The Utility of Ultrasound in Airway Management

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1 Introduction

Ultrasound utilization has become a mainstay in modern medical practice for a variety of diagnostic tests and procedures. Increased availability and usage can be attributed to decreased cost, increased clinician awareness, portability, safety, and ease of use. In recent years, the use of ultrasound for airway assessment and management has grown considerably, yielding promising results. While accurate anatomical assessment of the airway using ultrasound is dependent on operator skill, numerous studies have shown that clinician ability to reliably obtain accurate images requires minimal training and is easily reproducible [1]. This chapter will review relevant airway anatomy and the utility of ultrasound use for airway assessment and management.

2 Review of Basic Anatomy

All clinicians who are responsible for airway assessment and management need to have an understanding of basic airway anatomy. Generally, the airway can be divided into upper and lower sections. The upper airway consists of the mucous membrane lined pharynx and larynx. The pharynx is subdivided into the nasopharynx, oropharynx, and hypopharynx. The nasopharynx includes the posterior nasal cavity and is divided from the oropharynx via the palate and skull base. The oropharynx consists of the region between the palate and hyoid bone and connects the nasopharynx and hypopharynx. The hypopharynx is the area below the hyoid bone and connects the oropharynx to the cartilaginous larynx. The larynx contains the components necessary for speech, including the epiglottis and vocal cords. The lower airway consists of the trachea and lungs. The tubular shape of the trachea is supported by C-shaped hyaline cartilage, which allows for esophageal motility during swallowing. A detailed discussion of lung anatomy is beyond the scope of this chapter.

For the purpose of ultrasound assessment, the airway can be divided anatomically into suprahyoid and infrahyoid regions [2]. Suprahyoid anatomical structures include the mylohyoid, geniohyoid, tongue, and hyoid bone. Pertinent infrahyoid structures include the epiglottis, thyrohyoid membrane, pre-epiglottic space, thyroid cartilage, and tracheal cartilage. Curved low frequency transducers can be used to visualize deeper submandibular and supraglottic structures, while linear high frequency transducers are best suited to visualize superficial structures [2–7]. Ultrasound images of both the suprahyoid and infrahyoid structures have been found to correlate well with computed tomography [8]. The clinical relevance of the assessment of these aforementioned structures will be discussed below.

3 Predicting Difficult Airway Management

Throughout the years, numerous physical exam findings have been established for clinicians to help predict potential difficult airway management. These conventional markers include, but are not limited to patient height, weight, BMI, race, Mallampati score, thyromental distance, cervical spine range of motion, jaw mobility, and dentition [4]. While these assessments have been widely adopted internationally, they can have varying degrees of sensitivity and specificity, leaving clinicians vulnerable to the dreaded cannot intubate can-

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not ventilate situation. Several studies have found that preoperative airway assessment with ultrasound has increased both the sensitivity and specificity relative to these conventional assessments.

The inability to visualize the hyoid bone using sublingual ultrasound has been found to have high sensitivity and specificity to predict difficult intubation with a positive likelihood ratio of 21.6 [5]. Another study found that morbidly obese patients with a shorter hyomental distance ratio, or the distance between the hyoid bone and mandibular mentum in the neutral to the hyperextended neck position, is a sensitive predictor for difficult airway management [9]. A hyomental distance ratio of 1.0–1.05 was found to be associated with difficult airway management when compared to patients with a hyomental distance ratio of 1.12–1.16 [9].

Increased pre-tracheal tissue at the level of the vocal cords has been shown to be predictive for difficult airway management in obese patients of middle eastern descent [10]. However, it is worth noting that these findings were not duplicated when applied to western patient populations [11]. Small pilot studies have also shown that an anterior neck thickness greater than 2.8 cm at the level of the hyoid bone and the thyrohyoid membrane are accurate predictors of difficult intubation, but larger studies are needed prior to validation for routine screening [12].

Ultrasound has also been found to be sensitive and specific for the detection of subglottic stenosis. Several studies have found that ultrasound evaluation of the narrowest diameter of the cricoid lumen, or the transverse diameter, correlate well with findings from magnetic resonance imaging [13, 14]. Detection of subglottic stenosis allows for practitioners to preemptively chose the right endotracheal tube size, minimizing the potential for complications like hypoxia or airway trauma due to repetitive manipulation [13, 15]. Ultrasound evaluation of the subglottic transverse diameter has been found to be superior to both age based and height based formulas to estimate the correct endotracheal tube size [15, 16].

4 Regional Anesthesia

Ensuring adequate anesthesia of the airway via regional techniques is an essential component for successful awake intubation in patients with a known or suspected difficult airway. Ultrasound utilization can help facilitate regional techniques when normal anatomical landmarks are difficult to assess, due to morbid obesity or a history of previous surgery involving the airway or neck. The superior laryngeal nerve provides sensation to the epiglottis and to the airway mucosa to the level of the vocal cords. This nerve can be visualized in the space between the hyoid bone and thyroid cartilage when looking transversely at the level of the hyoid bone [17]. Visualization of anatomical landmarks and needle placement under ultrasound guidance can help to ensure adequate analgesia and maximize first pass success.

5 Confirmation of Airway Placement

Capnography and auscultation of the lungs are the most commonly used methods to confirm appropriate airway placement in the normal healthy patient. However, these conventional methods may not be as accurate or reliable in situations such as cardiovascular collapse, emergent difficult airway management with potential esophageal intubation, or severe refractory bronchoconstriction. Successful intubation can be confirmed quickly and easily via transtracheal ultrasound by the “double tract” or “double lumen” signs characterized by two hyperechoic lines [18, 19]. Multiple studies have shown that transtracheal ultrasound is a rapid and reliable method to confirm proper airway placement and correlates well when compared to end tidal capnography [18, 19].

6 Utilization in Emergency Situations

Preparation is a critical component for the successful management of emergent difficult airway scenarios. A cricothyrotomy is lifesaving technique to secure a definitive airway in unstable patients who are unable to be intubated or ventilated by conventional methods. The procedure involves cannulating the cricothyroid membrane by either a needle or percutaneous approach. The cricothyroid membrane is most often identified by locating the space below the thyroid prominence and above the cricoid cartilage. Often times, these anatomical landmarks can be difficult to recognize due to patient body habitus or pathology affecting the area, such as a thyroid mass. The use of ultrasound has been proven to be a quick and effective adjunct to identify these difficult to ascertain anatomical landmarks. With only minimal training, clinicians have been found to be able to identify the cricothyroid membrane using ultrasound in less than 25 seconds [20]. A subsequent study done on cadavers found that clinicians were able to identify the cricothyroid membrane in less than 4 seconds and complete the procedure with a high success rate in less than 30 seconds [21].

After successful cricothyrotomy, a formal tracheostomy is generally performed within 24 hours to establish a more definitive and secure airway. Ultrasound for percutaneous tracheostomy can help to avoid anterior neck structures and minimize the risk for posterior tracheal injury [22–25]. A randomized controlled trial from 2016 found that an ultrasound guided approach has similar efficacy to a bronchoscopy guided tracheostomy [26].

7 Conclusion

This chapter has described how ultrasound utilization has shown promise as an easy, useful, and reliable adjunct to both airway assessment and management. While larger studies need to be done for further validation, it is imperative for clinicians responsible for airway management and assessment to be familiar with the most up to date literature regarding the many potential indications for ultrasound use.

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