Original Article

Relationship Between Upper Airway Ultrasound Parameters and Degree of Difficult Laryngoscopy for Endotracheal Intubation

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Abstract

Background: Limited research has been conducted on the role of ultrasound in predicting difficult laryngoscopy (DL). This study aimed to evaluate the predictive values of upper airway ultrasound parameters for the degree of DL during intubation.

Materials and Methods: This observational-prospective study was performed on 120 patients requiring intubation during elective surgery. Initially, the degree of DL was assessed by the Mallampati Scale. The patient's neck circumference was then measured and recorded. Ultrasound was used to determine the hyomental distance in the neutral position (HMDN), the head extension (HMDE), as well as tongue width (TW), tongue thickness (TT), oral cavity height ratio (OCH), the amount of soft tissue (ST), and the Tongue thickness-to-oral cavity height ratio (TT/OCH). Afterward, the patients underwent general anesthesia and were intubated. The degree of difficult intubation was measured based on the Cormack-Lehane classification system. The patients were divided into easy and difficult laryngoscopy groups. Finally, the effectiveness of the two methods of ultrasound and intubation was compared.

Results: The Cormack score and Mallampati class recorded intubation difficulty as 28.3% and 30.8%, respectively. According to the Cormack score, only the neck circumference was significantly associated with intubation difficulty (P=0.002). Regarding Mallampati class, the neck circumference and HMDN, HMDE, TT, OCH, and ST were significantly associated with DL (P <0.05). The numerical value of the area under the curve (AUC) in the receiver operating characteristic (ROC) curve for sonographic parameters based on the Cormack score and Mallampati scoring system was poor (AUC <0.7).

Conclusion: The results showed that the accuracy of ultrasound criteria in predicting the severity of intubation with laryngoscopy is poor.

Keywords: Laryngoscopy, Intratracheal, Anesthesia, Area Under Curve

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Introduction

Airway management is critical in emergencies. Tracheal intubation is the primary method of securing a definite and reliable air passage. In previous studies, tracheal intubation has been reported to be associated with tube misplacement or displacement in 6-25% of cases (1, 2).

Preoperative assessments are vital for identifying patients with possibly difficult laryngoscopy (DL) and intubation, as difficult intubation can have serious consequences (3, 4). The complications of tracheal intubation include airway injury, pneumothorax, airway obstruction, aspiration, and bronchospasm. Improper airway management and difficult intubation are significant causes of mortality and anesthesia-related complications, so patients should be evaluated before airway interventions (5, 6). These rare complications are partly related to differences in test results and disagreements between observers (7). The accurate assessment of airways by the anesthesiologist can significantly reduce the risks associated with anesthesia (8).

The techniques used to confirm tracheal intubation must possess adequate sensitivity to verify the completion of the process. In addition, these techniques should be easily mastered and applicable by physicians so that they can timely perform the procedure to minimize the duration of hypoxia for patients and avoid esophagus ventilation and its subsequent complications such as vomiting and aspiration (2, 9).

Recent studies have proposed a role for ultrasound in determining the location of the endotracheal tube. This method has been suggested as safe, bedside, and accessible for assessing airways (10). Ultrasound can help indirectly predict the requirements and outcomes of tracheal intubation (11).

Several studies have proposed airway ultrasound parameters as indicators for difficult laryngoscopy (DL); however, research is ongoing to find accurate measures in this area (7, 12). For example, Ezri *et al*. showed that neck circumference (> 50 cm) predicted DL (12). In another study, a hyomental distance greater than 1.1 cm (the ratio of the neck hyomental in the neutral to hyperextension state) was a predictor of easy laryngoscopy in patients (13). Although ultrasound parameters may help identify patients with DL (12), there is inadequate evidence for this notion. It necessitates more research to confirm the reliability and applicability of airway ultrasound indicators (7, 14). This study aimed to investigate the predictive values of upper airway ultrasound parameters for the degree of DL during tracheal intubation.

Methods

The study was an observational-prospective conducted in two academic medical centers (Rajaei and Velayat) affiliated with Qazvin University of Medical Sciences in 2021. The study population included all the patients who required intubation during surgery. This study was approved by the ethics committee of Qazvin University of Medical Sciences, and written informed consent was obtained from all patients before participating.

Considering an independent t-test for the hyomental distance, study power of 90%, type I error of 10%, effect size of 0.1, and standard deviation of 0.23, the sample size was determined as 120. The patients over 18 years old and scheduled for elective surgery requiring tracheal intubation were included. Exclusion criteria encompassed a history of surgery on the upper or lower jaw, history of trauma to the maxillofacial region or the temporomandibular joint (TMJ), history of surgery due to pharyngeal abscess or Ludwig abscess, history of trauma to or surgery on cervical vertebrae, enlarged thyroid, and neck mass.

The Malampati Scale first assessed the degree of laryngoscopic difficulty. Then the patient's neck circumference was measured with a tape measure. In the Mallampati method, the patient is requested to sit up while placing the head in the natural position and opening the mouth as wide as possible. The Mallampati classification is as follows: class I: soft palate, the posterior and anterior columns of the tonsils and the small tongue are within sight; class II: the columns of the tonsils and the small tongue are hidden by the base of the tongue, class III: only the soft palate is observable, and class IV: the soft palate is not visible (15). In addition to the paraclinical imaging data, patients' demographic data (age, gender) were recorded on a checklist.

Before intubation, the patients were examined by a trained anesthesia resident to evaluate airway ultrasound criteria. All patients underwent evaluation for airway ultrasound parameters before surgery. Airway ultrasound was performed by an 8 X Sono Case device equipped with a 2-6 MHz transducer (with a curve probe). An airway ultrasound was performed in the supine position. For this purpose, the transducer was placed in the submandibular area on the sagittal and transverse planes. On the sagittal plane, the image was taken. At the same time, the patient's head was in a neutral position, and the mentum and hyoid bones were visible. An image was also saved when the patient's head had the maximum extension and the bone and hyoid were visible. Images were taken from the patient's head in the neutral position on the transverse plane. A qualified person evaluated the images stored in the device's memory to determine the measures required. These included: 1) hyomental distance with the head in the neutral position (HMDN). 2) hyomental distance with the head in the extended position (HMDE), which were determined in the sagittal scan from the upper limit of the hyoid bone to the lower limit of the mentum of the mandible in the neutral and extended positions. 3) Tongue width (TW) (cm) was measured as the distance measured in the transverse scan in the middle of the tongue. It was considered between the farthest upper surface points of the genioglossus muscle. 4) Tongue cross-sectional area (cm^2): this was measured by determining the limits of tongue muscles in the sagittal scan. 5) Oral cavity height (OCH) (cm): the distance between the ventral part of the tongue and the palate, which was measured by the sagittal scan in the neutral position and after pouring 5 mL of water into the mouth. 6) Soft tissue (ST): the average amount of para-tracheal soft tissue from the surface of the vocal cords. 7) Tongue thickness-to-oral cavity height ratio (TT/OCH) was measured in the sagittal scan.

After determining ultrasound measures, the patients underwent general anesthesia with hypnotic drugs (propofol and thiopental sodium) and a suitable muscle relaxant (atracurium, 0.5 mg/kg). After the elapse of the necessary time (i.e., 3 min), intubation was performed using laryngoscopy and a suitable Macintosh blade by an anesthesiology assistant who was unaware of the patient's ultrasound parameters. The degree of DL was carefully assessed and recorded based on the Cormack-Lehan system. The Cormack-Lehan system consists of four grades as follows: grade 1: fully in-sight glottis, grade 2a: partially in-sight glottis, grade 2b: only posterior glottis or arytenoid cartilages visible, grade 3: only epiglottis is detectable, with no visible gluteal parts, and grade 4: neither epiglottis nor glottis are visible. According to this classification system, patients with grades 1 and 2 are placed into the easy intubation group, and patients with grades 3 and 4 are categorized into the difficult intubation group (16). Finally, the two methods of ultrasound and laryngoscopy were compared efficiently.

Statistical Analysis: After data collection, the results were analyzed using SPSS software version 22. The Kolmogorov-Smirnov test was used to assess the normality of the data. Data were presented using frequency and percentage (for categorical variables) and mean and standard deviation (for continuous variables). The independent t-test was used to compare continuous variables, and the Chi-square test was used to compare categorical variables between study groups. The receiver operating characteristic (ROC) curve was used to determine the sensitivity and specificity of ultrasound parameters. A P value of <0.05 was considered as the statistical significance level. This research was supported by a grant from the Research Department of Qazvin University of Medical Sciences.

Results

Out of 120 patients who participated in this study, 60 (50%) were male. The mean age of the participants was 41.3 ± 14.9 years, with an age range of 18 to 76 years. The criteria for the degree of DL during intubation based on the Mallampati classification and the Cormack scoring system have been shown in Table 2. According to both criteria, the highest frequency was related to grade 2. According to the Cormack scoring system, the degree of intubation difficulty was easy (i.e., grade I & II) in 86 patients (71.7%) and difficult (i.e., grade III & IV) in 34 (28.3%) of them. Based on the Mallampati classification, the degree of intubation difficulty was easy in 83 (69.2%) and difficult in 37 (30.8%) of the patients. Table 1 compares patients' characteristics and ultrasound parameters based on DL during intubation according to the Cormack scoring system and the Mallampati classification.

Regarding the Cormack scoring system, only

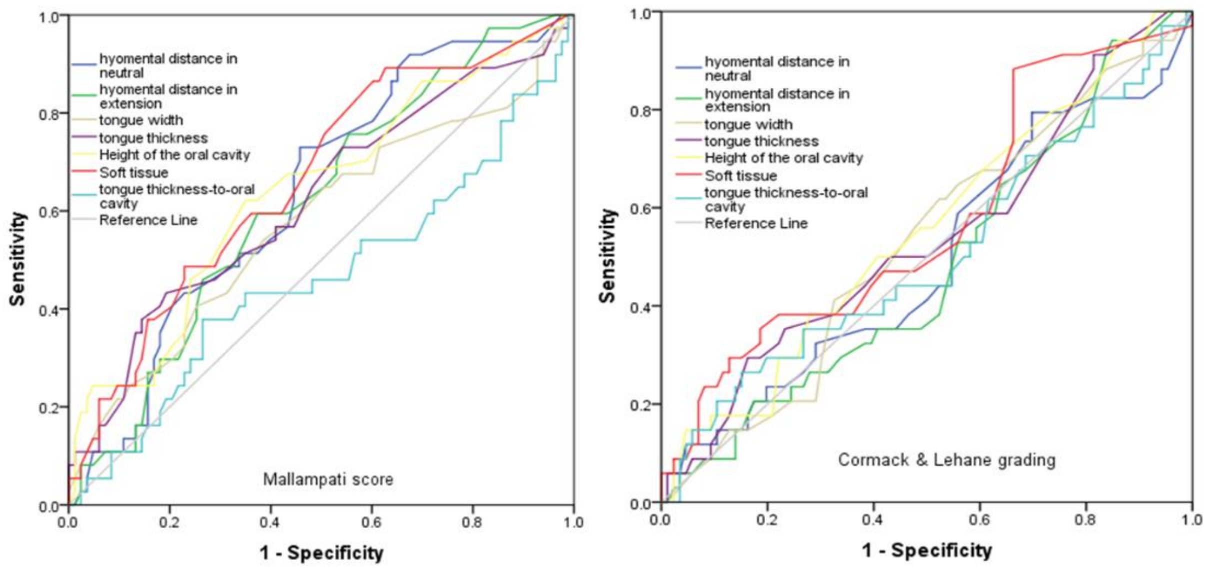

Figure 1. The ROC curves of ultrasound criteria indicate their predictive performance for the degree of intubation difficulty by laryngoscopy based on Mallampati classification and the Cormack scoring system.

Table 1: The Frequency Distribution of the Criteria Used for Predicting Difficult Intubation.

Variables	Level	N (%)	Cumulative frequency (%)
Cormack scoring system	1	20(16.7%)	16.7
	2	66(55%)	71.7
	3	33(27.5%)	99.2
	4	1(0.8%)	100
Mallampati classification	1	11(9.2%)	9.2
	2	72(60%)	69.2
	3	32(26.7%)	95.8
	4	5(4.2%)	100

the neck circumference was significantly associated with the degree of difficult intubation (P=0.002). Neither HMDN, HMDE, nor TT/OCH could significantly predict difficult intubation (P>0.05, Table 2). According to the Mallampati classification, the degree of intubation difficulty was significantly associated with HMDN, HMDE, tongue thickness, OCH, and ST (P<0.05) (Table 2).

The predictive values of ultrasound parameters for the degree of intubation difficulty during laryngoscopy based on Mallampati classification and the Cormack scoring system have been noted in Table 3 and Figure 1. The area under the ROC curve (AUC <0.7) showed ultrasound rendered poor accuracy in predicting the degree of intubation difficulty based on the Cormack scoring system and Mallampati classification, as indicated by the ROC curves of ultrasound criteria (Figure 1). According to the figure, the proximity of the curve related to each of the ultrasound criteria to the main diameter of the diagram indicates the poor performance of these criteria in predicting the degree of intubation difficulty using laryngoscopy.

Discussion

This study aimed to evaluate the larynx structure at the sagittal and transverse planes to determine the degree of DL. Our results revealed significant differences in some ultrasound parameters between the easy and difficult laryngoscopy groups. Regarding the Cormack

Table 2: Patients' Characteristics and Ultrasound Features Based on the Degree of Intubation Difficulty During Laryngoscopy According to Mallampati Classification and the Cormack Scoring System.

Variables		Cormack			Mallampati		
		Easy	Difficult	P	Easy	Difficult	P
Gender	Male	47(54.7%)	13(38.2%)	0.10	44(53%)	16(43.2%)	0.32
	Female	39(45.3%)	21(61.8%)		39(47%)	21(56.7%)	
Age (years)		41.8±15.8	40.2±12.4	0.79	41.53±16.19	40.84±11.69	0.8
Neck extent		51.81±6.24	49.34±9.52	0.34	51.69±6.03	49.80±9.68	0.55
Neck circumference		37.95±4.48	40.17±3.37	0.002	38.53±2.30	38.69±7	0.03
Hyomental distance in the neutral position		4.23±0.26	4.23±0.29	0.92	4.20±0.27	4.30±0.25	0.01
Hyomental distance in the extended position		4.37±0.29	4.37±0.25	0.73	4.34±0.28	4.43±0.26	0.04
Tongue width		4.99±0.15	5±0.11	0.64	4.98±0.15	5.02±0.13	0.17
Tongue thickness		3.96±0.19	4.01±0.18	0.51	3.94±0.16	4.03±0.23	0.03
Oral cavity height		4.17±0.20	4.23±0.24	0.34	4.15±0.16	4.28±0.29	0.01
Soft tissue amount		18.29±1.38	18.87±2.01	0.21	18.16±1.35	19.10±1.91	0.004
Tongue thickness-to-oral cavity height ratio		0.94±0.032	0.94±.035	0.94	0.95±0.030	0.94±.039	0.52

The values are based on frequency (%) and mean ± SD; * denotes P <0.05.

score, the only ultrasound parameter significantly correlated with difficult laryngoscopy was the neck circumference. Regarding Mallampati classification, the parameters of HMDN, HMDE, tongue thickness, OCH, and ST were significantly associated with difficult laryngoscopy. Regarding demographic characteristics, although difficult laryngoscopy was more frequent among female patients, neither gender nor age was significantly associated with the degree of DL. Consistently, Yao *et al*. (2017) and Andruszkiewicz *et al*. (2016) showed that the volume and thickness of the tongue could be associated with difficult intubation (12, 17). Other studies have also identified neck circumference as an indicator of difficult intubation (18, 19). Some studies have assessed the predictive value of the ultrasound-derived anterior soft tissue thickness parameter as a predictor of difficult laryngoscopy (20, 21). None of these studies have identified a standard criterion or method for predicting difficult intubation.

The analysis of respective ROC curves reflected the poor predictive accuracy of the ultrasound criteria assessed based on the Mallampati classification for the degree of difficult intubation by laryngoscopy. Although there was a link between difficult intubation (i.e., the easy and difficult groups) and some of the ultrasound parameters based on the Mallampati classification and the Cormack scoring system, these parameters had inadequate sensitivity and specificity in terms of the predictive value. Therefore, none of these parameters alone could desirably predict all the functional or anatomical features contributing to difficult laryngoscopy. Numerous studies have been performed to evaluate ultrasound accuracy in predicting difficult intubation. However, these studies have no consensus (7, 22). For example, in a similar study by Andruszkiewicz *et al.* (2016), significant differences were observed in ultrasound parameters between patients with easy and difficult laryngoscopy. Although these parameters showed relatively low sensitivity (42.9%-91%), they delivered high specificity (71.8%-97.7%), suggesting their potential to identify patients with difficult laryngoscopy (22). In another study, Falcetta *et al.* (2018) demonstrated that

Table 3: The Predictive Values of Ultrasound Criteria for the Degree of Intubation Difficulty by Laryngoscopy Based on the Cormack Scoring System and the Mallampati Classification.

Variables	Cormack				Mallampati			
	Sensitivity	Specificity	AUC	P	Sensitivity	Specificity	AUC	P
Hyomental distance in the neutral position	.35	.62	.49	.92	.48	.66	.64	.02
Hyomental distance in the extended position	.21	.80	.48	.74	.49	.68	.62	.04
Tongue width	.41	.67	.53	.64	.43	.69	.58	.18
Tongue thickness	.50	.57	.54	.51	.46	.71	.62	.03
Oral cavity height	.38	.67	.55	.35	.49	.73	.64	.01
Soft tissue amount	.45	.61	.57	.21	.49	.71	.66	.004
Tongue thickness-to-oral cavity height ratio	.38	.61	.50	.95	.38	.67	.46	.53

airway ultrasound could predict difficult laryngoscopy and intubation (23).

The difference between the results of our study and that of other studies can be due to specific circumstances regarding each parameter. For example, the difference observed in the hyomental distance can be justified by the variable positions of patients. A computed tomography study showed that postural changes could lead to hyoid bone displacement (24). In addition, the anesthesiologist's skills are determinant and may explain some of the variabilities observed. Therefore, available airway assessment methods cannot be definite predictors of difficult intubation, harboring a considerable error rate owing to the subjective nature of the problems occurring during intubation. It is possible to prevent these contradictory findings by standardizing many variables, including laryngoscopy equipment and anesthesiologists' skills and experience, to reduce the likelihood of bias and correct the perception of specialists (25, 26).

In this study, the procedure was accomplished by an anesthesiologist with more than 20 years of experience, which is a strength of the present study. In this study, we observed a parallel relationship between different structural components of the larynx. The area covered by the hyo-epiglottic ligament can change significantly by lifting the epiglottis during intubation. It causes the pre-epiglottic space to be less affected by the epiglottis movements during intubation. The ultrasound field of view at the sagittal plane can help objectify the hyoid bone and thyroid cartilage. The anesthesiologist's experience and skill help measure a relatively constant distance and visualize the structural link between adjacent parts of the larynx. Another advantage of the present study was assessing the relationship between ultrasound criteria and difficult intubation based on the Mallampati classification and the Cormack-Lehan system. The present study also suffers from some limitations, such as inadequate resources that allowed us to benefit from only one ultrasound device and a single experienced anesthesiologist, preventing us from recruiting more patients. Although the present study is not novel, it is a well-written and well-designed study. However, the authors cannot conclude that the Mallampati score is superior to the Cormack score in predicting difficult intubation because these two are different; the former is a part of the physical examination of the airway preoperatively, while the latter is described after induction of anesthesia and during laryngoscopy which is too late for predicting difficult intubation. Moreover, must be compared these two scores with a gold standard tool to compare their accuracy.

Conclusion

The results showed that some simple physical examinations might be associated with difficult laryngoscopy. According to the Cormack score, only the neck circumference was associated with intubation difficulty. Regarding Mallampati class, the neck circumference, HMDN, HMDE, TT, OCH, and ST were associated with DL degrees. The results showed that the accuracy of ultrasound criteria in predicting the severity of intubation with laryngoscopy is poor, and its relationship with ultrasound criteria is relative; nevertheless, more in-depth studies with larger sample sizes are required to reach more accurate conclusions about these parameters.

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None.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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