ORIGINAL ARTICLE

Evaluation of Point-of-care Ultrasound of Airway to Predict Difficult Laryngoscopy and Intubation in Intensive Care Unit Patients

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Received on: 21 September 2024; *Accepted on:* 19 November 2024; *Published on:* 30 December 2024

Abstract

Background: To evaluate the role of ultrasound (US) in the assessment of the airway and to determine whether US has the potential to serve as effective, noninvasive and less time-consuming method for the diagnosis of difficult intubation in ICU patients.

Patients and methods: This cross-sectional study was carried in 152 critically ill patients who underwent intubation in the ICU from December 2022 to April 2024. Prior to intubation thyromental height (TMH) and hyomental distance ratio (HMD-R) was measured using a scale and distance from skin to hyoid bone (SHB) and distance from skin to thyrohyoid membrane (STM) was measured using a US. Direct laryngoscopy was performed using a Macintosh blade, and the Cormack–Lehane (CL) grade was noted without external laryngeal manipulation. The laryngoscopy was classified as easy (CL Grade I and II) or difficult (CL Grade III and IV). The number of attempts at intubation, need for alternative difficult intubation approaches or inability to secure the airway was also noted.

Results: The incidence of difficult airway was 17.76%. The success rate for first-attempt intubation was 96.7%. Based on the receiver operating characteristic (ROC) curve analysis cut-off value of 1.97 cm [95% confidence interval (CI), 0.949–0.996, area under the curve (AUC), 0.972] for anterior soft tissue thickness from the skin to thyrohyoid membrane distinguished the difficult intubation group from the easy intubation group, with a sensitivity of 96.3% and specificity of 86.4%. For the hyoid bone level, a cut-off value of 0.905 cm (95% CI, 0.706–0.887, AUC, 0.797) had a sensitivity of 74.1% and specificity of 74.4%. Anterior soft tissue thickness from the skin to thyrohyoid membrane was a better predictor of a difficult airway. There was a significant correlation between clinical airway assessments and US airway assessments.

Conclusion: Point-of-care US can serve as an independent tool for assessing the airway in intensive care unit (ICU) patients, with anterior soft tissue thickness from skin to thyrohyoid membrane being a superior predictor. Combined models of sonographic and clinical tests could enhance the diagnostic value for identifying difficult intubation cases in ICU patients.

Keywords: Airway ultrasound, Difficult airways, Intensive care unit.

Indian Journal of Critical Care Medicine (2025): 10.5005/jp-journals-10071-24871

Highlights

Airway ultrasound is a noninvasive, less time-consuming, and efficient way of anticipating difficult airways. However, studies using various airway parameters to predict difficult airways in the ICU have not been widely carried out. Our study included adequate patients and was conducted in a tertiary care hospital.

Introduction

Tracheal intubation is not just a routine procedure but a vital component of the care provided to our most critically ill patients. Worse intubation conditions and a higher risk of complications were linked with tracheal intubations in the critical care unit compared with the operating room, underscoring the gravity of the situation. Intubation problems occur in the intensive care unit (ICU) 8–12% of the time.[1–3] Cardiac arrest (3.1%), severe hypoxemia (9.3%), and cardiovascular instability (42.6%) are the most common complications associated with the treatment, occurring at a rate of 45.2%.[4] There is an association between greater morbidity and delays in tracheal intubation as well as with repeated efforts at laryngoscopy.[5] In critically ill patients, the aim of tracheal intubation is a high first-attempt success rate without the associated adverse events. To provide the best possible preparation, equipment selection, and engagement of experienced professionals, it is essential to be able to recognize a potentially problematic airway, especially in urgent circumstances.[6] Patients in ICUs are generally recalcitrant, sedated, agitated, unstable, or delirious, and present airway evaluation methods have a low sensitivity and specificity.[7,8] Ultrasound (US) imaging methods have emerged as a game-changing tool for airway evaluation and treatment due to their innovative nature, simplicity, portability, and lack of invasiveness. Patients requiring

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How to cite this article: Mallick S, Das S, Pradhan S, Kar S. Evaluation of Point-of-care Ultrasound of Airway to Predict Difficult Laryngoscopy and Intubation in Intensive Care Unit Patients. Indian J Crit Care Med 2025;29(1):14–20.

Source of support: Nil

Conflict of interest: None

Fig. 1: Ultrasound machine and ventilator

Fig. 2: Thyromental height (TMH)

spinal stabilization due to cervical injuries may benefit from US as well, as it permits the removal of the front part of the collar while keeping in-line stabilization in place. It can also be utilized by clinicians at the bedside. Preoperative ultrasonography for the prediction of problematic airways has been the subject of studies in adult patients. In these controlled environments, patients are typically awake and cooperative, enabling the use of various patient positioning and scanning protocols. However, such valuable parameters are lacking in critical care scenarios, where patients may have unique anatomical and physiological characteristics complicating intubation. This makes the potential benefits of US imaging even more promising.

Patietns and Methods

Study Design

We performed a cross-sectional study in a mixed medical-surgical ICU of an academic hospital in India. Registration number CTRI/2022/11/047141 was assigned to the study by the Clinical Trials Registry of India. No commercial support was received for this project.

Patients

Patients in the ICU who were intubated and had ages ranging from 18 to 70 years were part of the study. The following groups of patients were not eligible to participate: Those who needed emergency intubation, were pregnant, had open injuries to the neck or injuries to the cervical spine, had maxillofacial fractures, or tumors, or were morbidly obese. A total of 173 patients were assessed for eligibility and 21 were excluded due to non-compliance with inclusion criteria or denial of participation.

Procedures (Fig. 1)

The patient was positioned supine with their head firmly placed and mouth closed on the ICU bed. Before intubation, the following parameters were recorded.

- Thyromental height (TMH) (Fig. 2): TMH was assessed using a ruler to measure the vertical distance between the anterior border of the thyroid cartilage (specifically at the thyroid notch located between the two thyroid laminae) and the anterior border of the mentum (at the mental protuberance of the mandible).
- Hyomental Distance Ratio (HMD-R) (Fig. 3): The HMD-R was determined using a scale to measure the distance between the hyoid bone and the anterior border of the mentum in two positions: the neutral position and the maximally extended position. The ratio of these measurements was then calculated.
- Ultrasound measurement of thickness of soft tissue in anterior neck: The anterior neck soft tissue thickness was measured at two specific levels by two operators trained in airway ultrasonography, using a neutral head and neck position.

Level 1: Skin to hyoid bone (SHB) thickness (Fig. 4)

Level 2: Skin to thyrohyoid membrane thickness (STM) (Fig. 5).

Ultrasound Protocol

Measurements were performed using a linear high-frequency transducer set at 11 MHz, with a depth range of 3.0–4.0 cm and a gain of 20–30. In the short-axis view:

- The hyoid bone appeared as an inverted U-shaped hyperechoic structure in the submandibular area. SHB thickness was measured using the US's "measure" function after freezing the image.
- The thyrohyoid membrane was visualized as a hyperechoic shadow located midway between the hyoid bone and the thyroid cartilage, and its thickness was recorded in a similarly.

Intubation and airway assessment: Intubation was performed by an experienced intensivist blinded to the ultrasonographic and preprocedural airway assessments. Direct laryngoscopy, using a Macintosh blade, was used to evaluate the Cormack–Lehane (CL) grade without external laryngeal manipulation.

The CL classification:[9]

Grade I: Full glottis visualization.

Grade II: Posterior glottis or arytenoid structures visible.

Grade III: Only the epiglottis is visible.

Grade IV: No glottic structures visible.

Patients were categorized into:

Group E (Easy Intubation): CL Grade I or II.

Group D (Difficult Intubation): CL Grade III or IV.

Figs 3A and B: (A) Hyomental distance in neutral position (HMD-N); (B) Hyomental distance in maximum extended position (HMD-E)

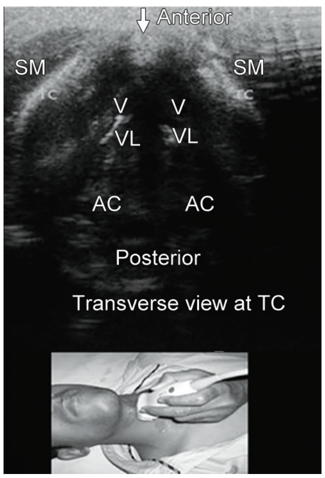

Fig. 4: Anterior neck soft tissue thickness from the skin to the hyoid bone (SHB) (Solid, single-headed arrow)

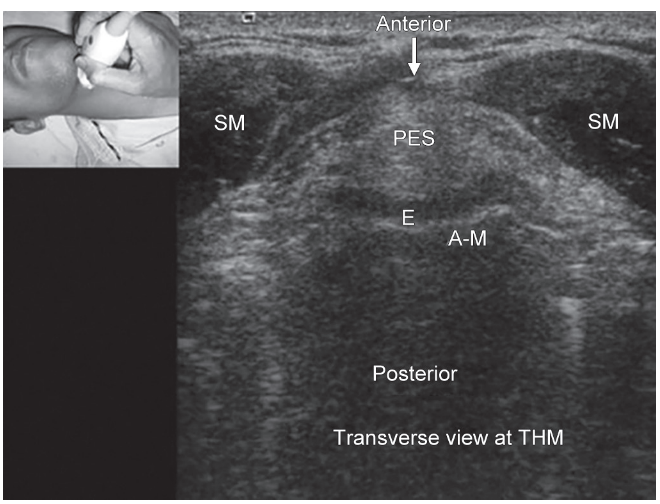

Fig. 5: Anterior neck soft tissue thickness from the skin to the thyrohyoid membrane (STM) (Solid, single-headed arrow)

External laryngeal pressure was applied after assessing the Cormack-Lehane grading for endotracheal tube insertion.

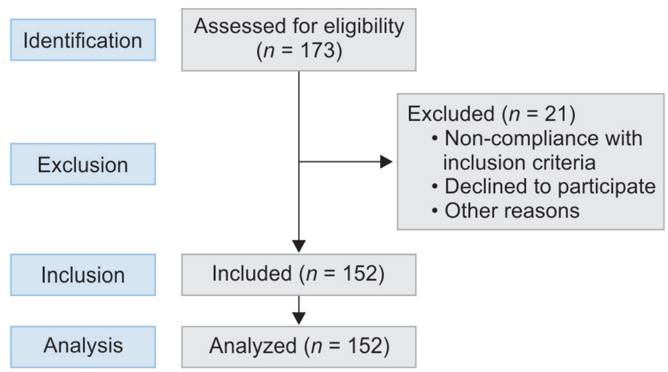

Fig. 6: STROBE diagram

The trachea was then intubated using an appropriately sized endotracheal tube, and subsequent management followed the ICU protocol. The study noted the number of intubation attempts, any requirement for alternative approaches for difficult intubation, or instances where securing the airway was not possible (Fig. 6).

Statistical Analysis

The data were analyzed using "IBM SPSS Version 29." Comparative analysis between Groups D and E was performed using a two-sided Student's *t*-test where applicable. "Receiver Operating Characteristic (ROC) curve analysis" was employed to establish cut-off values for SHB and STM levels, assessing their sensitivity and specificity. Correlations between clinical and US measurements were evaluated using "Spearman's Rank Correlation Coefficient." The "Chi-square test" was utilized to explore associations between categorical variables. To predict difficult intubations and investigate the impact of TMH, HMDR, SHB, and STM on the type of intubation, "logistic regression analysis" was used. A p-value of < 0.05 was considered statistically significant for all analyses.

Results

The study included 152 patients, categorized into two groups according to their Cormack–Lehane grading (Tables 1 to 5).

Group-E Easy airway.

Group-D Difficult airway.

In our study, the average age was 51.75 ± 14.80 years in Group E and 48.70 ± 14.36 years in Group D.

Out of the total 152 patients 66 (43.4%) were females and 86 (56.6%) were males.

According to the Cormack–Lehane grading, the incidence of difficult laryngoscopy and intubation in our study was 17.76%. The distribution of glottic visualization in our study as per the Cormack–Lehane grade was 58, 27, 14, and 1% among CL grades I, II, III, and IV.

Out of the 152 patients, 147 were intubated in the first attempt, 3 required two attempts, and 2 were intubated in the third attempt. The difference was statistically significant as the *p*-value was < 0.001.

Out of the 152 patients, only 2 required a second operator for successful intubation. A total of 11 patients required an alternative technique for successful intubation, which was bougie in our case and one patient required using a video laryngoscope. External laryngeal manipulation was required in 21 patients for successful intubation.

The mean thickness of the anterior neck soft tissue from the skin to the hyoid bone was 0.83 ± 0.12 cm in Group E and 0.97 ± 0.12 cm in Group D. This finding was statistically significant (Table 6).

The mean thickness of the anterior neck soft tissue from the skin to the thyrohyoid membrane was 1.66 ± 0.21 cm in Group E and 2.30 ± 0.25 cm in Group D. Both these findings were statistically significant (Table 7).

As per the ROC curve, the cut-off point delineating Group E and Group D was 0.905 cm, measured from SHB. The area under the curve (AUC) was 0.761. Of the 152 patients, 52 were found to be over the cut-off mark, while 100 were found to be below it. A total of 52 patients were predicted to be difficult to intubate, however, using the CL grading system, the number of patients in Group D remained at 27. Based on the CL grading system, 125 patients were assigned to Group E, even though the cut-off point anticipated 100 patients for the easy intubation group. It was determined to have a sensitivity of 74.1% and a specificity of 74.4% (Table 8).

As per the ROC curve, the cut-off point delineating Group E and Group D was 1.970 cm, measured from skin to thyrohyoid membrane. The AUC was 0.972. Of the 152 patients, 43 were found to be over the cut-off mark, while 109 were found to be below it. A total of 43 patients were predicted to be difficult to intubate, however, using the CL grading system, the number of patients in Group D remained at 27. Based on the CL grading system, 125 patients were assigned to Group E, even though the cut-off point anticipated 109 patients for the easy intubation group. It was determined to have a sensitivity of 96.3% and a specificity of 86.4% (Table 9).

The mean thyromental height was 5.20 ± 0.39 cm in Group E and 4.31 ± 0.24 cm in Group D. This finding was statistically significant (Table 10).

Table 1: Distribution of patients in the two groups

Parameter	*Group E*	*Group D*
No. of patients	125	27
Percentage	82.4%	17.76%

Table 2: Age distribution

Type	*Mean*	*Std. deviation*	*p-value*
Group E	51.75	14.80	0.346
Group D	48.70	14.36	

Table 3: Sex distribution

Type	*Male*		*Female*		*p-value*
Group E	69	45.4%	56	36.8%	0.460
Group D	17	11.2%	10	6.6%	
Total	86	56.6%	66	43.4	

Table 4: Cormack–Lehane grading distribution

Parameter	*CL grade*			
	1	2	3	4
n (152)	86	39	21	6

Table 5: Number of attempts

	No. of patients	
No. of attempts	*Group E*	*Group D*
1st attempt	125	22
2nd attempt	0	3
3rd attempt	0	2

Table 6: Thickness of anterior neck soft tissue from skin to hyoid bone

Type	*Mean (cm)*	*Std. deviation*	*p-value*
Group E	0.83	0.12	<0.001
Group D	0.97	0.12	

Table 7: Thickness of anterior neck soft tissue from skin to thyrohyoid membrane

Type	*Mean (cm)*	*Std. deviation*	*p-value*
Group E	1.66	0.21	<0.001
Group D	2.30	0.25	

Table 8: ROC analysis for Thickness of anterior neck soft tissue from skin to hyoid bone

			95% Confidence interval				
Parameters	*AUC*	*p-value*	*Lower bound*	*Upper bound*	*Sensitivity*	*Specificity*	*Cut-off value (cm)*
SHB	0.797	<0.001	0.706	0.887	74.1	74.400	0.905

Table 9: ROC analysis for thickness of anterior neck soft tissue from skin to thyrohyoid membrane

			95% Confidence interval				
Parameters	*AUC*	*p-value*	*Lower bound*	*Upper bound*	*Sensitivity*	*Specificity*	*Cut-off value (cm)*
STM	0.972	<0.001	0.949	0.996	96.300	86.400	1.970

Table 10: Thyromental height

Type	Mean (cm)	Std. deviation	p-value
Group E	5.20	0.39	<0.001
Group D	4.31	0.24	

Table 11: Hyomental distance ratio (HMD-R)

Type	Mean (cm)	Std. deviation	p-value
Group E	1.34	0.07	<0.001
Group D	1.25	0.06	

Table 12: Logistic regression analysis

Null model -2 Log-Likelihood			142.206
Full model - 2 Log-Likelihood			0.0000000326
Chi-squared			142.206
Significance level			$p < 0.0001$
Cox–Snell R^2			0.6076
Nagelkerke R^2			1.0000
Variables	*Coefficient*	*Standard error*	*p-value*
TMH	−171.80644	98543.53922	0.9986
HMDR	−133.50988	98543.53922	0.9997
SHB	156.1657	360297.9591	0.9997
STM	164.70103	76607.16926	0.9983

The mean hyomental distance ratio was 1.34 ± 0.07 in Group E and 1.25 ± 0.06 in Group D. This finding was statistically significant (Table 11).

To predict difficult intubations and investigate the impact of TMH, HMDR, SHB, and STM on the type of intubation, logistic regression analysis was used. The model as a whole is significant, according to logistic regression analysis ($\chi^2 = 142.206$, p-value < 0.0001). However, the influence of none of the four variables independently was statistically significant as p-value > 0.05. (Table 12).

Discussion

Tracheal intubation is a frequent and sometimes challenging procedure in the ICU, where patients often have complex conditions that make securing the airway more difficult. Success on the first intubation attempt is critical, as failed attempts can lead to severe complications, including hypoxia, low blood pressure, and an increased risk of mortality. Point-of-care US (POCUS) is gaining attention as a valuable tool in airway management. With recent technological advancements, POCUS devices are more portable and accessible, and their ability to provide real-time images of the upper airway makes them highly effective for assessing airway anatomy, predicting intubation challenges, and confirming tube placement without invasive measures. This combination of accuracy, portability, and noninvasive imaging makes upper airway US a promising option in ICU settings.

This cross-sectional study involved 152 ICU patients who required intubation and explored the effectiveness of US in evaluating the airway. It aimed to determine its potential as a reliable, noninvasive method for identifying difficult intubations in ICU settings.

Based on the CL grading, the incidence of difficult laryngoscopy and intubation in our study was 17.76%. This finding aligns with the results of Taboada et al., who observed a higher incidence of moderate (16%) and difficult intubation (9%) in the ICU setting compared with the operating room.[10] The glottic visualization distribution in our study (Cormack–Lehane grade I/II/III/IV: 58%/27%/14%/1%) also aligned closely with their findings (Cormack–Lehane grade I/II/III/IV: 56%/34%/9%/1%).

Many authors suggest that first-attempt success should be the primary objective of intubation in the ICU. In our research, the first-attempt success rate was 96.7%, significantly higher than the 89% success rate reported in the aforementioned study. This high success rate in our study could be due to the expertise of the intubators and the rigorous supervision of residents. Compared with less experienced operators, those with greater expertise execute tracheal intubations more successfully, with fewer attempts, fewer complications, and lower fatality rates.[10] In a similar vein, Schmidt et al. discovered that complications were significantly decreased (6 vs 22%) when attending anesthesiologists supervised emergency intubation.[11] Furthermore, Jaber et al. discovered that the likelihood of tracheal intubation issues was decreased when two operators were present.[2] In the ICU, neuromuscular blockade has been shown to improve intubation circumstances by enhancing the glottic view and decreasing the number of intubation attempts, both of which may help lower the incidence of complications.[12–14] In our study, we used a bougie in 11 patients and a video laryngoscope in 1 patient to aid successful intubation, which likely contributed to our high success rate. When direct laryngoscopy gives a poor glottic vision, data show that tracheal intubation is more manageable using alternative techniques such as a bougie introducer and video laryngoscope.[15]

Therefore, the higher success rate in our study could be attributed to the greater experience of the operators, a well-trained ICU team, and the use of neuromuscular blockade and airway adjuncts during intubation.

Our primary research aim was to examine the relationship between ultrasonography airway evaluations and Cormack–Lehane grades by direct laryngoscopy. Ultrasonographic measurements were taken at two levels of the anterior neck soft tissues—hyoid level (SHB) and thyrohyoid membrane level (STM)—based on the methodology described by Adikari et al.[16] We chose these two levels since the assessments don't take more than 2 minutes and they reliably indicate a difficult airway.

Our results showed that higher CL grades were associated with thicker anterior neck soft tissue at the hyoid bone level. In the difficult laryngoscopy group, the SHB was significantly higher (0.97 ± 0.12 cm) compared with the easy laryngoscopy group (0.83 ± 0.12 cm), with a p-value < 0.001. Wu et al. also identified SHB as an independent predictor of difficult laryngoscopy (1.51 ± 0.27 cm vs 0.98 ± 0.26 cm).[17] Other studies with consistent findings include Adikari et al. (1.69 ± 0.50 cm vs 1.37 ± 0.10 cm), Srinivasarangan et al. (0.73 ± 0.80 cm vs 0.47 ± 0.04 cm), and Kasinath et al. (0.82 ± 0.23 cm vs 0.70 ± 0.18 cm).[16,18,19]

Similarly, a higher CL grade was linked to increased STM thickness. STM was greater in the difficult laryngoscopy group (2.30 ± 0.25 cm) compared with the easy laryngoscopy group (1.66 ± 0.21 cm), with a p-value < 0.001. These results align with studies by Wu et al. (2.39 ± 0.34 cm vs 1.49 ± 0.30 cm) and Adikari et al. (3.47 ± 0.60 cm vs 2.37 ± 0.70 cm).[16,17]

Reddy et al. did not find a significant relationship between the likelihood of a difficult intubation and the thickness of the anterior neck soft tissues at the hyoid bone.[20] Dissimilarities in methodology, including varied laryngoscopic approaches, the implementation of Sellicks' maneuver, variances in ultrasonography methods, and the ethnic variety of the patient groups, may account for the discrepancies in the values found among research.

To validate the findings, ROC curves were created for the ultrasonographic parameters. Key thresholds were established to distinguish between easy (E) and difficult (D) intubation groups: SHB >0.905 cm, with an AUC of 0.797, sensitivity of 74.1%, and specificity of 74.4% and STM >1.970 cm, with an AUC of 0.972, sensitivity of 96.3%, and specificity of 86.4%. The ROC curve analysis indicated that measurements at the thyrohyoid membrane level were more accurate, sensitive, and specific for predicting difficult intubation. These findings align with those of Srinivasarangan et al.[18]

The results suggest that ultrasonography provides a simple, noninvasive method for predicting difficult intubation in the ICU by measuring the anterior neck soft tissue thickness. While previous studies have demonstrated correlations between difficult intubation and US-based airway assessments in surgical patients under general anesthesia, limited research has been conducted in ICU settings. Ahmed et al. explored similar techniques in respiratory ICU patients but did not identify a significant relationship between pretracheal soft tissue thickness near the vocal cords or suprasternal notch and difficult intubation.[21] Methodological differences may account for the lack of correlation in their findings.

Intubation difficulties were well predicted by TMH and HMDR, according to our research. With a *p*-value less than 0.001, the mean TMH in the group that had difficult laryngoscopy was 4.31 ± 0.24 cm, whereas in the group that had easy laryngoscopy, it was 5.20 ± 0.39 cm. The results are comparable to those of Prakash et al., who also found mean TMH values of 4.40 ± 0.90 cm and 4.90 ± 0.90 cm, respectively.[22] In our study, with a *p*-value less than 0.001, the mean HMDR for the group that had difficult laryngoscopy was 1.25 ± 0.06, whereas the mean HMDR for the group that underwent simple laryngoscopy was 1.34 ± 0.07. The reliability of an HMDR <1.2 as a predictor of difficult laryngoscopy in critical care unit patients was demonstrated in a study by Hrithma et al., which is similar to our results.[23]

Limitations of Our Study

- Observer Variations: Variations in assessing the Cormack–Lehane grading and ultrasound parameters could limit the study.
- Uncontrolled Variables: Factors such as the skill level of the intensivists, the type and quality of equipment, the number of intubation attempts, the use of external laryngeal maneuvers during intubation, and the glottis view used for CL grading (first view, best view, or view before passing the endotracheal tube) were all outside our control.
- Lack of Comparative Studies: No previous similar studies have been conducted in the ICU, making direct comparisons difficult.

Conclusion

Point-of-care US is a valuable standalone tool for airway assessment in ICU patients, with the anterior soft tissue thickness from the skin to the thyrohyoid membrane emerging as a particularly reliable predictor of difficult intubation. The strong correlation observed between clinical airway assessments, such as TMH and HMD-R, and ultrasonographic measurements suggests that integrating sonographic data with clinical evaluation could improve diagnostic accuracy. By combining these methods, a more comprehensive and effective model for predicting difficult intubation in ICU patients can be developed, ultimately aiding in better airway management and reducing complications.

Ethical Approval

An institutional ethics board gave its approval to the research (KIIT/KIMS/IEC/972/2022). The research was carried out per the 2008 Declaration of Helsinki and its subsequent revisions.

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