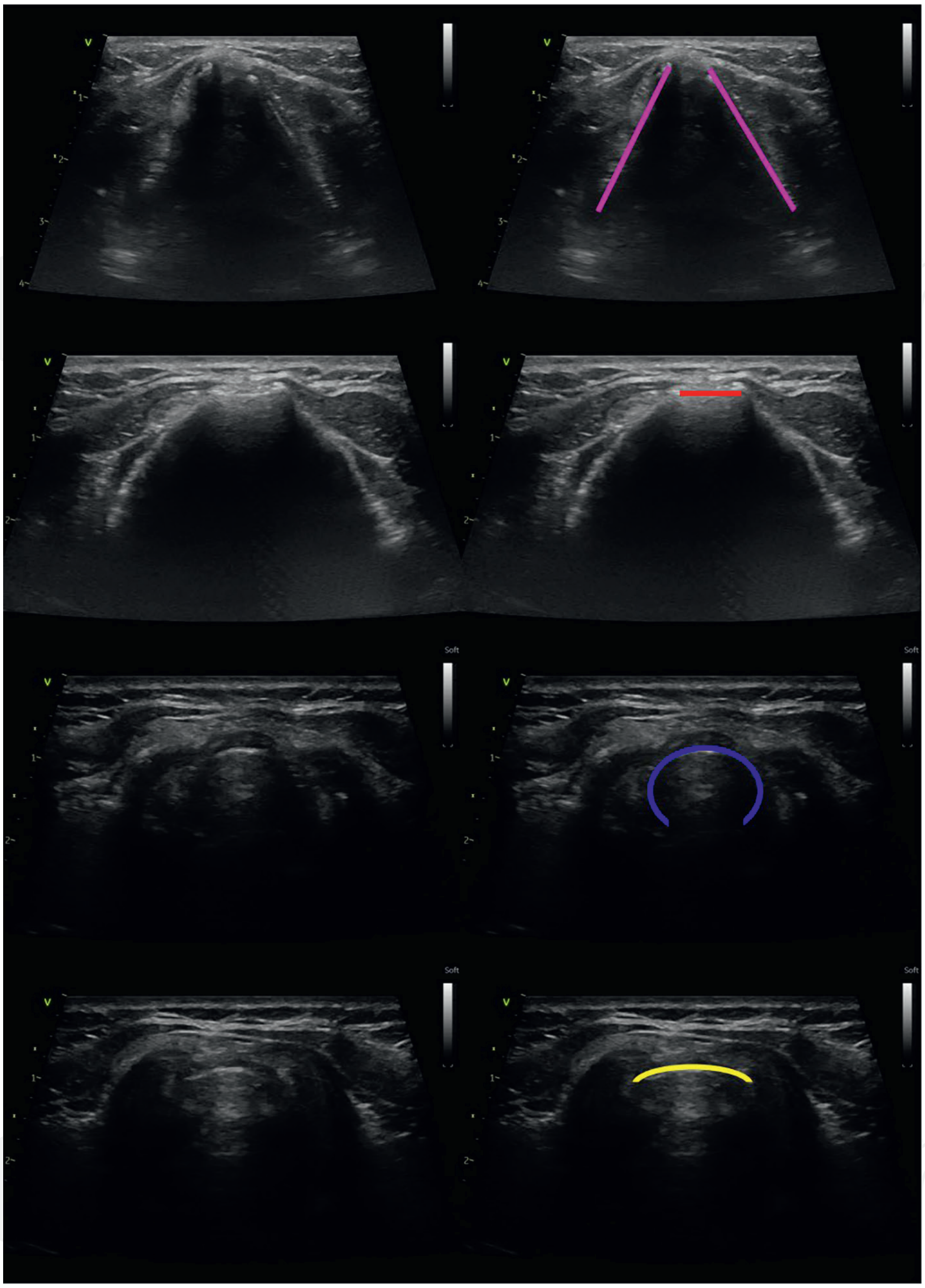

Figure 3.
With the US probe placed in the transverse plane and scanning cephalocaudally, the topmost image shows the thyroid cartilage (magenta) followed caudally by the cricothyroid membrane (red), cricoid (dark blue), and the trachea (yellow). (image credits: Author Dr Venkata Ganesh).

at hyoid bone level. The membrane between the thyroid cartilage and hyoid bone is an iso-echoic line from both sides of the hyoid bone with hyperechoic air below [16].

6.7 Ultrasound-guided intubation

Endotracheal intubation is conventionally confirmed by capnography, five point chest auscultation, and esophageal intubating devices. US-guided equal movement

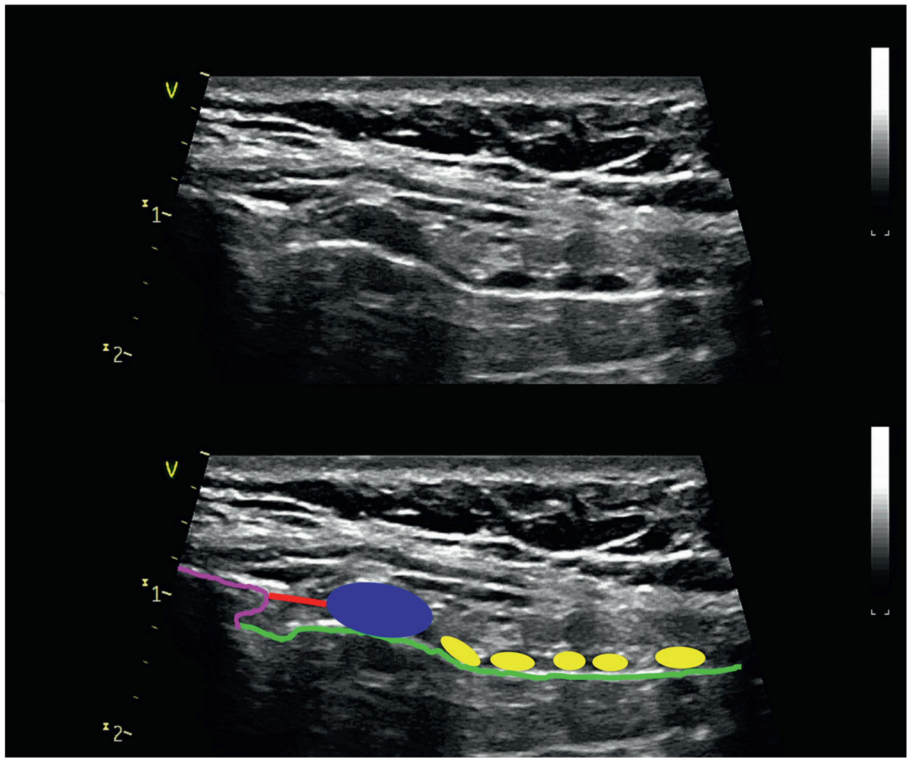

Figure 4.
String of pearls appearance (US probe placed in the saggital plane). Magenta—thyroid cartilage; red—cricothyroid membrane; dark blue—cricoid; yellow—trachea. (image credits: Author Dr Venkata Ganesh).

of bilateral pleura and diaphragm indicating expansion of lungs is an indirect sign of correct physiological function of the tracheal tube in mechanically ventilated patients. Lung sliding sign seen on intercostal US view at interface of lung-chest wall also indicates lung expansion.

Esophageal intubation can be identified if the esophagus is lateral to the trachea (**Figure 5**). When intubating under real-time ultrasound guidance, the lack of a disruption in the tracheal air column with a noticeable movement in the esophagus can detect esophageal intubations earlier than capnography or auscultation [17] *(image credits: Author Dr Venkata Ganesh)*

Esophageal intubation results in a paradoxical or immobile state of the diaphragm. Esophageal intubation causes paradoxical ventilation where the diaphragm moves toward the chest due to raised intra-abdominal pressure caused by stomach distension by positive pressure ventilation.

US can also be used to diagnose endobronchial intubation by assessing the diaphragm movement and lung-slide sign on the ventilated lung side (endobronchial) and absent or restricted diaphragm movement and absent lung-slide sign on the non-ventilated lung side [13].

Normal pediatric airway can be visualized in real time using US during tracheal intubation by assessing 1) trachea and tracheal rings identification, 2) vocal cords visualization, 3) widening of glottis with passage of ETT, and 4) confirmation of ETT position above the carina and visualization of sliding sign after manual lung ventilation.

6.8 Ultrasound-guided prediction of left-sided DLT size

Outer tracheal ring diameter is a useful predictor of left main bronchus diameter on ultrasonography and hence helps in selecting left-sided DLT.

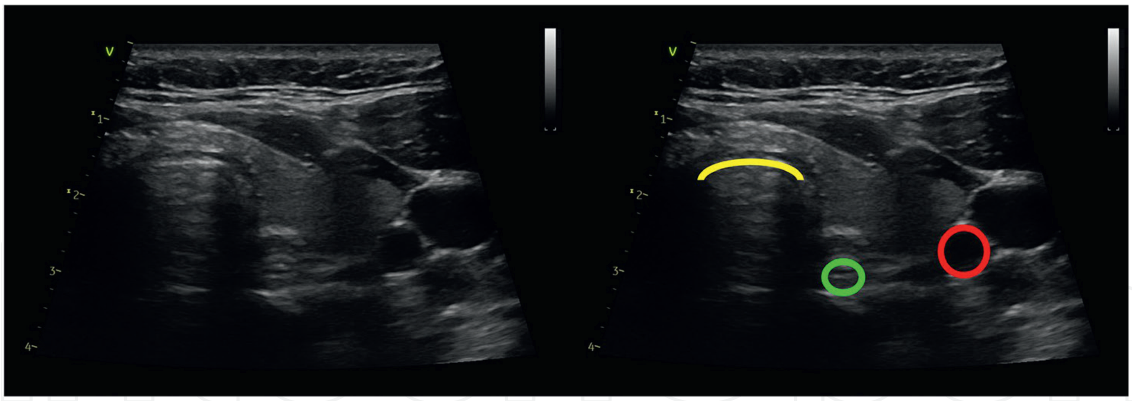

Figure 5.
US image showing trachea (yellow), esophagus to its right (green) and the carotid (red). (image credits: Author Dr Venkata Ganesh).

6.9 Ultrasound-guided detection of laryngeal mask airway position

With the help of US, position of the LMA cuff can be confirmed. For adequate ventilation, the LMA cuff should be placed at the proper position to seal the larynx. LMA should be repositioned if it is not visualized equally on both sides of the larynx on ultrasound [18].

6.10 Ultrasound-guided diagnosis of upper airway pathologies

The US can be used to assess and diagnose upper airway inflammatory diseases such as epiglottitis and mucosal swelling. It can also be used to assess vocal cord mobility. Before securing nasal intubation, maxillary sinusitis or basal skull fractures should be ruled out. Maxillary sinusitis can be diagnosed by US. Boundaries of the maxillary sinus are orbital floor superiorly, hard palate inferiorly, nasal wall medially, and zygoma laterally. Sinus is normally air filled and thus impairs ultrasonic beam transmission. Only the anterior wall is seen with some artifact (acoustic shadowing), which obscures all of the underlying structures. If the sinus is filled with fluid, the ultrasonic beam will travel through the fluid after penetrating the anterior wall and gets reflected by the posterior or lateral walls producing an image known as "sinusogram." In the case of air-fluid level in the sinus or mucosal thickening, partial sinusogram (only posterior wall or side wall seen) is seen. For this, patient should be in upright position or semi-recumbent position so that fluid (if present) flows according to gravity covering the floor of the sinus and coming in contact with anterior wall.

6.11 Ultrasound-assisted percutaneous dilatational tracheostomy

Many serious complications of percutaneous dilational tracheostomy like hemorrhage, high mediastinal vessels erosion, tracheal stenosis, esophageal disruption, and thyroid isthmus injury can be avoided by precise identification of anterior neck structures with the help of US [16]. Before attempting this, the neck should be examined for a midline trachea, the level of the tracheal ring, thyroid isthmus, vulnerable thyroid vessels, and diameter and the midline location of anterior jugular veins or other aberrant vasculature [18]. With advanced US technology, it will be possible in the future to have the real-time guidance in the placement of dilators and tracheostomy tubes.

7. Conclusion

As reviewed earlier, the use of ultrasound during airway management can help identify anatomical anomalies in the airway structures and the location of cricothyroid membrane (useful in cricothyrotomies) as real-time visual confirmation of endotracheal tube position. Ultrasound measurements can also help in the prediction of difficult mask ventilation and intubation. In addition, lung ultrasound can also help detect pneumothorax which can happen due to barotrauma (during ventilation or tracheostomy) as well as unilateral intubations. The use of ultrasound as a teaching aid during airway management can promote visual learning.

Author details

Ajay Singh*, Ankita Dhir, Shiv Lal Soni, Rekha Gupta, Naveen B Naik, Kashish Garg, Venkata Ganesh and Narender Kaloria
Department of Anaesthesia and Intensive Care, Post Graduate Institute of Medical Education and Research, Chandigarh, India

*Address all correspondence to: ajay.ydv2509@gmail.com

References

[1] Singh M, Chin KJ, Chan VWS, Wong DT, Prasad GA, Yu E. Use of sonography for airway assessment: An observational study. Journal of Ultrasound Medical Official Journal. 2010;**29**(1):79-85

[2] Koh W, Kim H, Kim K, Ro YJ, Yang HS. Encountering unexpected difficult airway: Relationship with the intubation difficulty scale. Korean Journal of Anesthesiology. 2016;**69**(3):244-249

[3] Adnet F, Racine SX, Borron SW, Clemessy JL, Fournier JL, Lapostolle F, et al. A survey of tracheal intubation difficulty in the operating room: A prospective observational study. Acta Anaesthesiologica Scandinavica. 2001;**45**(3):327-332

[4] Maharaj CH, Buckley E, Harte BH, Laffey JG. Endotracheal intubation in patients with cervical spine immobilization: A comparison of macintosh and airtraq laryngoscopes. Anesthesiology. 2007;**107**(1):53-59

[5] Seo SH, Lee JG, Yu SB, Kim DS, Ryu SJ, Kim KH. Predictors of difficult intubation defined by the intubation difficulty scale (IDS): Predictive value of 7 airway assessment factors. Korean Journal of Anesthesiology. 2012;**63**(6):491-497

[6] Sustić A, Kovac D, Zgaljardić Z, Zupan Z, Krstulović B. Ultrasound-guided percutaneous dilatational tracheostomy: A safe method to avoid cranial misplacement of the tracheostomy tube. Intensive Care Medicine. 2000;**26**(9):1379-1381

[7] Kaniyil S, Anandan K, Thomas S. Ratio of height to thyromental distance as a predictor of difficult laryngoscopy: A prospective observational study. Journal of Anaesthesiology Clinical Pharmacology. 2018;**34**(4):485-489

[8] Ezri T, Gewürtz G, Sessler DI, Medalion B, Szmuk P, Hagberg C, et al. Prediction of difficult laryngoscopy in obese patients by ultrasound quantification of anterior neck soft tissue. Anaesthesia. 2003;**58**(11):1111-1114

[9] Kheterpal S, Healy D, Aziz MF, Shanks AM, Freundlich RE, Linton F, et al. Incidence, predictors, and outcome of difficult mask ventilation combined with difficult laryngoscopy: A report from the multicenter perioperative outcomes group. Anesthesiology. 2013;**119**(6):1360-1369

[10] Shibasaki M, Nakajima Y, Ishii S, Shimizu F, Shime N, Sessler DI. Prediction of pediatric endotracheal tube size by ultrasonography. Anesthesiology. 2010;**113**(4):819-824

[11] Osman A, Sum KM. Role of upper airway ultrasound in airway management. Journal of Intensive Care. 2016;**4**(1):52

[12] Yao W, Wang B. Can tongue thickness measured by ultrasonography predict difficult tracheal intubation? BJA British Journal of Anaesthiology. 2017;**118**(4):601-609

[13] Adhikari S, Zeger W, Schmier C, Crum T, Craven A, Frrokaj I, et al. Pilot study to determine the utility of point-of-care ultrasound in the assessment of difficult laryngoscopy. Academic Emergency Medicine. 2011;**18**(7):754-758

[14] El Amrousy D, Elkashlan M, Elshmaa N, Ragab A. Ultrasound-guided

laryngeal air column width difference as a new predictor for postextubation stridor in children. Critical Care Medicine. 2018;**46**(6):e496

[15] Venkategowda PM, Mahendrakar K, Rao SM, Mutkule DP, Shirodkar CG, Yogesh H. Laryngeal air column width ratio in predicting post extubation stridor. Indian Journal of Critical Care Medicine. 2015;**19**(3):170-173

[16] Kim J, Kim JY, Kim WO, Kil HK. An ultrasound evaluation of laryngeal mask airway position in pediatric patients: An observational study. Anesthesia and Analgesia. 2015;**120**(2):427-432

[17] Chowdhury AR, Punj J, Pandey R, Darlong V, Sinha R, Bhoi D. Ultrasound is a reliable and faster tool for confirmation of endotracheal intubation compared to chest auscultation and capnography when performed by novice anaesthesia residents – A prospective controlled clinical trial. Saudi Journal of Anaesthesia. 2020;**14**(1):15-21

[18] Kajekar P, Mendonca C, Gaur V. Role of ultrasound in airway assessment and management. International Journal of Ultrasound and Applied Technologies in Perioperative Care. 2010;**1**(2):97-100