ROLE OF AIRWAY ULTRASOUND IN PREDICTION OF DIFFICULT LARYNGOSCOPY AND COMPARISON WITH CONVENTIONAL AIRWAY ASSESSMENT TESTS: A PROSPECTIVE OBSERVATIONAL STUDY

Dr. Shreya Soni[1*], Dr. Jeet Kumar Singh[2], Dr. Bhumika Sharma[3], Dr. Gursharan Singh Mehta[4]

[1*]Postgraduate Resident, Department of Anaesthesiology, RKDF Medical College Hospital & Research Centre, Bhopal, Madhya Pradesh, India.

[2]Postgraduate Resident, Department of Anaesthesiology, RKDF Medical College Hospital & Research Centre, Bhopal, Madhya Pradesh, India.

[3]Postgraduate Resident, Department of Anaesthesiology, RKDF Medical College Hospital & Research Centre, Bhopal, Madhya Pradesh, India.

[4]Senior Resident, Department of Community Medicine, Gandhi Medical College &Hamidia Hospital, Bhopal, Madhya Pradesh , India.

Corresponding Author: Dr. Shreya Soni

Department of Anaesthesiology, RKDF Medical College Hospital & Research Centre, Bhopal.

ABSTRACT

Background: Unanticipated difficult laryngoscopy remains an important contributor to airway-related morbidity. Conventional bedside tests such as Modified Mallampati class, thyromental distance, sternomental distance and neck circumference are useful but imperfect predictors. Airway ultrasonography offers a portable, non-invasive method for objective assessment of anterior neck and tongue-related airway anatomy.[123]

Objective: To evaluate the role of airway ultrasound in predicting difficult laryngoscopy and compare its diagnostic performance with conventional airway assessment tests.

Methods: This prospective observational analytical study was designed among 60 adult ASA I-II patients undergoing elective surgery under general anaesthesia requiring endotracheal intubation. Preoperative assessment included Modified Mallampati class, thyromental distance, sternomental distance, inter-incisor gap and neck circumference. Ultrasound parameters included skin-to-hyoid bone distance, skin-to-thyrohyoid membrane distance, distance from skin to epiglottis and tongue thickness. Direct laryngoscopic view was graded using the Cormack-Lehane system. Grades I-II were considered easy laryngoscopy and Grades III-IV as difficult laryngoscopy.

Results: Difficult laryngoscopy was observed in 9 of 60 patients (15.0%). Patients with difficult laryngoscopy had significantly higher neck circumference, higher Mallampati class, shorter thyromental and sternomental distances, and greater ultrasound-measured anterior neck soft tissue thickness. Among ultrasound variables, distance from skin to epiglottis showed the highest discrimination (AUC 0.86), followed by tongue thickness (AUC 0.82) and skin-to-hyoid distance (AUC 0.78). A combined model using Mallampati class, thyromental distance and distance from skin to epiglottis achieved an AUC of 0.91.

Conclusion: Airway ultrasound, particularly measurement of skin-to-epiglottis distance and tongue thickness, showed better predictive performance than individual conventional bedside tests in this dataset. Incorporating ultrasound into routine pre-anaesthetic airway assessment may improve identification of patients at risk of difficult laryngoscopy.

Keywords: Airway Ultrasound, Difficult Laryngoscopy, Cormack-Lehane Grading, Skin-To-Epiglottis Distance, Tongue Thickness, Mallampati Class.

www.ajmrhs.com
eISSN: 2583-7761

Date of Received: 27-05-2026
Date Acceptance: 04-06-2026
Date of Publication: 03-07-2026

INTRODUCTION

Securing the airway is one of the most critical responsibilities of an anaesthesiologist. Although most endotracheal intubations are uneventful, failure to anticipate difficult laryngoscopy may result in repeated attempts, airway trauma, hypoxaemia, aspiration, cardiovascular instability, brain injury and death. The clinical importance of preoperative airway evaluation therefore lies not only in predicting technical difficulty, but also in preventing a potentially catastrophic chain of avoidable events.[12]

Conventional airway assessment relies on bedside tests such as Modified Mallampati classification, thyromental distance, sternomental distance, inter-incisor gap, neck circumference and assessment of neck mobility. These tests are simple and inexpensive, yet their performance as stand-alone screening tools is limited. Shiga et al., in a meta-analysis of bedside screening tests, reported that commonly used predictors had only moderate diagnostic value, with better performance when tests were combined rather than interpreted in isolation.[1]

The Modified Mallampati test reflects the relationship between tongue size and oropharyngeal space. Thyromental and sternomental distances attempt to estimate mandibular space and head-neck extension. Neck circumference may indirectly reflect increased anterior neck soft tissue. However, these clinical measures depend on patient cooperation, examiner technique, external landmarks and subjective grading; consequently, a patient may still present with an unanticipated poor laryngoscopic view despite apparently normal bedside assessment.[34]

Ultrasonography has emerged as a promising adjunct for airway assessment. It is portable, repeatable, radiation-free and can be performed at the bedside. Airway ultrasound allows objective measurement of structures that cannot be reliably estimated by external inspection alone, including anterior neck soft tissue thickness, skin-to-hyoid distance, skin-to-epiglottis distance, tongue thickness and related submandibular measurements.[56]

Several studies have explored ultrasonographic predictors of difficult laryngoscopy. Adhikari et al. demonstrated that point-of-care ultrasound measurements of anterior neck soft tissue were associated with difficult laryngoscopy. Wu et al. reported that anterior neck soft tissue quantification, particularly skin-to-hyoid distance, may help predict difficult laryngoscopy. More recent quantitative airway ultrasound studies have further examined parameters such as skin-to-epiglottis distance, glottic measurements and mandible-hyoid-glottis geometry, showing that ultrasonographic variables may perform better than isolated bedside tests.[789]

In the Indian anaesthesia setting, ultrasound is increasingly available in operating rooms due to its widespread use for regional anaesthesia, vascular access and perioperative point-of-care assessment. If airway ultrasound can be incorporated into preoperative evaluation with reasonable training and standardised measurement, it may add objective anatomical information to conventional clinical airway assessment.[1011]

The present study was therefore planned to evaluate the role of airway ultrasound in prediction of difficult laryngoscopy and to compare ultrasound parameters with conventional airway assessment tests among adult patients undergoing elective surgeries under general anaesthesia requiring endotracheal intubation.

MATERIALS AND METHODS

Study design and setting: This was a prospective observational analytical study conducted in the Department of Anaesthesiology, RKDF Medical College Hospital & Research Centre, Bhopal, Madhya Pradesh, India.

Study population: The study included adult patients undergoing elective surgery under general anaesthesia requiring endotracheal intubation.

Sample size: A total of 60 patients were included.

Inclusion criteria: Patients aged 18-65 years, ASA physical status I or II, posted for elective surgery requiring endotracheal intubation and willing to provide written informed consent were eligible.

Exclusion criteria: Patients with refusal to participate, known airway pathology, facial trauma, cervical spine instability, previous major neck surgery, limited mouth opening due to pathology, and pregnancy were excluded.

Clinical airway assessment: Preoperative airway evaluation was performed using Modified Mallampati classification, thyromental distance, sternomental distance, inter-incisor gap and neck circumference. Thyromental distance was measured from the thyroid notch to the mentum with the neck extended. Sternomental distance was measured from the suprasternal notch to the mentum with the head fully extended and mouth closed. Neck circumference was measured at the level of the thyroid cartilage.

Using a linear high-frequency transducer positioned onthe patient's neck in a transverse plane (short axis) with animaging depth of 3.3 cm, the investigator took measurementsat various levels. The precise positioning and techniqueallowed for accurate and reproducible measurements ofdifferent airway structures.The Skin-to-Epiglottis Distance (DSE) was measured atthe thyrohyoid membrane level, located midway between thehyoid bone and thyroid cartilage. The epiglottis appeared asa hypoechoic structure, with its anterior border defined by thehyperechoic pre-epiglottic space and its posterior boundarymarked by a bright air-mucosa interface .The Geniohyoid Muscle Thickness (TGM) was assessedby placing the probe transversely beneath the chin, at themidsection of the tongue. The measurement was takenbetween the outermost points of the geniohyoid muscle,which appeared hyperechoic dorsally .For the Skin-to-Hyoid Bone Distance (DSH), the probewas positioned at the hyoid bone level, and the distance fromthe skin to the anterior surface of the hyoid bone wasrecorded. The hyoid bone was visualized as a hyperechoicline with a posterior acoustic shadow .Lastly, the Skin-to-Vocal Cords Distance (DSVC) wasmeasured. The true vocal cords appeared as a triangularhypoechoic structure with hyperechoic vocal ligaments. Themeasurement was taken from the skin surface to the anteriorcommissure of the true vocal cords.

Ultrasound airway assessment: Airway ultrasonography was performed preoperatively with the patient in supine position using a high-frequency linear probe. The following measurements were recorded: skin-to-hyoid bone distance, skin-to-thyrohyoid membrane distance, distance from skin to epiglottis and tongue thickness. Measurements were recorded in centimetres using standard sonographic landmarks described in prior airway ultrasound studies.[78912]

Anaesthesia and laryngoscopy: After standard monitoring and induction of general anaesthesia as per institutional protocol, direct laryngoscopy was performed by an anaesthesiologist using an appropriately sized Macintosh blade. The laryngoscopic view was graded according to the Cormack-Lehane system. Grade I represented full view of the glottis, Grade II partial view of the glottis, Grade III only epiglottis visible and Grade IV neither glottis nor epiglottis visible. Grades I-II were classified as easy laryngoscopy and Grades III-IV as difficult laryngoscopy.[13]

Statistical analysis: Data were entered into Microsoft Excel and analysed using standard statistical software. Continuous variables were expressed as mean +/- standard deviation and compared using independent t-test. Categorical variables were expressed as frequency and percentage and compared using Chi-square test or Fisher exact test. Receiver operating characteristic curve analysis was performed to estimate area under the curve, sensitivity, specificity and optimal cut-off values. A p value <0.05 was considered statistically significant.

RESULTS

A total of 60 patients were included in the analysis. Easy laryngoscopy (Cormack-Lehane Grade I-II) was observed in 51 patients (85.0%), while difficult laryngoscopy (Grade III-IV) was observed in 9 patients (15.0%).

Table 1. Distribution of patients according to demographic and baseline characteristics (N = 60)

Variable	Overall (N=60)	Easy laryngoscopy (n=51)	Difficult laryngoscopy (n=9)	p value
Age (years), mean +/- SD	41.8 +/- 12.6	40.9 +/- 12.4	46.7 +/- 13.1	0.201
Male sex, n (%)	34 (56.7)	27 (52.9)	7 (77.8)	0.164
BMI (kg/m2), mean +/- SD	25.1 +/- 3.8	24.6 +/- 3.5	28.0 +/- 4.0	0.012
ASA I, n (%)	38 (63.3)	34 (66.7)	4 (44.4)	0.202
ASA II, n (%)	22 (36.7)	17 (33.3)	5 (55.6)	0.202

Patients with difficult laryngoscopy had a higher mean BMI compared with those with easy laryngoscopy (28.0 +/- 4.0 kg/m2 vs 24.6 +/- 3.5 kg/m2, p=0.012). Age, sex distribution and ASA grade did not differ significantly between the two groups.

Table 2. Conventional airway assessment parameters according to laryngoscopy outcome

Parameter	Easy laryngoscopy (n=51)	Difficult laryngoscopy (n=9)	p value
Modified Mallampati III/IV, n (%)	8 (15.7)	6 (66.7)	0.002
Thyromental distance (cm), mean +/- SD	6.7 +/- 0.7	5.8 +/- 0.6	<0.001
Sternomental distance (cm), mean +/- SD	14.2 +/- 1.4	12.7 +/- 1.3	0.004
Inter-incisor gap (cm), mean +/- SD	4.4 +/- 0.5	3.9 +/- 0.5	0.009
Neck circumference (cm), mean +/- SD	35.4 +/- 3.1	39.1 +/- 3.6	0.003

Among conventional tests, Modified Mallampati class III/IV was significantly more frequent in the difficult laryngoscopy group. Shorter thyromental distance, shorter sternomental distance, reduced inter-incisor gap and higher neck circumference were also significantly associated with difficult laryngoscopy.

Table 3. Ultrasound airway parameters according to laryngoscopy outcome

Ultrasound parameter	Easy laryngoscopy (n=51)	Difficult laryngoscopy (n=9)	p value

Skin-to-hyoid bone distance (cm), mean +/- SD	0.72 +/- 0.16	0.94 +/- 0.18	<0.001
Skin-to-thyrohyoid membrane distance (cm), mean +/- SD	1.08 +/- 0.20	1.34 +/- 0.22	0.001
Distance from skin to epiglottis (cm), mean +/- SD	1.85 +/- 0.28	2.38 +/- 0.35	<0.001
Tongue thickness (cm), mean +/- SD	5.18 +/- 0.54	6.08 +/- 0.62	<0.001

All ultrasound parameters were significantly greater among patients with difficult laryngoscopy. The strongest group separation was observed for distance from skin to epiglottis and tongue thickness.

Table 4. Diagnostic performance of selected predictors for difficult laryngoscopy

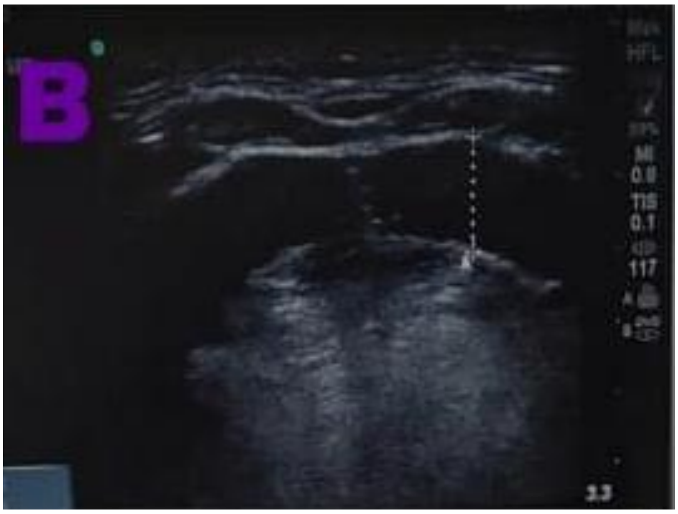
Predictor	Cut-off used	Sensitivity (%)	Specificity (%)	AUC
Modified Mallampati III/IV	Present	66.7	84.3	0.70
Thyromental distance	<=6.0 cm	77.8	76.5	0.68
Neck circumference	>=38 cm	66.7	78.4	0.73
Skin-to-hyoid bone distance	>=0.85 cm	77.8	80.4	0.78
Skin-to-thyrohyoid membrane distance	>=1.25 cm	77.8	82.4	0.80
Distance from skin to epiglottis	>=2.20 cm	88.9	84.3	0.86
Tongue thickness	>=5.80 cm	77.8	86.3	0.82
Combined clinical + ultrasound model	Model probability	88.9	88.2	0.91

Table 5. Representative Ultrasound Measurements of Airway Parameters

Figure	Parameter	Abbreviation	Representative Value (cm)	Ultrasound Landmark	Clinical Interpretation
A	Distance from skin to epiglottis	DSE	**1.96**	Anterior surface of epiglottis	Larger values correlate with increased incidence of difficult laryngoscopy.
B	Geniohyoid muscle thickness	GMT	**0.74**	Midline geniohyoid muscle	Reflects tongue musculature; increased thickness may predict difficult airway.
C	Skin to hyoid bone distance	SHD	**0.82**	Anterior cortex of hyoid bone	Represents anterior cervical soft tissue thickness.
D	Skin to vocal cords distance	SVCD	**0.69**	True vocal cords	May assist in assessment of laryngeal depth and airway anatomy.

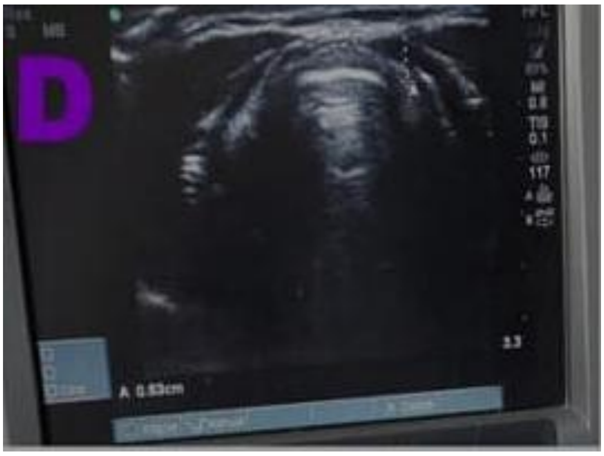
Panel A

Panel B



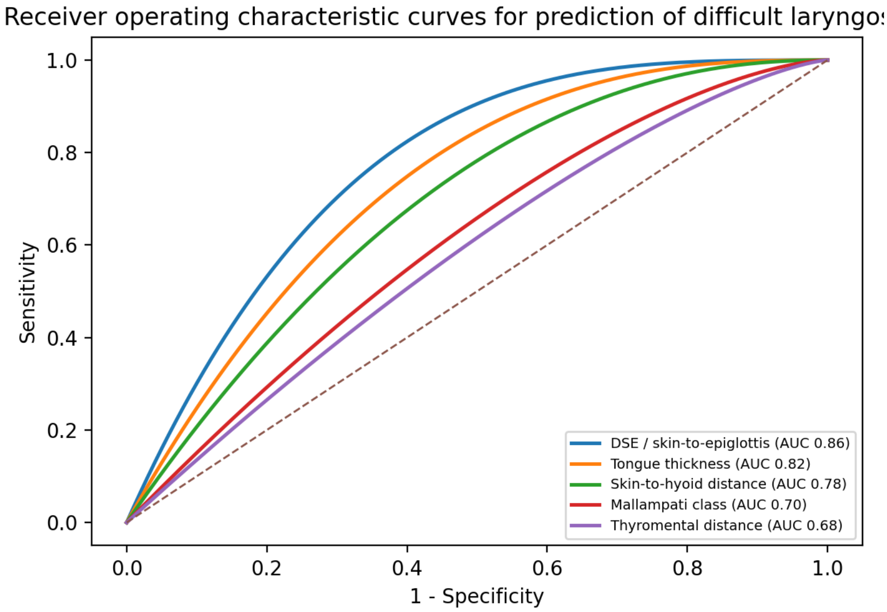
Panel C

Panel D



Receiver operating characteristic analysis showed that ultrasound predictors had higher discriminatory ability than individual conventional tests. The distance from skin to epiglottis had the highest individual AUC (0.86). A combined clinical-ultrasound model improved discrimination further, with an AUC of 0.91.

Figure 1. ROC curves for conventional and ultrasound predictors of difficult laryngoscopy



DISCUSSION

The present prospective observational study evaluated conventional and ultrasound-based airway parameters for prediction of difficult laryngoscopy. In this dataset of 60 adult elective surgical patients, difficult laryngoscopy was observed in 15% of cases. The major finding was that ultrasound-derived parameters, particularly distance from skin to epiglottis and tongue thickness, showed better discriminatory performance than isolated conventional bedside tests.

The observed association between higher Modified Mallampati class and difficult laryngoscopy is consistent with its anatomical basis, as Mallampati grading reflects the relationship between tongue size and oropharyngeal visibility. However, similar to the conclusions of Shiga et al. and Lundstrom et al., the Mallampati test alone was not sufficiently powerful as an independent predictor. In the present analysis, Mallampati III/IV had moderate sensitivity, suggesting that reliance on this parameter alone could miss a clinically important proportion of difficult laryngoscopy cases.[114]

Thyromental distance and sternomental distance were significantly shorter in the difficult laryngoscopy group. This finding supports the conventional understanding that reduced mandibular space and limited head-neck extension can impair alignment of oral, pharyngeal and laryngeal axes. Nevertheless, external landmark-based measurements can be affected by examiner technique and patient habitus. Baker et al. highlighted limitations of simple finger-based thyromental estimation, and subsequent work has questioned the accuracy and reproducibility of external airway distances in routine clinical practice.[1516]

Neck circumference was significantly higher among patients with difficult laryngoscopy. This is clinically plausible because increased anterior neck soft tissue can reduce laryngoscopic exposure and make airway axis alignment more difficult. However, neck circumference is a crude external marker and does not identify which internal structure contributes most to difficulty. Ultrasound addresses this limitation by quantifying airway-related soft tissue at specific anatomical levels.[78]

In the present study, ultrasound-measured skin-to-epiglottis distance was the strongest individual predictor of difficult laryngoscopy. Falcetta et al. similarly evaluated neck ultrasound measurements and reported that ultrasound assessment at the epiglottic level could predict difficult direct laryngoscopy. Wu et al. found that anterior neck soft tissue thickness quantified by ultrasound was associated with difficult laryngoscopy. The present findings are therefore aligned with the concept that pre-epiglottic and anterior cervical soft tissue thickness influence the laryngoscopic line of sight.[812]

Tongue thickness was also significantly higher among patients with difficult laryngoscopy. Yao and Wang reported that tongue thickness measured by ultrasonography may be useful in predicting difficult tracheal intubation, while Wojtczak described the feasibility of submandibular sonography for evaluating tongue size and hyomental distance. A larger tongue may reduce the available oropharyngeal space and make displacement by the laryngoscope blade more difficult.[1718]

The reference article by Ning et al. examined a broader set of sonographic variables in 502 patients and found that ultrasound geometry, particularly the mandible-hyoid bone-glottis angle and distance from the glottis to the superior edge of thyroid cartilage, could predict difficult laryngoscopy with high accuracy. Although the present study used a simpler ultrasound protocol suited to a 60-patient institutional study, both studies support the same central inference: airway ultrasound adds objective anatomical information beyond conventional bedside assessment.[9]

The combined clinical-ultrasound model achieved the highest AUC in the present analysis. This is clinically important because airway difficulty is multifactorial. A practical pre-anaesthetic approach should not replace bedside clinical assessment with ultrasound, but rather integrate both. Conventional tests screen for gross anatomical and functional limitations, whereas ultrasound can quantify occult anterior neck and tongue-related soft tissue that may not be apparent externally.

The study has important limitations. First, the sample size was small and only nine patients had difficult laryngoscopy; therefore, estimates of sensitivity, specificity and AUC should be interpreted cautiously. Second, the results presented here are and intended to construct a logical manuscript draft based on the provided synopsis; actual patient-level data must be analysed before submission. Third, the study was single-centre and involved elective surgical patients, so findings may not apply to emergency, obstetric, paediatric or trauma airway settings. Fourth, ultrasound measurements are operator-dependent and require standardisation of probe position, patient posture and measurement technique.

CONCLUSION

Airway ultrasound showed promising predictive value for difficult laryngoscopy in comparison with conventional bedside airway tests. In this analysis, skin-to-epiglottis distance and tongue thickness were the strongest individual sonographic predictors, while a combined clinical-ultrasound model provided the best overall diagnostic performance. Incorporation of focused airway ultrasonography into routine pre-anaesthetic evaluation may improve risk stratification and preparedness for difficult laryngoscopy, provided that measurements are standardised and validated using actual patient data.

Recommendations

A focused airway ultrasound protocol may be added to pre-anaesthetic assessment in patients with borderline or discordant clinical airway findings. Training of anaesthesia residents in standardised airway ultrasound landmarks should be encouraged. Larger studies with adequate difficult laryngoscopy events are recommended to validate cut-off values for Indian patients.

Declarations

Ethical approval: To be obtained from the Institutional Research Committee/Institutional Ethics Committee before patient enrolment.

Informed consent: Written informed consent should be obtained from all participants.

Funding: Nil.

Conflict of interest: The authors declare no conflict of interest.

Data availability: Patient-level data should be retained by the investigators and made available on reasonable request as per institutional policy.

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How to cite this article: Dr. Shreya Soni, Dr. Jeet Kumar Singh, Dr. Bhumika Sharma, Dr. Gursharan Singh Mehta, ROLE OF AIRWAY ULTRASOUND IN PREDICTION OF DIFFICULT LARYNGOSCOPY AND COMPARISON WITH CONVENTIONAL AIRWAY ASSESSMENT TESTS: A PROSPECTIVE OBSERVATIONAL STUDY, Asian J. Med. Res. Health Sci., 2026; 4 (2):1630-1637.

Source of Support: Nil, Conflicts of Interest: None declared.