Role of Ultrasound in Airway Assessment and Management

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ABSTRACT
Ultrasound has gained widespread popularity in several aspects of perioperative and intensive care management. There is now growing evidence of it being a useful tool in the assessment and management of potentially difficult airway. With advances in technology and greater understanding of sonographic clinical anatomy, a greater insight into its uses has been gained. This article gives an overview of the possible clinical applications of ultrasound in day to day airway management in anaesthesia and intensive care.

Keywords: Airway, Ultrasound, Intubation, Tracheostomy.

INTRODUCTION
The ultrasound has been in clinical use since the early 1900s and its use in airway management has been published since then. It has been used to image the upper airway, trachea and pleural cavity. The ultrasound is now more readily available and its advantages are that it is safe, simple, non-invasive, and repeatable. When combined with a thorough knowledge of regional anatomy and practical skills in ultrasound technology, it can provide vast amount of information which can be used to improve the quality of care we deliver to patients.

Challenges of Imaging Airway
Ultrasound imaging depends on the transmission and reflection of acoustic waves (typically 2.5-10 MHz for medical use) through a medium. Airways are superficial structures and filled with air (high acoustic impedance) which does not allow proper transmission of the ultrasound signals through the air filled passage, hence produces poor ultrasound image. The modern ultrasound systems are equipped with multiarray and variable frequency transducers that are combined with cross beam imaging facility with improved lateral and spatial resolution which produces high-quality image with better definition of superficial soft tissues and airways.

Upper Airway Imaging
Sonography of the upper airway can help to visualise the structures mainly oral cavity, pharynx, larynx, and upper trachea. Although filled with air, being relatively superficial in position, it enables us to view partially or completely frontal and lateral walls of nearly all upper airway segments.1

The tongue and floor of the oral cavity can be imaged by diagonal and vertical sections from the mandible to the hyoid bone. The tongue is seen as a muscular organ with a typical hypo/isoechoic structure. The valleculae and the palatopharyngeal folds can be visible on both sides of tongue leading to hypopharynx.1

To visualise the pharyngeal and laryngeal structures, both sublingual and transcutaneous approach can be used. The sublingual scanning approach requires a high frequency curved array probe in imaging the oropharyngeal and glottic structures. Visualisation of the structures like epiglottis is quite challenging due to the posterior acoustic shadowing of the hyoid bone and artifacts.2,3

The transcutaneous approach allows the visualisation of airway structures in the transverse and parasagittal planes. Bony structures (the mandible and hyoid) are visible as bright hypechoic image with an underlying hypechoic acoustic shadow.4 The epiglottis can be visualised both above and below the hyoid bone; the part of it behind the hyoid is obscured due to acoustic shadow of the hyoid. It can also be seen between the hyoid and thyroid cartilage as hypechoic structure with a curvilinear shape on parasagittal views and inverted C on transverse views.4

Both the above scanning approaches can be used together to provide complementary views in evaluating the airway.

Larynx
The larynx and vocal cords can be visualised through the thyroid cartilage (Fig. 1) and the movements with respiration can be
appreciated by the use of ultrasound. In a recent study, authors were able to visualise most of the relevant anatomic structures of the upper airway in a group of 24 patients by using either a linear or a curved transducer oriented in one of the three planes: Sagittal, parasagittal and transverse. The larynx, which is a musculocartilaginous structure formed by nine cartilages could be clearly visualised and its intraluminal surface was outlined by a bright airmucosa interface. It may be difficult to visualise the posterior aspect of pharynx, posterior commissure and posterior wall of the trachea because of artefacts created by an intraluminal air column.

Predicting Difficult Intubation
Ultrasound quantification of the anterior neck soft tissue has been used to predict difficult intubation. The measurement of pretracheal soft tissue at the level of the vocal cords was found to be a good predictor of difficult laryngoscopy in Middle Eastern obese patients in Israel. However, Komatasu et al could not replicate these findings in American obese patients. The difference between the two observations has been postulated due to the difference in the fat distribution between ethnic groups. Other studies have demonstrated a relationship between difficult airway and presence of abundant neck soft tissue in the pharynx, retropharynx, suprascapular region as measured from CT scans and MRI. Neck ultrasound measurements are found to be as accurate as MRI for quantification of fat depth. In patients with sleep apnoea, upper airway ultrasonography has been used to visualise approximation of the tongue base posteriorly and inferiorly towards the hypopharynx to cause airway obstruction. Pharyngeal or laryngeal pathology, such as tumours, abscesses or epiglottitis which may have a significant effect during airway management, are detected by the use of US scan.

Tracheal Intubation
The current methods of confirming tracheal intubation, such as auscultation, end tidal CO₂ monitoring and oesophageal detector devices can lead to false positive results. Capnography has proven to be the most reliable although it has its own limitations. In cardiac arrest and low cardiac output states, its sensitivity may be very low as end tidal CO₂ may be undetectable. Ultrasonography has shown to be a safe, reliable and non-invasive way of confirming the correct position of the endotracheal tube (ETT) with high sensitivity and specificity. In a recent study, the authors used a combination of transcricoid membrane ultrasonography and ultrasonographic sliding lung sign in 30 patients in emergency department to confirm endotracheal intubation and found the sensitivity, specificity, positive predictive value and negative predictive value to be 100% each. The US can be used to directly visualise the ETT being positioned in the trachea by external scanning technique at the level of the cricoid at the time of intubation. The correct placement of ETT in the trachea typically produces a dense hyperechoic shadowing, or "comet tail" appearance (Fig. 2). There have been reports of using US to document ETT position with the echogenicity enhanced by retaining a stylet in the tube or by filling the ETT cuff with fluid and air bubbles. US can also be used to visualise the motion of the diaphragm and pleura, which are indirect quantitative and qualitative indicators of lung expansion. When ETT is in correct position in the trachea bilateral equal motion of the diaphragm towards the abdomen can be seen, which represents the equal bilateral expansion of the lungs.

Intercostal ultrasonographic view of the lung pleura can provide direct anatomic evidence of lung expansion, and therefore of ventilation. The parietal and visceral surfaces of pleura can be visualised by US as distinct bright interfaces (echogenic lines) sliding across each other with each ventilation and lung expansion (Fig. 3). This is described as the sliding lung sign and indicates ventilation of that hemithorax. In theory a correctly positioned ETT should show sliding lung sign bilaterally. The absence of sliding lung sign on both sides is assumed to indicate oesophageal intubation. The potential pitfalls of using the sliding lung sign to confirm intubation...
include the presence of a pneumothorax where the sliding lung sign is absent. Using the same principle, US imaging can be used to confirm the correct placement of double lumen tubes. A few studies have also used the ultrasound to calculate the appropriate size of endotracheal and double lumen tubes.

Cricothyroidotomy
Cricothyroidotomy can be a life-saving procedure in an unanticipated difficult airway in a "can't intubate and can't ventilate" scenario. It can also be used prophylactically prior to induction of anaesthesia in an anticipated difficult intubation. US can be used in identifying the anatomical landmarks for performing cricothyroidotomy (Fig. 4).

Role of Ultrasound in Intensive Care
The US has various roles in the intensive care settings from vascular access, regional blocks for analgesia to assessment of cardiac function. Its use to diagnose and treat respiratory problems is increasingly practiced now. Various respiratory pathologies like pleural effusions, haemothorax and pneumothorax can be diagnosed with the use of bedside ultrasound and treatment can be initiated using the same. The presence of air between the pleural layers interferes with visualisation of lung sliding during ventilation, thereby diagnosing the pneumothorax. It is now commonly used during the insertion of chest drains in intensive care. Ultrasound has a definitive role in percutaneous tracheotomies too. Diagnostic ultrasound may be used to assess the suitability of patients for bedside percutaneous dilatational tracheostomy in the intensive care unit by visualising the pretracheal structures prior to the procedure. It can be used to assess the pretracheal structures especially to identify vascular structures and also to identify the intended site of tracheostomy. It can be used to assess the tracheal width to determine the appropriate tube size which can be particularly useful in children. Numerous studies and case reports claim a decrease in the incidence of complications by using US. Injection of saline into the tracheal tube cuff enables adequate tube withdrawal to be demonstrated with ultrasound and prevent needle damage and transfixing of the tracheal tube. US can be used to assess the depth of trachea and appropriate puncture point at the optimal intercartilaginous space for tracheostomy tube placement (Fig. 5). The site of puncture is usually selected between the second and third tracheal rings, after a clear US verification of anatomy of the thyroid and cricoid cartilage, and tracheal rings. The correct position of the tracheostomy tube can also be confirmed at the end of the procedure by means of US. Ultrasonography of the anterior neck does appear to provide a margin of safety in avoiding prominent vessels and facilitating midline insertion at the correct level. However, due to the ultrasonic acoustic shadow, visualisation of the posterior tracheal wall is not possible during percutaneous tracheostomy. Therefore, to prevent the damage to posterior tracheal wall, fiberoptic assistance may still be required.

Fig. 3: Sliding lung sign: 1, Parietal pleura; 2, Visceral pleura

Fig. 4: Parasagittal view demonstrating cricothyroid membrane. 1, Thyroid cartilage; 2, Cricothyroid membrane; 3, Cricoid cartilage

Fig. 5: Tracheal depth and width at the level of 2nd tracheal ring
CONCLUSION

Ultrasoundography has a potential role in airway assessment and in the management of difficult airway. It is easy and rapid to perform and is an inexpensive way of assessing airway difficulties. The increasing availability of small, portable US devices has led to an increased use of US even in the critical care setting. Correct interpretation of US images requires a sound knowledge of sonographic anatomy, otherwise the acoustic artefacts can be mistaken for abnormal structures. The superficial structures can be interpreted quite easily but the interpretation of deeper structures can still be quite challenging.

In future, ultrasound has a great potential and can become routine in airway management.

REFERENCES