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Research Article

Ultrasound-Based Prediction of Mask Ventilation and Laryngoscopy Difficulty in Patients Undergoing General Anesthesia Using Airway Assessment Criteria

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ABSTRACT

Background: Reflex Given the critical role of anatomical airway structures in tracheal intubation, this study aimed to predict the difficulty of mask ventilation and laryngoscopy using ultrasound-based airway evaluation criteria.
Methods: This cross-sectional study involved 205 patients undergoing tracheal intubation. During intubation evaluation based on the Cormack-Lehane classification, neck ultrasound was performed. The diagnostic value of neck sonographic parameters was assessed using receiver operating characteristic (ROC) analysis.
Results: According to the Cormack-Lehane classification, intubation was easy in 170 patients (82.9%) and difficult in 35 patients (17.1%). Ultrasound findings revealed statistically significant differences in all parameters, including neck circumference, between the easy and difficult intubation groups. All measured values were higher in the difficult intubation group.
Conclusion: The findings suggest that ultrasound is a useful, practical tool for predicting difficult intubation. However, due to study limitations such as the small sample size, further research is recommended.

Introduction

In all surgical procedures, the risk of failed airway intubation can pose a serious threat to patients [1-2]. Despite predictive assessments for difficult intubation or mask ventilation, approximately 1.5%–13% of cases may still present with unexpected difficulty in laryngoscopy [3].

Securing the airway—either prior to or after a failed intubation attempt—is crucial. Nevertheless, distinguishing between difficult mask ventilation (DMV) and difficult laryngoscopy (DL) remains challenging [4-6]. Over the years, numerous diagnostic tools and methods have been explored, with ultrasound receiving particular attention due to its speed, ease of use, and high diagnostic accuracy.

Traditional clinical assessment methods include the Mallampati classification, inter-incisor distance, thyromental and sternomental distances, and neck mobility. Despite these evaluations, 1%–8% of patients still experience DL during laryngoscopy [7-9].

The incidence of a difficult airway is notably higher in patients with head and neck cancer. Apart from clinical and measurable criteria, demographic factors such as age, sex, race, history of obstructive sleep apnea, body mass index (BMI), and neck mobility (extension/flexion) can also influence airway difficulty [10].

Combining ultrasound assessments of anterior neck soft tissues at various anatomical levels with conventional airway evaluation techniques may enhance the prediction of DL. However, studies focusing on DMV are more limited, even though both aspects are critical in airway management [11].

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Some studies have found that even when clinical and ultrasound findings disagree, ultrasound can still correctly predict airway difficulty. In contrast, neither ultrasound nor clinical tests reliably predicted difficult airways in obese patients. In other cases, anterior neck soft tissue thickness was identified as an independent predictor of DL, showing greater specificity than BMI [12].

Ultrasound measurements taken at the hyoid bone, thyrohyoid membrane, and anterior commissure have demonstrated high diagnostic sensitivity. Among various grading systems, the Han scale has been widely used to categorize DMV, although it lacks sufficient practical reliability.

Five anatomical ultrasound measurements have been proposed for DMV prediction:

- DSTI: Distance from Skin to Thyroid Isthmus
- DSTJ: Distance from Skin to Trachea at Jugular Notch
- DSHB: Distance from Skin to Hyoid Bone
- DSAC: Distance from Skin to Anterior Commissure
- DSEM: Distance from Skin to Midpoint Between Hyoid and Thyroid Cartilage

An increase in anterior neck soft tissue thickness correlates with both DL and DMV [13].

Advanced imaging techniques like CT and MRI are also used for evaluating anterior neck structures but are impractical in operating rooms due to cost and inaccessibility [10, 12, 14].

Ultrasound, on the other hand, offers a radiation-free, cost-effective, and portable alternative with MRI-comparable accuracy. In this study, ultrasound was used to measure anterior neck soft tissue thickness at multiple anatomical sites to predict DL and DMV. These results were then compared with clinical predictors like the Cormack-Lehane grade [10].

Methods

Study design

This descriptive-analytical cross-sectional study was conducted in 2022 at Al-Zahra and Ayatollah Kashani Hospitals in Isfahan, Iran. The study population included patients undergoing elective surgeries under general anesthesia requiring tracheal intubation.

Inclusion criteria

- The informed consent to participate
- Age between 18 and 70 years
- American Society of Anesthesiologists (ASA) physical status I or II
- Scheduled for elective surgeries requiring tracheal intubation

exclusion criteria

- Anatomical airway deformities requiring fiberoptic intubation
- Previous thyroid or tracheostomy surgery
- History of facial or neck surgeries
- Head, neck, or epiglottic cancers
- Trauma to the face or neck
- Pregnant women
- History of obstructive sleep apnea
- Presence of masses or anomalies during laryngoscopy

A non-probability convenience sampling method was employed. Using a formula based on prevalence studies, the required sample size was estimated at 200 patients, considering a 95% confidence interval, 80% power, and an assumed ultrasound sensitivity of 40% based on previous literature.

Procedure

Eligible patients were identified in the operating room admission units. After obtaining informed consent, each patient underwent a clinical airway assessment, including Mallampati classification. A portable ultrasound device was then used to perform airway ultrasound in two positions:

1. Neutral neck position
2. Sniffing position (neck flexed and head extended)

Ultrasound Measurements

Five ultrasound-based parameters were measured using a high-frequency linear probe (6–13 MHz):

- DSTI: Distance from skin to thyroid isthmus
- DSHB: Distance from skin to hyoid bone
- DSAC: Distance from skin to anterior commissure
- DSTJ: Distance from skin to trachea at jugular notch
- DSEM: Distance from skin to the midpoint between the hyoid bone and thyroid cartilage (approximating the epiglottis)

Anesthesia Induction and Intubation

After placing the patient in the supine position with the head and neck in neutral alignment, standard monitoring was applied. General anesthesia was induced with 4 mL fentanyl, 5 mg/kg thiopental sodium, 0.6 mg/kg atracurium, and 1.5 mg/kg lidocaine. Mask ventilation was performed using a size 4 or 5 disposable face mask. Ventilation grading was assessed using the Han Scale, which classifies mask ventilation into four grades:

1. Easy ventilation
2. Ventilation with adjuncts (with/without muscle relaxant)
3. Difficult ventilation requiring two operators
4. Impossible ventilation

Following neuromuscular blockade, tracheal intubation was performed using a Macintosh laryngoscope. The modified Cormack-Lehane classification was used to evaluate the laryngoscopic view.

Data Analysis

All collected data were analyzed using SPSS version 26. Statistical tests included chi-square, t-test, ROC analysis, and diagnostic value assessments. A p-value of <0.05 was considered statistically significant.

Results

A total of 205 patients undergoing laryngoscopy were evaluated in this study. The mean age of the participants was 41.24 ± 15.6 years (range: 18–81 years), and the mean weight was 71.75 ± 15.6 kg (range: 27–122 kg). Of these, 99 patients (48.3%) were male, and 106 (51.7%) were female. (Table 1).

Anatomical Measurements

- Mean inter-incisor distance: 43.08 ± 6.7 mm
- Mean thyromental distance: 7.77 ± 0.76 cm
- Mean sternomental distance: 14.51 ± 1.53 cm
- Mean mentohyoid distance: 4.67 ± 0.81 cm

Mask Ventilation Grades (Han Scale)

- Grade I: 128 patients (62.4%)
- Grade II: 53 patients (25.9%)
- Grade III: 21 patients (10.2%)
- Grade IV: 3 patients (1.5%)

Laryngoscopy Grades (Modified Cormack-Lehane)

- Grade 1: 149 patients (72.7%)
- Grade 2a: 21 patients (10.2%)
- Grade 2b: 15 patients (7.3%)
- Grade 3a: 11 patients (5.4%)
- Grade 3b: 9 patients (4.4%)

According to the mask grade, 128 (62.4%) were grade 1, 53 (25.9%) were grade 2, 21 (10.2%) were grade 3, and 3 (1.5%) were grade 4. According to the Cormack-Lehan grade, 149 (72.7%) were grade 1, 21 (10.2%) were grade 2a, 15 (7.3%) were grade 2b, 11 (5.4%) were grade 3a, and 9 (4.4%) were grade 3b (Figure 1). According to the Spearman test, there was a direct correlation of 60% between mask grade and Cormack-Lehan, which was statistically significant (P < 0.001).

There was a statistically significant direct correlation (r = 0.60, p < 0.001) between mask ventilation grade and Cormack-Lehane grade. Based on the Cormack-Lehane criteria, tracheal intubation was classified as easy in 170 patients (82.9%) and difficult in 35 patients (17.1%). (Table 2).

Evaluation of ultrasound findings in the studied patients showed that all ultrasound items and neck circumference measurements had significant differences between the two groups with easy and difficult intubation, and the mentioned values were higher in the difficult intubation group (Table 2). The diagnostic value criteria of ultrasound parameters are shown in (Table 3).

The DSEM neutral position parameter had the highest sensitivity, and the DSEM sniffing position parameter had the highest specificity. According to the results, the positive predictive value (the probability of intubation difficulty in a person with a positive test result) was evaluated as low for all parameters, so that the highest positive predictive value was related to the DSEM sniffing position.

In contrast, the negative predictive value criterion (the probability of simple intubation in a person with a negative test result) was high for all parameters. According to the results, among the 9 parameters examined in ultrasound, the DSEM sniffing position parameter had the highest accuracy.

Table 1- Demographic and Anatomical Variables by Intubation Difficulty

Variable	Easy Intubation (n = 170)	Difficult Intubation (n = 35)	P value
Age (years)	40.9 ± 15.9	43 ± 14.6	0.47
Weight (kg)	69.3 ± 13.9	83.5 ± 18.1	< 0.001
Inter-incisor Distance (mm)	43.2 ± 6.6	42.6 ± 7.4	0.62
Thyromental Distance (cm)	7.82 ± 0.75	7.54 ± 0.81	0.046
Sternomental Distance (cm)	14.79 ± 1.34	13.14 ± 1.66	< 0.001
Mentohyoid Distance (cm)	4.71 ± 0.81	4.47 ± 0.8	0.11
Gender (Male/Female)	82/88	17/18	0.97

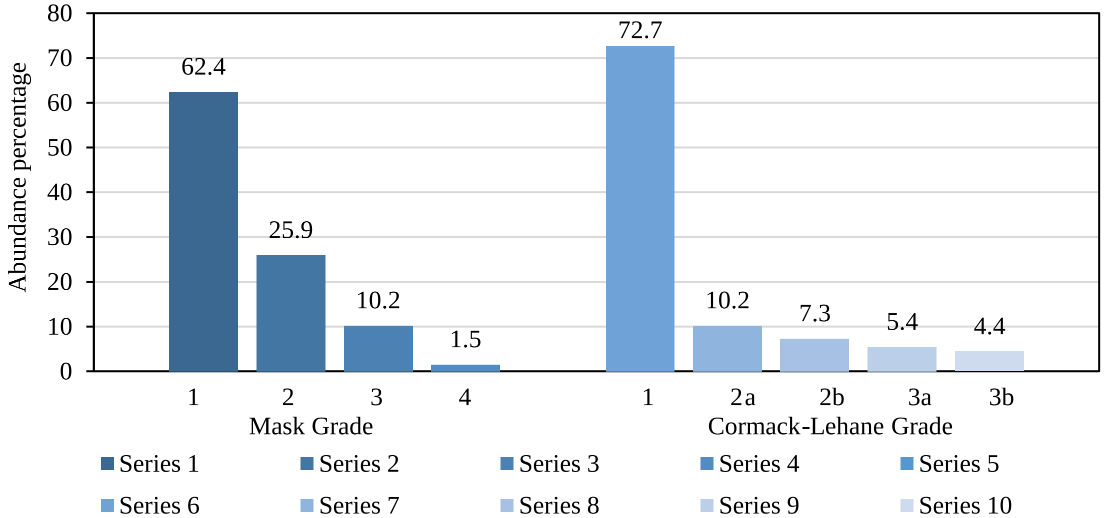

Figure 1- Percentage of frequency of Mask grade and Cormack-Lehan grade in patients.

Table 2- Mean and standard deviation of ultrasound findings in two groups with easy and difficult intubation

Ultrasound	Findings	Intubation	Status	P
		Easy	Difficult	
	DSTI	0.07 ± 0.27	0.11 ± 0.33	0.001>
	DSHB	0.28 ± 0.96	0.3 ± 1.17	0.001>
Neutral Position	DSAC	0.19 ± 0.79	0.23 ± 0.89	0.007
	DSTJ	0.33 ± 1.16	0.41 ± 1.45	0.001>
	DSEM	0.30 ± 1.16	0.46 ± 1.46	0.001>
	DSTI	0.07 ± 0.27	0.1 ± 0.33	0.001>
	DSHB	0.27 ± 0.96	0.29 ± 1.20	0.001>
Sniffing Position	DSAC	0.18 ± 0.80	0.19 ± 0.92	0.001
	DSTJ	0.3 ± 1.15	0.42 ± 1.47	0.001>
	DSEM	0.29 ± 1.18	0.33 ± 1.50	0.001>
	Neck circumference	4.22 ± 37.14	5.51 ± 41.91	0.001>

Table 3- Diagnostic value criteria of ultrasound in predicting difficult intubation

Parameter		Sensitivity	Specificity	PPV	NPV	Accuracy
	DSTI	77.1	55.3	26.7	92.2	0.59
	DSHB	74.3	60	27.7	91.9	0.37
Neutral Position	DSAC	54.3	65.9	24.7	87.5	0.64
	DSTJ	68.6	71.2	32.9	91.7	0.71
	DSEM	80	49.4	24.6	92.3	0.55
	DSTI	62.9	74.7	33.8	90.7	0.73
	DSHB	85.7	50.6	26.3	94.5	0.57
sniffing position	DSAC	88.6	43.5	24.4	94.9	0.51
	DSTJ	82.9	58.2	29	94.3	0.62
	DSEM	48.6	91.2	53.1	89.6	0.84
	NC	65.7	81.2	41.8	92	0.79

PPV: Positive Predictive Value; NPV: Negative Predictive Value; NC Neck circumference.

Discussion

Ultrasound has increasingly become a reliable, portable, and relatively low-risk diagnostic tool across many fields of medicine. Since tracheal intubation remains a critical and potentially challenging component of general anesthesia, the inability to anticipate intubation difficulty can result in repeated intubation attempts and serious patient complications. Additionally, current clinical criteria alone are often insufficient to accurately predict difficult laryngoscopy. The present study aimed to evaluate the utility of ultrasound in predicting the difficulty of both mask ventilation and laryngoscopy. Our findings indicate that ultrasound-derived parameters were significantly higher in patients classified as difficult intubations based on the Cormack-Lehane scale. Furthermore, these parameters demonstrated acceptable sensitivity for predicting difficult intubation.

A study by Agarwal et al. involving 1,043 patients also showed high sensitivity and specificity of ultrasound parameters in predicting difficult intubation [15]. Similarly, a systematic review by Ji et al. that included 17 studies and 8,779 patients found that ultrasound had an overall sensitivity of 84% and a specificity of 62.5%—results closely aligning with our findings [16].

In a study by Pournasrollah et al., ultrasound demonstrated 100% sensitivity, 83% specificity, 95% positive predictive value, and 100% negative predictive value in confirming correct endotracheal tube placement [17]. Benavides et al. reviewed 24 studies and found ultrasound had a sensitivity of 75% and specificity of 61% for predicting difficult laryngoscopy [18]. Wu et al. also reported significantly higher ultrasound values in patients with difficult laryngoscopy, consistent with our findings [19].

These comparisons suggest that ultrasound can serve as a valuable adjunct in predicting difficult intubation. Given the clinical priority of minimizing missed difficult airway cases, sensitivity is especially critical—and ultrasound excels in this regard. Although the high false-positive rate may lead to overestimation, it does not interfere with intubation procedures and thus remains acceptable.

Despite its advantages, the use of airway ultrasound still faces practical limitations in clinical settings, including operator dependence and equipment availability. Therefore, cost-benefit analyses should be considered when implementing ultrasound as a routine screening tool.

Conclusion

Our findings suggest that ultrasonography is a valuable and practical method for predicting difficult tracheal intubation. Due to the limitations of this study, including its relatively small sample size, further large-scale, multicenter investigations are recommended to validate and expand upon these results.

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Ethical approval

The study obtained the approval of the institutional review board at the School of Medicine, Isfahan (code: IR.MUI.MED. REC.1401.079).

Informed consent

All patients provided informed consent before participation in this study.

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