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Original Article

Evaluation of Neck Ultrasound as a Tool to Predict Difficult Airway: An Observational Study

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ABSTRACT

Background: Prediction of difficult direct laryngoscopy remains an important challenge in airway management. Conventional bedside airway assessment tools have limited sensitivity and specificity. Point-of-care ultrasonography has emerged as a promising modality for evaluation of anterior neck soft tissue parameters associated with difficult airway.

Methods: This prospective observational study included 300 adult patients undergoing direct laryngoscopy and endotracheal intubation in operating theatre or intensive care unit settings. Preoperative airway ultrasound was performed using a high-frequency linear probe to measure median skin-to-epiglottis distance (mDSE), pre-epiglottic area (PEA), and median skin-to-vocal cord distance (mVC). Difficult laryngoscopy was defined as Cormack–Lehane (CL) grade >2a. Receiver operating characteristic (ROC) curve analysis, Spearman correlation, and logistic regression analyses were performed to evaluate predictive performance and identify independent predictors.

Results: Difficult laryngoscopy was observed in 37 patients (12.3%). Both mDSE and PEA were significantly higher in the difficult laryngoscopy group ($p < 0.001$ for both), whereas mVC showed no significant association. ROC analysis demonstrated excellent predictive performance for PEA (AUC 0.981, sensitivity 100%, specificity 94.3% at cut-off ≥4.44 cm²) and mDSE (AUC 0.936, sensitivity 91.9%, specificity 91.6% at cut-off ≥2.54 cm). Moderate positive correlations were observed between CL grade and both PEA ($\rho = 0.429$, $p < 0.001$) and mDSE ($\rho = 0.369$, $p < 0.001$). On multivariable logistic regression analysis, PEA remained an independent predictor of difficult laryngoscopy (adjusted OR 23.08, 95% CI 1.64–325.23, $p = 0.020$).

Conclusion: Pre-epiglottic area measured by airway ultrasonography independently predicts difficult direct laryngoscopy with excellent diagnostic accuracy. Area-based anterior neck ultrasound assessment may represent a valuable adjunct to conventional airway evaluation and warrants further validation in larger multicentre studies.

Keywords: *Airway ultrasound, difficult laryngoscopy, difficult airway, preepiglottic area, mDSE, airway assessment, Cormack Lehane grade.*

INTRODUCTION

Airway management remains one of the most critical responsibilities of anesthesiologists and intensivists. Failure to anticipate difficult laryngoscopy can result in hypoxemia, aspiration, airway trauma, and life-threatening complications.[1,2]

Conventional bedside airway assessment tools such as the Mallampati classification, thyromental distance, and mouth opening have demonstrated limited predictive value and inconsistent reproducibility.[3-5]

Point-of-care ultrasonography has emerged as a non-invasive modality capable of visualizing anterior neck soft tissues and airway structures in real time.[6,7] Several ultrasound-derived measurements, including distance from skin to epiglottis (DSE), distance from skin to vocal cords (DSVC), distance from skin to hyoid bone (DSHB), pre-epiglottic area (PEA), and median skin-to-epiglottis distance (mDSE) have demonstrated variable predictive value for difficult laryngoscopy in previous studies.[8-13] However, data regarding the independent predictive value of area-based anterior neck ultrasound measurements remain limited.

The present study was designed to evaluate the diagnostic performance of ultrasound-derived anterior neck measurements in predicting difficult direct laryngoscopy and to determine whether any parameter independently predicts difficulty after adjustment for confounding variables.

METHODS

Study Design and Population

This prospective observational study was conducted at a tertiary care teaching hospital after obtaining approval from institutional ethics committee. Written informed consent was taken from all participants before enrollment. This study was conducted in accordance with the principles of Declaration of Helsinki. This study included 300 adult patients requiring direct laryngoscopy and orotracheal intubation as part of their anaesthesia management or ICU management. Patients with known airway pathology, previous neck surgery, limited mouth opening, cervical spine immobilization, pregnancy, emergency intubation and who require rapid sequence intubation were excluded.

Ultrasound Measurements

Preoperative airway ultrasound was performed in the supine position with the head in a neutral position using a high-frequency (6–13 MHz) linear ultrasound probe. The following parameters were measured:

1. Median skin-to-epiglottis distance (mDSE) at the level of thyrohyoid membrane
2. Pre-epiglottic area (PEA) measured by calculating the area of the pre-epiglottic soft tissue at the level of the thyrohyoid membrane.
3. Median skin-to-vocal cord distance (mVC) (from skin to the apex of vocal cord)

Measurements were obtained in the preoperative area or the ICU by experienced anesthesiologists/intensivists who were blinded to laryngoscopic findings.

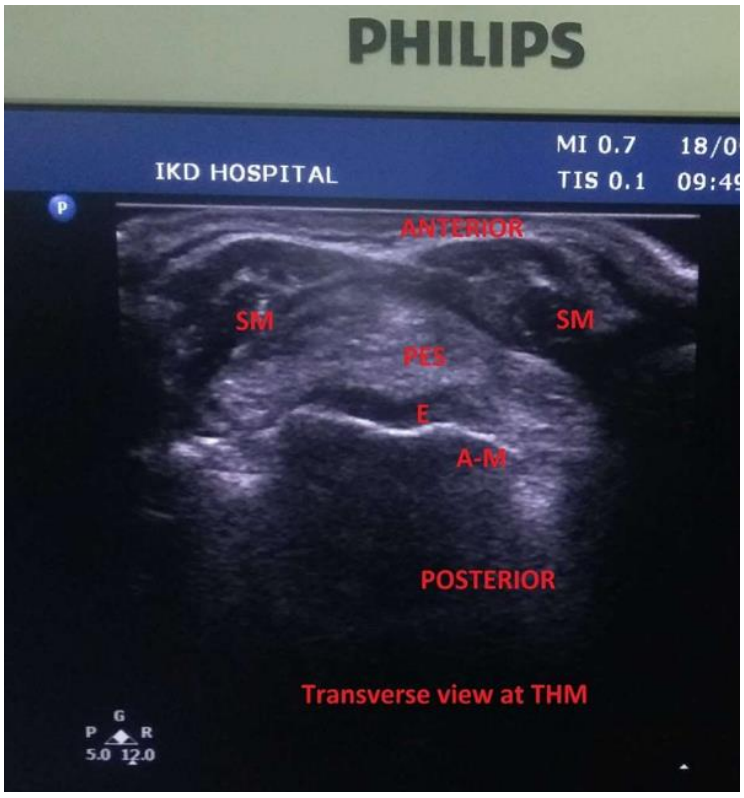


Figure 1. Small Face Sign

Laryngoscopic Assessment

Direct laryngoscopy was performed by an anesthesiologist or intensivist who was blinded to the ultrasound measurements, using a Macintosh blade. Cormack–Lehane grading was recorded. Difficult laryngoscopy was defined as CL grade >2a.

Statistical Analysis

Data were analyzed using SPSS version XX. Continuous variables were expressed as mean ± SD or median IQR, and categorical variables as n %. ROC analysis, Youden index, sensitivity, specificity, likelihood ratios, Spearman correlation, and logistic regression were used. OR with 95% CI were reported. A p-value <0.05 was considered significant.

RESULTS

A total of 300 patients were analyzed. CL grade 1 was most common, seen in 186 patients (62.0%), followed by CL 2a in 77 (25.7%). Difficult laryngoscopy, defined as CL grade >2a, was observed in 37 patients (12.3%), while 263 patients (87.7%) had easy laryngoscopy (Table 1, Table 2).

Table 1. Distribution of Cormack–Lehane (CL) grades among the study population

Cormack-Lehane Grade	Frequency	Percentage
CL 1	186	62.0%
CL 2a	77	25.7%
CL 2b	26	8.7%
CL 3a	9	3.0%
CL 3b	2	0.7%
CL 4	0	0%

Table 2. Incidence of difficult laryngoscopy based on Cormack–Lehane grading

Variable	Frequency	Percentage
Easy laryngoscopy (CL ≤ 2a)	263	87.7%
Difficult laryngoscopy (CL > 2a)	37	12.3%

Patients with difficult laryngoscopy were significantly older than those with easy laryngoscopy (47 vs 41 years; p = 0.028). mDSE and PEA were significantly higher in the difficult laryngoscopy group (p <0.001 for both), while sex, BMI, and mVC showed no significant difference (Table 3).

Table 3. Comparison of Demographic and Ultrasound Parameters between Easy and Difficult Laryngoscopy

Variable	Easy (≤2a) (n=263)	Difficult (>2a) (n=37)	p-value
Age (years)	41.00 (32.00–52.00)	47.00 (40.00–60.00)	0.028
Sex (Male), n (%)	168 (63.9%)	22 (59.5%)	0.602
Sex (Female), n (%)	95 (36.1%)	15 (40.5%)	
BMI (kg/m²)	25.08 (22.49–27.50)	25.20 (23.68–27.93)	0.566
mDSE (cm)	2.19 (1.86–2.38)	2.66 (2.60–2.73)	<0.001
PEA (cm²)	3.36 (2.88–3.80)	5.28 (5.15–5.41)	<0.001
mVC (cm)	1.31 (1.08–1.45)	1.37 (1.09–1.52)	0.421

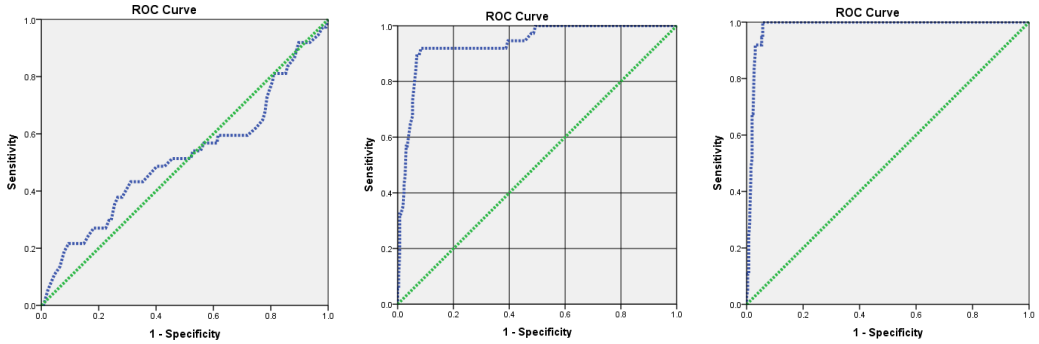
ROC analysis showed that PEA had the best diagnostic performance for difficult laryngoscopy, with an AUC of 0.981, sensitivity of 100.0%, and specificity of 94.3% at a cut off ≥4.44 cm². mDSE also showed excellent accuracy with an AUC of 0.936. mVC showed poor predictive ability (AUC = 0.517) (Table 4, Figure 2).

Table 4. Receiver operating characteristic (ROC) curve analysis of ultrasound airway parameters for prediction of difficult direct laryngoscopy

Parameter	AUC	p-value	Cut-off Value	Sensitivity (%)	Specificity (%)	Youden Index (J)	LR+	LR−
mDSE (cm)	0.936	<0.001	≥ 2.54	91.9	91.6	0.835	10.94	0.09
PEA (cm²)	0.981	<0.001	≥ 4.44	100.0	94.3	0.943	17.54	0.00
mVC (cm)	0.517	0.721	≥ 1.62	21.6	90.5	0.121	2.27	0.87

AUC = area under the receiver operating characteristic (ROC) curve; LR+ = positive likelihood ratio; LR− = negative likelihood ratio.

Figure 2. Receiver operating characteristic (ROC) curves of ultrasound airway parameters (mDSE, PEA, and mVC) for the prediction of difficult direct laryngoscopy



(Figure 1a: ROC curve for mVC. Figure 1b: ROC curve for mDSE. Figure 1c: ROC curve for PEA)

Spearman correlation showed moderate positive correlations of CL grade with PEA and mDSE, while mVC showed no significant correlation (Table 5). On univariate analysis, mDSE and PEA were significant predictors of difficult laryngoscopy (Table 6). On multivariable analysis, only PEA remained an independent predictor (adjusted OR 23.08, 95% CI 1.64 to 325.23; p = 0.020) (Table 7).

Table 5. Correlation between ultrasound airway parameters and Cormack–Lehane grade (Spearman correlation analysis)

Parameter	Spearman rho (ρ)	p-value	Interpretation
mDSE	0.369	<0.001	Moderate positive correlation
PEA	0.429	<0.001	Moderate positive correlation

Table 6. Univariate logistic regression analysis of ultrasound airway parameters as predictors of difficult laryngoscopy (CL grade > 2a)

Parameter	OR (Odds ratio)	95% CI (confidence interval)	p-value
mDSE	74729.5	2363.5 – 2362821.0	<0.001
PEA	60.0	16.46 – 218.86	<0.001
mVC	1.29	0.32 – 5.28	0.721

Table 7. Multivariate logistic regression analysis of ultrasound airway parameters as independent predictors of difficult laryngoscopy (CL grade > 2a).

Parameter	Adjusted OR	95% CI	p-value
mDSE	9.60	0.02 – 4086.69	0.464
PEA	**23.08**	**1.64 – 325.23**	**0.020**
mVC	2.36	0.19 – 29.77	0.507

DISCUSSION

This prospective study of 300 patients demonstrates that both pre-epiglottic area (PEA) and median skin-to-epiglottis distance (mDSE) are strongly associated with difficult direct laryngoscopy, while only PEA remained an independent predictor after multivariable adjustment, with excellent discriminatory performance. These findings suggest that area-based quantification of anterior neck soft tissue may provide superior predictive information compared with linear distance measurements.

In this study conducted in both operating theatre and intensive care settings, ultrasound-derived anterior neck soft tissue measurements were significantly associated with difficult laryngoscopy. Among the parameters evaluated, mDSE and PEA demonstrated consistent predictive value, whereas BMI, sex, and median skin-to-vocal cord distance (mVC) were not independently associated with laryngoscopic difficulty. Similar observations regarding the limited predictive value of glottic-level measurements have been reported in previous airway ultrasound studies.[10-13]

The anatomical basis for these findings may relate to the mechanics of direct laryngoscopy. Successful glottic exposure depends on effective displacement of the tongue base and pre-epiglottic soft tissues. Increased tissue volume within the pre-epiglottic space may restrict anterior displacement and impair line-of-sight visualization during laryngoscopy. Unlike linear measurements, area-based assessment may more comprehensively reflect the total soft-tissue burden and mechanical impedance during laryngoscopy.

PEA demonstrated excellent diagnostic capability with a very high area under the ROC curve. Importantly, the positive likelihood ratio associated with the identified cut-off suggests substantial rule-in value, while high sensitivity supports exclusion of difficult laryngoscopy when the measurement is below threshold.

Our findings closely align with those reported by Falcetta et al., who demonstrated that ultrasound-measured anterior cervical soft tissue thickness at the thyrohyoid membrane strongly predicts difficult direct laryngoscopy.[10] In their cohort, both mDSE (AUC 0.906) and PEA (AUC 0.93) showed good discrimination for CL grade ≥2b views, whereas measurements at the vocal cord level were non-predictive. Our results confirm these observations and demonstrate even stronger discriminatory performance for PEA (AUC 0.981). Furthermore, our multivariable analysis identified PEA as the sole independent predictor after adjustment for other ultrasound parameters.

Interestingly, the optimal mDSE cut-off in both studies was identical (2.54 cm), suggesting reproducibility of this threshold across different populations.[10] However, the optimal PEA cut-off in our cohort (4.44 cm^2) was slightly lower than the 5.04 cm^2 reported by Falcetta et al., possibly reflecting demographic or anatomical variability between study populations. Both studies consistently demonstrated that measurements at the level of the vocal cords lack meaningful predictive value, suggesting that glottic-level soft-tissue thickness may not significantly influence the laryngoscopic view.

The present study also corroborates previous investigations that evaluated anterior neck soft-tissue thickness as a predictor of difficult laryngoscopy. Studies by Ni et al., Çinar Köse et al., and Fernandez-Vaquero et al. consistently identified epiglottic-level soft-tissue measurements as among the most reliable ultrasound parameters, with reported AUCs ranging from approximately 0.84 to 0.94.[11-13] However, whereas most prior studies demonstrated moderate-to-good discrimination, our findings suggest near-excellent predictive performance for PEA.

Recently, De Luis-Cabezón et al. proposed a composite airway score that integrates clinical and ultrasound parameters to improve prediction of difficult laryngoscopy.[14] In contrast, the present study demonstrates that PEA alone exhibits excellent predictive accuracy and remains independently associated with difficult laryngoscopy on multivariable analysis. These findings suggest that focused evaluation of anterior epiglottic soft tissue may offer a simpler yet highly effective predictive strategy without requiring complex composite scoring systems.

BMI was not independently predictive in our cohort, suggesting that global anthropometric indices may inadequately reflect regional airway anatomy. Ultrasound, by directly quantifying anterior neck soft tissue, may therefore offer a more objective and anatomically relevant method for airway assessment.[6,7]

Limitations

This single-centre study did not assess inter-observer variability and included only direct Macintosh laryngoscopy. External validation and assessment across different laryngoscopic techniques are warranted. Additionally, the study excluded those patients with anticipated difficult airways or emergency conditions; therefore, the findings may not be directly applicable to all clinical settings. Future multicenter studies incorporating multiple operators and diverse patient populations are warranted to validate these cut-off values and further refine ultrasound-based airway assessment protocols.

Clinical Implications

From a translational perspective, these findings support the potential integration of point-of-care airway ultrasound into pre-intubation assessment algorithms. Ultrasound is portable, non-invasive, rapidly performed, and increasingly available in both operating theatres and ICUs. Incorporating mDSE or PEA measurements into pre-intubation evaluation may facilitate early risk stratification, prompting timely mobilisation of experienced operators, advanced airway devices, or modified induction strategies. In high-acuity ICU environments, where time-sensitive decision-making is required, a rapid, objective anatomical assessment may complement existing bedside predictors, which are often limited or impractical.

Importantly, ultrasound should not be viewed as a replacement for established airway assessment but rather as an adjunctive tool. Its greatest value may lie in situations where conventional predictors are unreliable, such as in uncooperative, obtunded, or immobilised patients. The anatomical specificity provided by ultrasound may enhance clinical confidence in planning airway management, particularly when risk tolerance is low.

Limitations and Future Directions

Several limitations warrant consideration. This was a single-centre study, and ultrasound measurements were obtained by trained operators; interobserver reproducibility was not formally assessed. The study focused on direct Macintosh laryngoscopy, and extrapolation to video laryngoscopy requires further investigation. Additionally, although ultrasound parameters were associated with laryngoscopic grade, we did not evaluate downstream clinical outcomes such as hypoxaemia, first-pass success, or airway-related complications. Whether ultrasound-guided risk stratification translates into improved patient-centred outcomes remains to be determined.

Future work should prioritise multicentre validation, threshold standardisation, and assessment of interobserver agreement. Randomised studies evaluating ultrasound-informed airway planning strategies would be particularly valuable in determining whether anatomical risk prediction can modify clinical outcomes in both operative and critical care contexts.

CONCLUSION

The present study demonstrates that preoperative neck ultrasonography, particularly measurements of mDSE and PEA, provides a reliable, objective, and non-invasive method for predicting difficult direct laryngoscopy. Incorporation of airway ultrasound into routine pre-anesthetic evaluation may significantly enhance airway risk stratification and improve patient safety. Pre-epiglottic area measured by preoperative airway ultrasound independently predicts difficult direct laryngoscopy with excellent diagnostic accuracy. Area-based anterior neck assessment may represent a valuable adjunct to conventional airway evaluation and warrants further validation in larger multicentre studies.

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