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# Airway POCUS for airway assessment in hospital and critical care environment: A comprehensive review

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**Abstract**
Ultrasound (US) imaging improves the dependability and precision of airway intervention and assessments. In recent years, scientific research on utilizing ultrasound in the management of airway has advanced, aligning with the increased availability of portable and affordable US machines. After being used in the insertion of central venous catheter and regional blocks, it is now increasingly used in preparation for dealing with a difficult airway and ensuring its secure maintenance. It has questioned the conventional strategy of clinical airway evaluation and enables a more active assessment at the bedside. This review article will seek to offer a brief overview of ultrasound's applications in the management of airway.

**Keywords:** Airway management, critical care environment and cricothyroid membrane

## Introduction
Skillful airway management emerges as a significant aspect for anesthesiologists. The conventional approach, relying on comprehending regional anatomy and conducting practical sessions on patients, is consistently utilized with variable outcomes regarding evaluating accuracy, executing a maneuver and validating it, and managing emergencies. This method doesn't entirely address factors connected to individual diversity. Currently, the use of ultrasonography plays a major role in improving airway management in the intensive care unit (ICU), emergency department and operating room [1]. Ultrasonography is considered the most fitting approach in this realm because of its universal availability, reasonable cost, ease of use, safety, pain-free application, speed and replicability by trained operators [2]. It offers information about the complete upper airway, encompassing the subglottic, glottis and supraglottic regions [3].
The Implementation of ultrasound (US) imaging improves the dependability and precision of airway intervention and assessments. In recent years, scientific research on utilizing ultrasound in the management of airway has advanced, aligning with the increased availability of portable and affordable US machines. Real-time intervention or gathering information regarding airways can be accomplished without the requirement of seeking advice from other medical professionals, including radiologists; this approach is particularly beneficial for swift decision formation in emergency circumstances. To achieve optimal benefit, it is recommended to actively utilize ultrasonography in every phase of airway technique - after, during or before each airway instrumentation [4]. Thus, optimizing airway management is possible by combining airway ultrasonography and personal skills [5].

## Equipment and technical issues
Ultrasounds are also called acoustic waves, have a frequency exceeding the range of human detection 6. Frequencies between 2 and 15 MHz are routinely used in medical imaging [4]. US probes utilize piezoelectric materials, which transmit and generate sound waves, obtaining echoes from human tissues influenced by their specific electrical and mechanical properties. Based on the reflection pattern of obtained sound waves, influenced by the distinct impedance of ultrasound on each tissue, transducers replicate the internal makeup of the examined organs [1, 6]. When different acoustic interfaces are available, the major echoes originate from tissues appeared as white, identified as hyperechoic [4]. When there are only few acoustic interfaces, the echoes are markedly decreased; the formations look black and are termed hypoechoic [4]. A reciprocal correlation is present between the frequency of

ultrasound and its capability to enter tissues (e.g. deep tissue penetration is correlated with low frequency), and a direct association between potential resolution of image and frequency [1, 6]. During airway examination, superficial structures situated 2-3 cm below the surface of skin can be attained utilizing 7.5 MHz linear probes [1, 7]. Although airways are predominantly superficial formations, the appearance of air hinders accurate visualization of their deeper portions [1]. In the same way, the visualization of the endotracheal tube's filled cuff becomes impractical because of the existence of air inside. Ultrasounds are reflected, resulting in the formation of artifacts because air weakly conducts ultrasound. To achieve good-quality images, it is suggested to employ transducers with variable frequencies and incorporate cross-beam imaging [5], or it might be significant to use tricks to improve the pattern of US reflection e.g. adding fluids or air bubbles into the endotracheal tube's cuff such as normal saline [1], or observing the tube during its transverse view via the larynx.

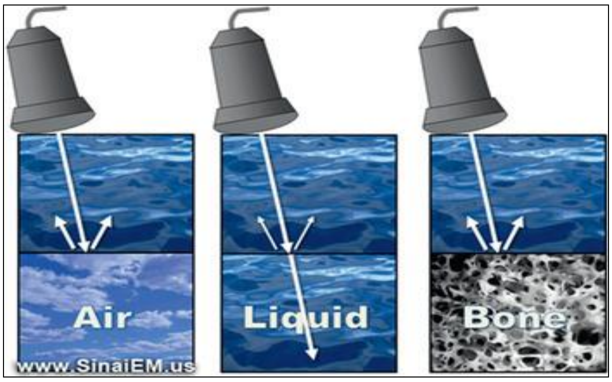


**Fig 1:** http://new.sinaiem.us/snells-law Accessed February 20th, 2024

A fundamental investigation of the airway is conducted by employing three scanning-planes in a transcutaneous method: parasagittal, sagittal and transverse, taking the anterior midline of the extended neck functions as a guide. These planes allow visualization of the mouth and the lateral and frontal wall of the larynx, upper trachea and pharynx [2, 5]. Ultrasound images are disrupted by the elevated acoustic impedance of the bone; at the junction of bone and tissue, ultrasound reflects strongly, leading to an acoustic shadowing effect that blocks the view beyond the bone. The hyoid bone obscures the back part of the airway and the epiglottis, while the mandibular rami conceals the muscles on the side of the oral floor. The segment of the epiglottis below and above the hyoid bone can be seen, yet visualizing the segment situated behind it may be challenging [5]. Using parasagittal scanning by means of the hyo-thyroid window optimizes the epiglottis visualization, lessening the influence of bone and air [8]. It's been suggested that sublingual scanning may provide diverse images for a unique spatial strategy. The sublingual fossa serves as a host for curved-array probe, which delivers a high frequency of 8 MHz. Improved contact of the probe with the tissues provides the resulting images [9]. The two sublingual and transcutaneous strategies can provide additional details to refine the accuracy of evaluation. Various imaging modes can be observed in US, like Doppler mode, M-mode, B-mode and A-mode [6]. In airway management, the last three are the primary focus. B-mode ultrasonography offers static images in two dimensions (2D); M-mode displays B-mode images swiftly, showing movements; while Doppler mode shows B-mode structures, deriving velocity-based details [4]: for instance, properties exhibited by the flow within a vessel.

**Sonography applications in airway management**

Sonography finds various applications in the management of airway with significant developments in recent years. They are categorized into three broad categories: tracheostomy, Endo tracheal intubation and Cricothyroidotomy.

**Prediction or Identification of difficult airway**

Adhikari *et al*.'s [10] research study consisted of a pilot investigation of around 51 patients, in which they used ultrasound to assess the tongue thickness and the soft tissue situated in the anterior neck at the level thyrohyoid membrane and hyoid bone. The study observed that the thickness of soft tissue at these areas is a significant factor in distinguishing between easy and challenging intubation. Ezri *et al*. [11] assessed the thickness of soft tissue situated in the anterior neck at the suprasternal notch and vocal cords in obese individuals. Their findings suggested a correlation between greater soft-tissue and difficult laryngoscopy at the vocal cords level. Numerous ultrasonographic parameters, including thickness of anterior neck soft tissue at different levels [12] and different derived ratios have been evaluated, however, none has achieved undisputed acceptance for this purpose.

**Determination of cricothyroid membrane**

This becomes highly advantageous in situations involving emergencies, challenging airway anatomy, cricothyrotomy, percutaneous tracheotomy, retrograde intubation, and other relevant circumstances [13]. Besides helping in positioning the cricothyroid membrane, the sonographic technique also helps in finding the accurate gap between tracheal rings, prevents bleeders by recognizing adjacent blood vessels, and also determines distance from the skin to the intended site, specifically in obese individuals.

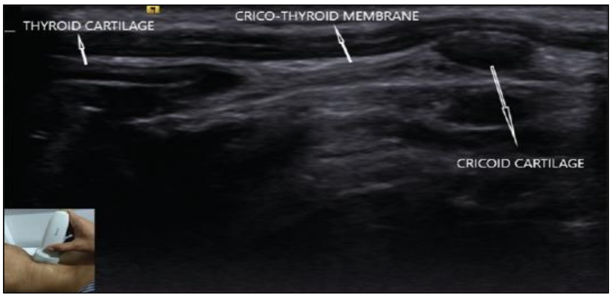


**Fig 2:** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7047677/figure/F4/ Assessed on February 20th, 2024

**Confirmation of successful endotracheal intubation**

Capnography is known as the best method to verify the correct positioning of an endotracheal tube. In specific conditions, alternative techniques are necessary to verify the position of an ETT, as capnography might not be applicable in some situations. Anesthesiologists, who are experts in the management of airway, must be knowledgeable about this technique to effectively address any unforeseen situations. These circumstances consist of individuals with severe bronchospasm, pulmonary embolism, cardiopulmonary arrest, and technical Issues associated with capnography. Trachea usually displays as a curved and bright ringed structure with air-cartilage interface and comet-tail artifact, while endotracheal intubation leads to heightened shadowing and artefact limited to the tracheal region. Ultrasonography shows the unique "double tract" sign when esophageal intubation takes place [14, 15, 16]. Confirming placement of endotracheal tube with ultrasound might be determined indirectly by evaluating bilateral lung movement during the process of ventilation in an individual under paralysis.

**Confirmation of accurate ETT depth**

Ultrasound has demonstrated its advantages, specifically in pregnant women and children. In neonates and infants, place the probe in the midline of the sternum to confirm the tip of endotracheal tube, usually aiming for 1 - 1.5 cm above the superior portion or aortic arch of the right pulmonary artery, serving as a substitute indicator for the carina [17, 18, 19]. Tracheal Rapid Ultrasound Saline Test, also known as T.R.U.S.T addresses the problem of nonvisualization resulted by air-filled ETT cuffs by inflating them with saline. The precise placement of the endotracheal tube can be determined by examining ETT cuff filled with saline with the ultrasound probe placed transversely at the sternal notch level [20, 21].

**Detection of endobronchial intubation**

Diagnosing endobronchial intubation involves evaluating the moment of diaphragm and lung-sliding sign is noted in the ventilated lung, linked with limited moment of diaphragm and the lack of lung-sliding sign on the side not receiving ventilation.

**Facilitation of percutaneous dilatational tracheostomy**

Ultrasound significantly improve the integrity of this process. It aids in the identification of the proper puncture point, avoiding injuries to nearby soft tissue and vessels while also avoiding the generation of "false passages," evaluating tracheostomy tube size, and also validation of procedure's success. This proves beneficial in circumstances involving alteration in the anatomy of airway, as noted in patients with thyroid issues, neck tumors, and similar circumstances. The capability to gauge the distance from trachea to skin holds specific importance in individuals with obesity and also provides guidance for choosing the suitable length of the tube. Conducting real-time ultrasound-guided tracheostomy is viable and has shown fewer complications in contrast to guidance utilizing bronchoscopy strategies or traditional landmarks [26-29].

## Conclusion

Despite its constraints, this technique is rapidly advancing in the realm of anesthesiology, being used in nearly every function. As mentioned earlier, it is increasingly utilized for prediction or identification of difficult airway, determination of cricothyroid membrane, confirmation of successful endotracheal intubation, confirmation of accurate ETT depth, detection of endobronchial intubation and facilitation of percutaneous dilatational tracheostomy. Its applications for different objectives are quickly progressing as skill, knowledge, awareness, dynamic assessment and real-time acceptance among clinicians increase.

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