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REVIEW

ULTRASONOGRAPHY – A NEW METHOD FOR AIRWAY ASSESSMENT: A REVIEW OF THE LITERATURE

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Abstract. Introduction: *Endotracheal intubation is an important part of the anesthetic practice; however, sometimes, it can be difficult and/or impossible. Complications of difficult airway management include hypoxia, hypoxic brain injury, cardiovascular instability, cardiac arrhythmias and death. The objective of the current review is to determine the feasibility and advantages of ultrasonography as a method for airway assessment in patients undergoing laryngeal surgery.* ***Materials and Methods:*** *The literature review is conducted using the PubMed, Scopus and Google Scholar scientific databases to identify relevant studies and clinical guidelines related to difficult airway management and methods of assessment. The literature review revealed 16,300 articles during the period from 1 January 2014 to 2024, of which only 54 most closely represented the specific issues.* ***Results and Discussion:*** *There are numerous bedside tests for identifying and evaluating difficult airways, but their sensitivity remains unclear. Ultrasonography is a non-invasive, safe, painless, and easy-to-perform method. It provides dynamic real-time images, as well as detailed anatomical information of the pathological changes of the larynx.* ***Conclusion:*** *According to various studies, ultrasonography has been found to be an effective method for the identification and evaluation of difficult airways in patients undergoing elective surgery.*

Key words: *endotracheal intubation, difficult airway, ultrasonography*

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INTRODUCTION

Successful anesthetic management during laryngeal surgery requires tight cooperation between the surgeon and the anesthesiologist [1]. When the pathologic process causes airway obstruction, the anesthesiologist must consider not only the anatomical complexity of the upper airways and the specifics of the pathological process, but also all the steps of the surgical procedure [2, 3]. The ability of the anesthesiologist to safely share the patient's airway with the surgeon, along with knowledge of the possible intra- and postoperative complications of laryngeal surgery, contributes to safe patient management in the perioperative period [4, 5].

Endotracheal intubation (ETI) is a crucial part of anaesthetic practice, primarily the responsibility of the anesthesiologist, but it can sometimes be difficult and/or impossible [6]. Difficult endotracheal intubation is associated with high rates of morbidity and mortality. In various studies, the incidence of difficult endotracheal intubation has been found to be 0.16-20% [7]. The incidence is even higher during ENT surgery because of the laryngeal obstruction.

The presence of laryngeal obstruction as a result of the pathologic process requires a precise assessment of the feasibility of ETI [8]. A preliminary examination of the laryngeal anatomy and any specific changes is crucial for selecting the proper ventilation technique. Preoperative evaluation of the degree of laryngeal obstruction is of high importance for choosing the best technique for ventilation [9].

Endotracheal intubation is required for most surgical operations and maintenance of breathing in critically ill patients. Identification of potentially difficult intubation can help the anesthesiologist prepare for any complications. The inability to anticipate and plan for a patient with a difficult airway is the single most important contributing factor to the catastrophic “can’t intubate, can’t ventilate” situation. Although this occurs in less than 1/5000 elective procedures under general anesthesia and requires surgical airway management in less than 1/50 000 cases, these situations can lead to serious complications associated with long-term morbidity and high mortality rates and are a contributing cause for up to 25% of anesthesia-related deaths [10].

Patients with advanced airway obstruction and inspiratory stridor comprise some of the most complicated cases for the anesthesiologist. When difficult intubation is expected, a preliminary plan for the airway management is essential if the intubation proves to be impossible [11, 12]. Therefore, it is essential for the anesthesiologist to recognize and assess potentially difficult airways and to be prepared with appropriate equipment and medication [13, 14]. Numerous bedside tests exist to identify difficult airways; however, their sensitivity remains unclear. No standard single preoperative prediction method demonstrates clear advantages in predicting difficult tracheal intubation [15]. Ultrasonography is a non-invasive, safe, painless, and easy-to-perform procedure. It also gives dynamic real-time images. It is widely available and, due to the ability to provide detailed anatomical information, is used in many medical specialties as well as for airway evaluation [16, 17]. It is used to determine the correct endotracheal tube number, to confirm correct laryngeal mask placement or pulmonary intubation, as well as to diagnose upper airway pathology and guide percutaneous tracheostomy or cricothyroidotomy.

MATERIALS AND METHODS

The literature review is performed using the PubMed, Scopus and Google Scholar scientific databases for search of the following key words: endotracheal intubation, difficult airway and ultrasonography. The search was limited to articles published after 2014, and that included abstracts and/or free full-text articles. A total of 16,300 articles met the key words, of which 54 were selected that most closely matched the search issues. Of these, five were meta-analyses, and six were systematic reviews.

RESULTS AND DISCUSSION

The literature review reveals that the following parameters are used for ultrasonographic prediction of difficult laryngoscopy and difficult intubation: the hyoid bone visualization, distance from the skin to the hyoid bone, distance from the skin to the epiglottis, the size of the preepiglottic space, distance from the skin to the anterior commissure of the vocal cords, the hyomental distance in the neutral and extended positions as well as the ratio between the hyomental distance in the extended and neutral positions of the head, distance from the skin to the anterior aspect of trachea at the level of thyroid isthmus, tongue thickness, tongue width and volume [18]. Anterior neck soft tissue thickness is found to be an independent predictor for difficult laryngoscopy. It also may be associated with airway motility during laryngoscopy. Adipose tissue also affects the view during direct laryngoscopy [19]. Assessment of the airway before intubation is a valuable skill that needs to be done quickly and accurately [20].

The linear and curved probes are used to measure these parameters. Fundamentally, ultrasound imaging is based on the generation of high-frequency sound waves, ranging from 2 to 15 MHz, which penetrate different body tissues at different speeds. The reflected waves from the tissues are received by the transducer and then are analysed by a computer to form images. Bone structures appear as bright hyperechogenic lines with an acoustic shadow behind them, muscles and connective tissue membranes appear hypoechogenic with a heterogeneous striped appearance, while structures that lie behind an air column are completely obscured. The thyroid gland and submandibular gland appear mildly to severely hyperechogenic with a homogeneous appearance, depending on their fat content. For the purpose of ultrasound diagnosis, the upper airway is divided into two regions: suprahyoid and infrahyoid. The curved low-frequency transducer (2-5 MHz) is used to visualize deeper structures in the submandibular and supraglottic regions, whereas the linear high-frequency transducer (5-14 MHz) is used to visualize more superficial structures located 2-5 cm from the skin surface. Sagittal, parasagittal and transverse views are used [21].

The respiratory tract is completely filled with air, which prevents visualization of the structures behind it. This determines the difficulty of using ultrasound of the upper airway [22]. For proper ultrasound evaluation of the upper airway, patients are placed in a sniffing position with the head and neck in a neutral position. Some of the explored techniques are included in the following sections.

Distance From Skin to Hyoid Bone

According to many authors, hyoid bone visualization is a very important parameter in the algorithm of difficult airway assessment. The linear ultrasound probe is placed transversally over the hyoid bone. The hyoid bone is visualized as a curved echogenic structure with a posterior acoustic shadow. The distance between the skin and the hyoid bone is also measured. This is the distance in centimetres measured in a straight line from the skin to the middle of the hyoid bone (Fig. 1). Inability to visualize the hyoid bone and increased distance between skin and the hyoid bone determines difficult laryngoscopy [23, 24]. A DSHB value greater than 0.66 cm was predicted as a difficult airway, and less than 0.66 cm as an easy airway [25]. Measuring greater than 1.28 cm can predict difficult laryngoscopy with a sensitivity and specificity of 85% [26]. In another study, a distance of 1.41 ± 0.30 cm had a sensitivity of 80.4% and a specificity of 60.1% [27].

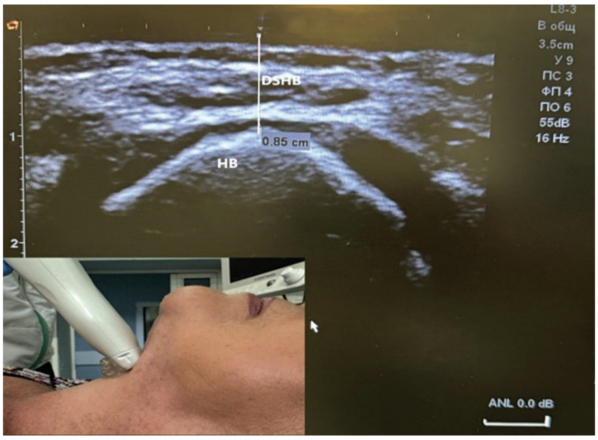

Fig. 1. Placement of a linear probe in transverse orientation across the hyoid bone. H – hyoid bone, DSHB – distance between skin and hyoid bone

Distance From Skin to Epiglottis

Another indicator for difficult airway assessment is the distance between the skin and the epiglottis (SED). The linear high-frequency ultrasound probe is placed transversally and measures the distance in centimeters in a straight line. Once the hyoid bone is visualized, the linear probe is moved caudally. Through the thyroid membrane, the epiglottis is visualized as a hypoechoic curved structure. On ultrasonography, the epiglottis is anteriorly outlined by a preepiglottic space (PES), which is visualized as a hyperechogenic structure. Posteriorly, it is bounded by a bright hyperechogenic line, representing the air-mucosa interface. Ultrasound measurement of the SED is an indicator for the angulation of the epiglottis (Fig. 2). Greater distance means greater angulation and poor visualization of the glottis [28, 29].

On the other hand, ultrasound identification of larger PES may predict difficulties in raising the epiglottis during direct laryngoscopy. The PES is measured midway at the level of the cricothyroid membrane from the anterior surface of the epiglottis to the anterior edge of the strap muscles. PES contains adipose tissue, elastic fibers, collagen fibers and lymph vessels [27, 30]. It is called Boyer's space. The epiglottis is not easily visualized because of its depth, cartilaginous structure and hiding behind the hyoid bone. The whole image looks like a "little face" in which the strap muscles are like eyes, and the epiglottis is like the mouth [31, 32]. A measured value of more than 2.36 cm is a good predictor of difficult intubation [33]. Sonographic measurement of Pre-E/E-VC ratio greater than 1.90 indicates a CL grade of 3.4. It appears to be a more reliable indicator than SED [34].

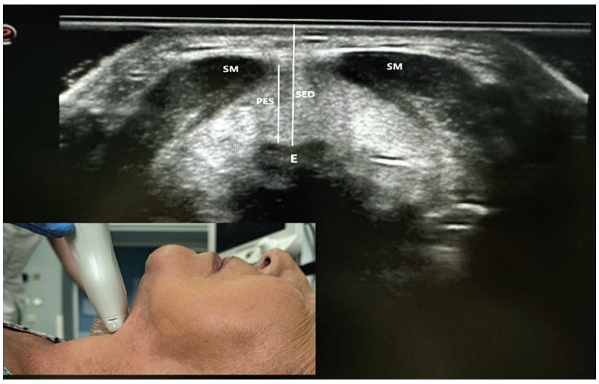

Fig. 2. Placement of the thyrohyoid probe on the patient's neck. Placement of a linear probe in transverse orientation across the thyrohyoid membrane. PES – pre-epiglottic space, E – epiglottis, ST – strap muscle

Distance between the skin and the vocal cords

It is measured in centimeters between the skin and the anterior commissure of the true vocal cords. Ultrasound probe is placed transversely. The thyroid cartilage is visualized as a large inverted V-shape structure. The true vocal cords are triangular and move medially during respiration. They reveal fine tissue echogenicity and are medially connected to the hyperechogenic vocal ligaments. False vocal cords are round to oval and have a hyperechogenic structure due to their fat content. They are positioned parallel and cephalic to true ones and do not move during phonation. The vocal cords are attached to the arytenoid cartilages. They are visible behind the thyroid cartilage and are more visible in women and young people than in men and elderly people [35-37].

Hyomental distances

Hyomental distance (Fig. 3) in a neutral head position and in extension can be very helpful in assessing a difficult airway. The measurement is performed with a curved, low-frequency transducer placed in the mid-sagittal plane. Patients are positioned supine with their heads in a neutral position. They are instructed to look up directly, close their mouth, and hold their tongue at the floor of the mouth. After the first series of scans, patients are instructed to straighten their necks as much as possible, being careful not to lift their shoulders off the table. Mentum and hyoid bone appear as hyperechogenic structures with hypoechogenic shadowing. Hyomental distances in neutral and extended positions are measured from the inferior border of the mentum to the superior border of the hyoid bone [38, 39]. The ratio between hyomental distance in extension and hyomental distance in neutral position of the head of the patient (HRM ratio) is a predictor of reduced extension ability at the atlantooccipital joint. Hyomental distance is the most reliable indicator of difficult intubation. A shorter distance determines a more difficult laryngoscopy [40, 41].

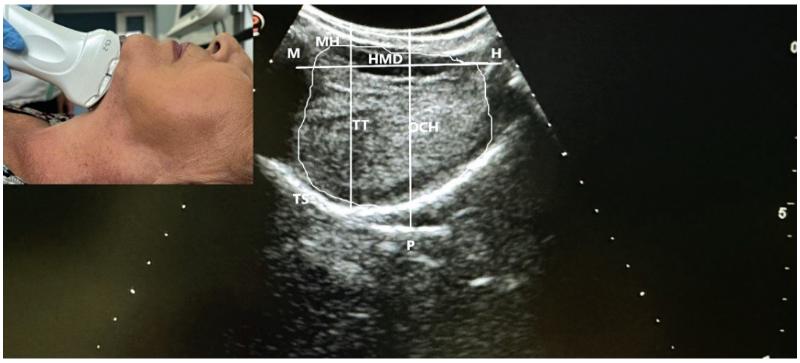

Fig. 3. Midsagittal scan of the submandibular area and positioning of the ultrasound transducer. H – hyoid bone, HMD – hyomental distance, M – mandible, MH – mylohyoid muscle, OCH – oral cavity height, P – palate, TS – tongue surface, and TT – tongue thickness

Compared with HMDR, sonographic measurement of the Pre-E/E-VC ratio has been shown to be a more reliable indicator of CL classification. A Pre-E/E-VC ratio greater than 1.90 indicates that the case is difficult for laryngoscopy (CL grade 3.4) [34]. An HMDR of ≤ 1.2 can indicate difficult laryngoscopy with a sensitivity of 100% and a specificity of 90.5% [42].

Tongue Measurements

It has been found that ultrasound can visualize the patient's tongue and accurately measure the width, thickness and volume of the tongue [43, 44]. According to various authors, the larger these parameters are, the more difficult laryngoscopy is, which respectively increases the risk of difficult endotracheal intubation. The measurements are performed with the high-frequency linear probe, which is placed under the lower chin in the neck area in the mid-sagittal plane. Patients are positioned supine, with their mouths closed and tongues relaxed, without phonation. The transducer is adjusted so that the entire outline of the tongue is clearly visible on the screen. Tongue thickness is measured as the maximum vertical dimension from the skin to the tongue surface (Fig. 4). It is normally less than 6.1 cm [45, 46].

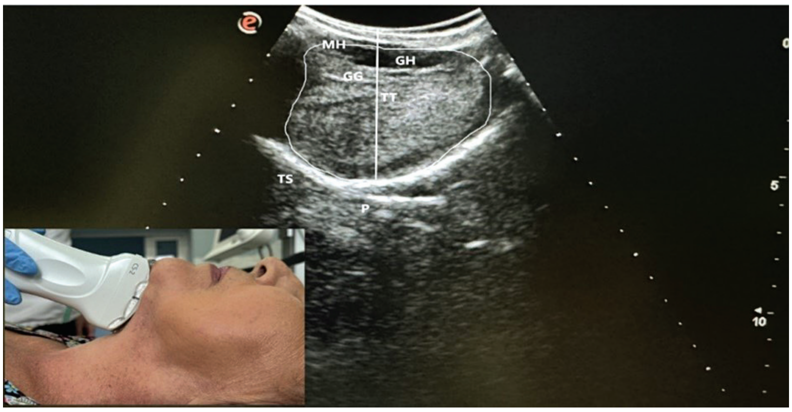

Fig. 4. Midsagittal scan of the submandibular area and positioning of the ultrasound transducer. GG indicates genioglossus muscle, GH – geniohyoid muscle, MH – mylohyoid muscle, P – palate, TS – tongue surface, and TT – tongue thickness.

The width of the tongue is measured by positioning the probe transversely at the base of the mouth and measuring the distance between the two lingual arteries using Doppler [47, 48]. It has been found that if the distance between the two lingual arteries exceeds 28 mm, there is a high probability of difficult intubation. Tongue width may be a poor predictor of difficult laryngoscopy [49].

The incidence of difficult endotracheal intubation during ENT surgery is higher compared with other surgical subspecialties. This is because of the pathology of the upper airways. For a selected group of patients, many procedures of the oral cavity can be effectively performed with adequate topical anesthesia of the patient's airway, which is part of the preparation of the patient for awake oral and nasal flexible fiberoptic intubation [50, 51]. Many ENT surgical procedures can be performed in a patient under conscious sedation or with the patient anesthetized [52]. The ventilation options for patients under general anesthesia consist of different techniques such as endotracheal intubation, apneic intermittent ventilation and jet ventilation [53, 54]. Ultrasound can be used for non-invasive identification and evaluation of the airways of the patient without consecutive complications. It can also be very helpful in choosing the best anesthetic technique for patients with expected difficult airways, especially those with different kinds of laryngeal pathology.

CONCLUSION

According to various studies, ultrasonography has been found to be an effective method for difficult airway assessment. The routine use of this non-invasive technique in practice will improve preoperative assessment of patient airways and reduce complications during specific types of surgical procedures. However, higher-level research is still needed to determine the best parameters to use and their potential incorporation into clinical practice.

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Ethical statement: *This study has been performed in accordance with the ethical standards as laid down in the Declaration of Helsinki.*

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