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Original Research Article

Preoperative Ultrasound Assessment of Skin-to-Tongue Mucosal Distance for Prediction of Difficult Laryngoscopy

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ABSTRACT

Background: Accurate preoperative prediction of a difficult airway is essential in anesthetic practice. Traditional bedside evaluations, such as the Modified Mallampati Test (MMT), are subjective and demonstrate limited standalone predictive accuracy. This study evaluated the utility of ultrasonographic measurement of the skin-to-tongue mucosal distance as a quantitative predictor of difficult laryngoscopy.

Methods: This prospective observational study included 100 adult patients with American Society of Anesthesiologists (ASA) physical status I or II who were scheduled for elective surgery under general anesthesia requiring endotracheal intubation. Preoperative assessment included the MMT and ultrasonographic measurement of the skin-to-tongue mucosal distance. Based on predefined cutoffs, patients were categorized into three groups: Group A (3.5–5.4 cm), Group B (5.5–5.8 cm), and Group C (>5.8 cm). The primary outcome was the incidence of difficult laryngoscopy, defined as a Modified Cormack–Lehane (MCL) grade ≥2b.

Results: The overall incidence of difficult laryngoscopy was 21.0%. Increasing skin-to-tongue mucosal distance was significantly associated with a higher incidence of difficult laryngoscopy (0.0% in Group A, 22.9% in Group B, and 61.9% in Group C; $p < 0.001$). Using a cutoff value of >5.8 cm, ultrasonographic skin-to-tongue mucosal distance predicted difficult laryngoscopy with a sensitivity of 61.9%, specificity of 89.9%, positive predictive value (PPV) of 61.9%, and negative predictive value (NPV) of 89.9%. In comparison, a Modified Mallampati Class III/IV demonstrated lower sensitivity (33.3%) but higher specificity (96.2%), with a PPV of 70.0% and an NPV of 84.4%.

Conclusion: Ultrasonographic measurement of the skin-to-tongue mucosal distance demonstrated moderate sensitivity and high specificity for predicting difficult laryngoscopy. Compared with the Modified Mallampati Test, ultrasound showed higher sensitivity while providing objective anatomical quantification of airway structures. These findings suggest that preoperative airway ultrasound may serve as a valuable adjunct to conventional bedside airway assessment.

Keywords: Airway management; difficult laryngoscopy; airway ultrasound; point-of-care ultrasound; Modified Mallampati Test; preoperative airway assessment.

INTRODUCTION

Airway management is a cornerstone of anesthetic practice, and failure to secure a patent airway can result in serious complications, including dental trauma, airway injury, hypoxic brain damage, or death. [1,2] A difficult airway - defined as a situation in which a trained anesthesiologist encounters challenges with facemask ventilation, tracheal intubation, or both - remains a significant cause of anesthesia-related morbidity and mortality. [3,4] Accurate preoperative assessment is therefore essential to identify at-risk patients and to guide the formulation of safe, individualized airway management strategies.

Traditionally, clinicians have relied on bedside physical examination tests to predict difficult laryngoscopy. Among these, the Mallampati classification is widely used due to its simplicity. [5] However, this assessment indirectly estimates tongue size relative to the oropharyngeal cavity and demonstrates only modest predictive accuracy. Subjectivity in interpretation, along with relatively high rates of false-positive and false-negative results, has been consistently reported in extensive meta-analyses and systematic reviews, [6-8] underscoring the need for more objective predictors. Other conventional bedside metrics, such as the thyromental distance and upper lip bite test, similarly suffer from inconsistent inter-observer reliability and poor standalone predictive value. [9-11]

In recent years, point-of-care ultrasonography (POCUS) has emerged as a valuable, non-invasive modality for airway assessment. [12,13] Unlike conventional bedside tests, ultrasound provides real-time visualization of upper airway anatomy, allowing for quantitative evaluation of parameters such as tongue thickness, skin-to-epiglottis distance, and pretracheal soft tissue thickness. [14,15] Studies have increasingly highlighted that anterior neck soft tissue, particularly at the level of the hyoid bone and thyrohyoid membrane, strongly correlates with difficult glottic visualization. [16,17] These sonographic measurements hold promise for improving preoperative airway evaluation by reducing reliance on subjective interpretation. [18,19]

Although multiple ultrasound-derived parameters have been investigated, evidence directly correlating them with the Modified Cormack–Lehane (MCL) grading of direct laryngoscopy remains limited and sometimes conflicting. [20-22] To address this gap, the present study evaluates the utility of the skin-to-tongue mucosal distance measured with ultrasound as a predictor of the laryngoscopic view. We hypothesize that a greater skin-to-tongue mucosal distance is significantly associated with higher MCL grades, supporting its potential role as an objective tool in preoperative airway assessment.

MATERIALS & METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of Anaesthesiology at Pacific Institute of Medical Sciences, Udaipur, Rajasthan, India. The study was carried out over a 12-month period from January 2025 to December 2025. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Sample Size Calculation

The sample size was determined based on the primary outcome, namely the incidence of difficult laryngoscopy. Based on previous literature, the anticipated prevalence of difficult laryngoscopy in the general adult population undergoing elective surgery was approximately 15%. The required sample size was calculated using the standard formula for estimating a population proportion:

$n = Z^2P(1 - P)/d^2$

where Z is the standard normal variate (1.96 for a 95% confidence level), P is the anticipated prevalence (0.15), and d is the absolute margin of error (0.07). Applying these values, the minimum required sample size was calculated to be 99.96. Therefore, a total of 100 patients were consecutively enrolled in the study.

Study Population

A total of 100 adult patients were enrolled in the study.

Inclusion Criteria

- Age between 18 and 65 years.
- American Society of Anesthesiologists (ASA) physical status I or II.
- Scheduled for elective non-obstetric surgery under general anaesthesia requiring endotracheal intubation.

Exclusion Criteria

- Patients with a known or anticipated difficult airway (e.g., previous history of difficult intubation, facial trauma, or airway tumours).
- Patients with cervical spine pathology or limited neck mobility.
- Emergency surgical procedures.
- Patients with a body mass index greater than 35 kg/m².
- Patients unable to provide informed consent.

Study Protocol

Preoperative Airway Assessment

During the pre-anaesthetic check-up, all enrolled patients underwent a standardized airway assessment performed by a single investigator to ensure consistency.

Modified Mallampati Test

The Modified Mallampati Test (MMT), as described by Samsoon and Young, was performed with the patient in the sitting position. Patients were instructed to open their mouth maximally and protrude their tongue without phonation. The oropharyngeal view was graded from Class I to Class IV.

Ultrasonographic Assessment

Airway ultrasonography was performed using an Esaote MyLab Seven ultrasound system equipped with a high-frequency linear array probe (6–13 MHz).

Positioning

Patients were placed in the supine position with the head maintained in the sniffing position, consisting of neck flexion and head extension.

Technique

A water-soluble gel was applied to the submental region. The probe was positioned in the midline sagittal plane superior to the hyoid bone to visualize the posterior one-third of the tongue.

Measurement

The skin-to-tongue mucosal distance was measured as the vertical distance from the skin surface to the hyperechoic air–mucosal interface of the tongue. Three measurements were obtained at the end of expiration, and the average value was recorded for analysis.

Patient Grouping

Based on the ultrasonographic measurement, patients were stratified into three groups. These cut-off values were adopted from a previous observational study by Kumar et al.[23] who identified these specific thresholds via receiver operating characteristic (ROC) analysis as providing the optimal balance of sensitivity and specificity for predicting difficult laryngoscopy.

- Group A: Skin-to-tongue mucosal distance 3.5–5.4 cm
- Group B: Skin-to-tongue mucosal distance 5.5–5.8 cm
- Group C: Skin-to-tongue mucosal distance >5.8 cm

Intraoperative Management and Laryngoscopy

In the operating room, standard ASA monitoring was applied. Following preoxygenation with 100% oxygen for three minutes, anaesthesia was induced using intravenous fentanyl (2 µg/kg) and propofol (2–2.5 mg/kg). Neuromuscular blockade was achieved with vecuronium (0.1 mg/kg).

After three minutes of gentle mask ventilation, direct laryngoscopy was performed using an appropriately sized Macintosh blade by a senior anaesthesiologist with more than five years of experience who was blinded to the preoperative ultrasound and Mallampati findings.

Outcome Measurement

The laryngeal view obtained during direct laryngoscopy was assessed using the Modified Cormack–Lehane (MCL) grading system before endotracheal tube placement.

Easy Laryngoscopy

- MCL Grade 1 or 2a (full or partial view of the glottis)

Difficult Laryngoscopy

- MCL Grade 2b, 3, or 4 (only the epiglottis visible or no glottic structures visible)

Statistical Analysis

Data were entered into a Microsoft Excel spreadsheet and analysed using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean±standard deviation (SD). Comparisons between groups were performed using one-way analysis of variance (ANOVA). Categorical variables, including MMT class, MCL grade, and the incidence of difficult laryngoscopy, were expressed as frequencies and percentages and analysed using the Chi-square test where appropriate. A p-value less than 0.05 was considered statistically significant.

RESULT

A total of 100 patients who met the inclusion criteria were enrolled and completed the study. The demographic characteristics of the patients stratified according to ultrasound group are presented in Table 1. There were no statistically significant differences among the three groups with respect to age (p = 0.91), sex (p = 0.94), body mass index (BMI) (p = 0.10), or ASA physical status (p = 0.95), indicating that the groups were comparable at baseline. Despite 21 patients demonstrating difficult laryngoscopy (MCL 2b/3/4), all patients were successfully intubated on the first attempt using direct laryngoscopy by a senior anesthesiologist (with more than five years of experience) who was blinded to the preoperative ultrasound and MMT findings.

Table 1: Demographic Characteristics of Study Groups

Characteristic	Group A (n=44)	Group B (n=35)	Group C (n=21)	p-value
Age (years), mean ± SD	41.8 ± 12.9	43.1 ± 13.5	42.6 ± 13.3	**0.91**
Sex (Male/Female), n (%)	25 (56.8) / 19 (43.2)	19 (54.3) / 16 (45.7)	11 (52.4) / 10 (47.6)	**0.94**
BMI (kg/m²), mean ± SD	26.5 ± 4.0	27.3 ± 4.2	28.4 ± 4.1	**0.10**
ASA Status (I/II), n (%)	28 (63.6) / 16 (36.4)	21 (60.0) / 14 (40.0)	13 (61.9) / 8 (38.1)	**0.95**

Preoperative Airway Assessment

Based on preoperative ultrasonographic measurement of the skin-to-tongue mucosal distance, patients were allocated to three study groups: Group A (3.5–5.4 cm; n = 44), Group B (5.5–5.8 cm; n = 35), and Group C (>5.8 cm; n = 21).

Laryngoscopic View and Incidence of Difficult Laryngoscopy

The overall incidence of difficult laryngoscopy, defined as Modified Cormack–Lehane (MCL) Grade 2b, 3, or 4, was 21.0% (21/100 patients).

The association between ultrasound-based grouping and the incidence of difficult laryngoscopy is shown in Table 2. No patient in Group A experienced difficult laryngoscopy. In Group B, difficult laryngoscopy was encountered in 8 patients (22.9%), whereas the highest incidence was observed in Group C, where 13 patients (61.9%) experienced difficult laryngoscopy. The incidence of difficult laryngoscopy increased significantly with increasing skin-to-tongue mucosal distance ($p < 0.001$).

Table 2: Association between Ultrasound Group and Laryngoscopic View

Ultrasound Group	Easy Laryngoscopy (MCL 1, 2a) n (%)	Difficult Laryngoscopy (MCL 2b, 3, 4) n (%)	Total
Group A (3.5–5.4 cm)	44 (100.0)	0 (0.0)	44
Group B (5.5–5.8 cm)	27 (77.1)	8 (22.9)	35
Group C (>5.8 cm)	8 (38.1)	13 (61.9)	21
Total	**79 (79.0)**	**21 (21.0)**	**100**

Chi-square = 32.95, df = 2, p < 0.001

The distribution of patients according to the Modified Mallampati Test (MMT) was as follows: 59 patients (59.0%) were classified as Class I, 31 patients (31.0%) as Class II, 8 patients (8.0%) as Class III, and 2 patients (2.0%) as Class IV.

Association Between Modified Mallampati Test and Laryngoscopic View

The relationship between preoperative MMT classification and laryngoscopic view is presented in Table 3 and Graph 2. The incidence of difficult laryngoscopy increased progressively with higher Mallampati classes.

Among patients classified as MMT Class I, difficult laryngoscopy occurred in 1 patient (1.7%). Among MMT Class II patients, difficult laryngoscopy was observed in 13 patients (41.9%). In MMT Class III, 5 of 8 patients (62.5%) experienced difficult laryngoscopy, while both patients classified as MMT Class IV (100%) had difficult laryngoscopy.

A statistically significant association was observed between MMT classification and laryngoscopic difficulty ($\chi^2 = 29.24$, $p < 0.001$).

Table 3: Association between Mallampati Test (MMT) and Laryngoscopic View

MMT Class	Easy n (%)	Difficult n (%)	Total
MMT I	58 (98.3%)	1 (1.7%)	59
MMT II	18 (58.1%)	13 (41.9%)	31

MMT III	3 (37.5%)	5 (62.5%)	8
MMT IV	0 (0.0%)	2 (100.0%)	2
Total	**79 (79.0%)**	**21 (21.0%)**	**100**

Chi-square = 29.24, df = 3, p < 0.001

Correlation Between Ultrasound Measurement and Mallampati Classification

A significant association was also observed between ultrasound-based grouping and MMT classification, as shown in Table 4 and Graph 3. Patients in Group A, characterized by shorter skin-to-tongue mucosal distances, predominantly belonged to the lower Mallampati classes. In contrast, patients in Group C demonstrated a higher proportion of advanced Mallampati classes, suggesting a positive relationship between increasing skin-to-tongue mucosal distance and higher Mallampati grades.

Table 4: Association between Ultrasound Group and Mallampati Test (MMT)

Ultrasound Group	MMT I n (%)	MMT II n (%)	MMT III n (%)	MMT IV n (%)	Total
Group A	38 (86.4%)	6 (13.6%)	0 (0.0%)	0 (0.0%)	44
Group B	16 (45.7%)	14 (40.0%)	4 (11.4%)	1 (2.9%)	35
Group C	5 (23.8%)	11 (52.4%)	4 (19.0%)	1 (4.8%)	21
Total	59 (59.0%)	31 (31.0%)	8 (8.0%)	2 (2.0%)	100

Chi-square = 28.38; df = 6; p < 0.001

Diagnostic Accuracy of Predictive Tests

The diagnostic accuracy of the ultrasound-guided depth measurement and the Mallampati test for predicting difficult laryngoscopy are presented in Table 5. For the ultrasound measurement, a cutoff of >5.8 cm (Group C) was used. For the Mallampati test, a cutoff of Class III or IV was used. The ultrasound measurement demonstrated a sensitivity of 61.9%, a specificity of 89.9%, a positive predictive value (PPV) of 61.9%, and a negative predictive value (NPV) of 89.9%. In comparison, the Mallampati test showed a lower sensitivity (33.3%) but a higher specificity (96.2%), with a PPV of 70.0% and an NPV of 84.4%.

Table 5: Diagnostic Accuracy for Predicting Difficult Laryngoscopy

Test	Parameter	Value
Ultrasound (>5.8 cm)	Sensitivity	61.9%
	Specificity	89.9%
	Positive Predictive Value (PPV)	61.9%
	Negative Predictive Value (NPV)	89.9%
Mallampati (Class III/IV)	Sensitivity	33.3%

	Specificity	96.2%
	Positive Predictive Value (PPV)	70.0%
	Negative Predictive Value (NPV)	84.4%

DISCUSSION

This study evaluated the role of a suprahyoid ultrasonographic parameter, the skin-to-tongue mucosal distance, in predicting difficult laryngoscopy. The principal finding of this study was that a greater skin-to-tongue distance was strongly associated with a higher incidence of difficult laryngoscopy, defined as a Modified Cormack–Lehane (MCL) Grade ≥2b. Our results highlight the anatomical relevance of tongue base volume and soft tissue thickness in the floor of the mouth as critical determinants of glottic visualization during laryngoscopy.

These findings closely parallel the study by Kumar et al. [23], who first investigated these specific ultrasonographic cutoffs in a smaller cohort of 60 patients. Unlike Kumar et al., who derived these cutoffs using ROC analysis, the present study externally validated the previously reported thresholds in an independent patient cohort. Similar to their findings, our study observed that a skin-to-tongue mucosal distance of 3.5–5.4 cm (Group A) was associated with a 0% incidence of difficult laryngoscopy. By validating these predetermined cutoffs in a larger sample size (N = 100), our study confirms that increasing skin-to-tongue mucosal distance correlates with increasing laryngoscopic difficulty. Furthermore, a measurement exceeding 5.8 cm was associated with a markedly increased incidence of difficult laryngoscopy and demonstrated high specificity, supporting its role as a clinically useful predictor of a difficult airway.

These findings are concordant with the broader, growing evidence supporting airway point-of-care ultrasound (POCUS) as a valuable adjunct to traditional bedside evaluation. [24] Unlike conventional bedside tests, which are subjective and demonstrate only modest standalone predictive accuracy, ultrasonography provides objective, reproducible measurements. Prior studies have demonstrated the predictive value of parameters such as tongue thickness, hyomental distance ratio, and skin-to-epiglottis distance. [25,26] In our study, a cutoff value of >5.8 cm yielded a sensitivity of 61.9% and a specificity of 89.9%. Furthermore, our findings align with recent meta-analyses, such as Carsetti et al. (2022), which reported a pooled sensitivity and specificity of approximately 82% and 79% for airway ultrasound parameters. [19] While the sensitivity in our study is slightly lower than some previously reported ultrasound metrics - such as skin-to-epiglottis distance, which has shown sensitivities approaching 80–85% in studies including obese populations [26] - the high specificity indicates that a measurement above 5.8 cm is a strong indicator of an impending difficult airway. This supports the clinical utility of ultrasound as a robust, quantitative tool for airway risk stratification.

The Modified Mallampati Test (MMT), while commonly used, showed a different performance profile in our study. Its sensitivity was low (33.3%), but its specificity was very high (96.2%). This pattern reflects the test's inherent limitation: a reduced ability to detect all difficult airways (high false negatives), but strong predictive power when high grades (III/IV) are actually present. Indeed, 62.5% of MMT Class III and 100% of MMT Class IV patients encountered a difficult laryngoscopy. This high specificity but low sensitivity is a well-documented phenomenon in airway literature, corroborating comprehensive reviews that caution against using MMT as an isolated screening tool. [6-8] Notably, a substantial proportion of difficult laryngoscopies in our cohort occurred in MMT Class II patients (41.9%), which may suggest that the conventional Class III/IV cutoff underestimates risk in this population and that a lower clinical threshold warrants further evaluation. Thus, the MMT may serve as a useful “rule-in” tool, while ultrasound provides improved sensitivity and objective anatomical quantification. The significant correlation observed between the ultrasound measurement and MMT score further suggests that the Mallampati classification indirectly reflects tongue base size, which ultrasound can measure more reliably and without subjective bias.

This study has limitations. It was conducted in a single center with a limited sample size (n = 100) comprising only ASA physical status I–II patients undergoing elective surgery, which may restrict generalizability to emergency settings or patients with known airway pathologies. In addition, although all measurements were performed by a single investigator to minimize variability, ultrasound is inherently operator-dependent. Inter-observer reproducibility for this specific measurement should be assessed in future studies.

CONCLUSION

Ultrasonographic measurement of the skin-to-tongue mucosal distance demonstrated moderate sensitivity (61.9%) and high specificity (89.9%) for predicting difficult laryngoscopy. Compared with the Modified Mallampati Test, ultrasound showed higher sensitivity while providing objective anatomical quantification of airway structures. These findings suggest that preoperative airway ultrasound may serve as a valuable adjunct to conventional bedside airway assessment. Larger multicentre studies are required to validate these findings, establish standardized cutoff values, and compare the predictive performance of different ultrasonographic airway parameters.

Declaration by Authors

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