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Original Research Article

CORRELATION OF ULTRASONOGRAPHIC AIRWAY PARAMETERS WITH CORMACK–LEHANE GRADING FOR PREDICTION OF DIFFICULT INTUBATION: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Aim: Prediction of difficult intubation remains a key challenge in airway management. Unanticipated difficult intubation in patients with apparently normal airways represents the most dangerous airway scenario in anaesthetic practice, as conventional bedside predictors are often subjective and unreliable. While existing literature has largely focused on anticipated difficult airways, objective tools for the unanticipated setting remain limited. Ultrasonographic airway assessment offers a promising objective alternative. This study aimed to evaluate the correlation between ultrasonographic airway measurements and Cormack–Lehane (C–L) grading in patients with no obvious preoperative predictors of difficulty, and to compare their predictive accuracy with conventional clinical methods.

Materials and Methods: This prospective observational study included 189 ASA I and II patients aged 18–60 years undergoing elective surgery under general anesthesia. Preoperative assessment included Modified Mallampati score, thyromental distance, upper lip bite test, and ultrasonographic measurements of distance from skin to epiglottis (DSE) and hyoid bone (DSHB). Direct laryngoscopy was performed by blinded anaesthesiologists, and C–L grading was recorded. Statistical analysis included correlation, ordinal logistic regression, and ROC analysis.

Results: Difficult laryngoscopy (C–L Grade III/IV) was observed in 10% of patients. A strong correlation between DSE and DSHB was noted in Grade III cases. DSE emerged as the most significant predictor, outperforming conventional airway assessments. A DSE cut-off of 1.8 cm showed optimal diagnostic performance. BMI was significantly associated with difficult intubation, while TMD indicated easier laryngoscopy. ROC analysis demonstrated excellent predictive ability (AUC = 0.88).

Conclusion: Ultrasonographic airway assessment, particularly DSE, is a reliable and objective predictor of difficult intubation. Its incorporation into routine practice may improve airway assessment and patient safety.

Keywords: Difficult intubation; Ultrasonography; Airway assessment; Distance from skin to epiglottis; Cormack–Lehane grading; Predictive accuracy.

INTRODUCTION

Effective airway management is fundamental to safe anesthetic and critical care practice, with endotracheal intubation being an essential intervention in both elective and emergency scenarios. Despite considerable advancements in airway management strategies and devices, unanticipated difficult intubation continues to remain a significant concern, contributing substantially to

perioperative morbidity and mortality. The incidence of difficult tracheal intubation following direct laryngoscopy in patients with apparently normal airways has been reported to be as high as 5–10%.[1,2] Failure to secure the airway remains one of the leading causes of anesthesia-related complications and adverse outcomes.[3]

Unanticipated difficult intubation, particularly when accompanied by compromised ventilation, can have serious and potentially fatal consequences if not managed promptly. Crucially, the danger lies not in cases where difficulty is foreseen, but in those where no warning signs are identified – and the clinician proceeds with a standard technique only to encounter an unexpectedly poor laryngoscopic view. Evidence suggests that the majority of airway-related complications arise precisely from this failure: difficult airway predictors go unrecognised during preoperative assessment, and no contingency plan is in place.[4] The findings of the 4th National Audit Project further emphasize that insufficient airway evaluation and poor clinical judgment in apparently normal patients significantly contribute to unfavourable outcomes.[5] These observations highlight the urgent need for more sensitive and objective screening tools capable of identifying the unanticipated difficult airway before induction of anaesthesia.

Traditionally, several bedside clinical predictors including the Mallampati classification, thyromental distance (TMD), Sternomental distance (SMD), neck circumference, upper lip bite test (ULBT), and Wilson score have been utilized to assess the likelihood of difficult intubation. However, these methods are inherently subjective, exhibit considerable inter-observer variability, and are often associated with limited sensitivity and specificity.[6] Their performance is especially poor in the unanticipated difficult airway setting: by definition, these patients score reassuringly on conventional tests, making false-negative predictions the dominant failure mode. Consequently, there is a pressing need for more objective, quantitative tools that can detect anatomical risk factors invisible to clinical examination alone.

In recent years, point-of-care ultrasound (POCUS) has emerged as a promising modality for airway evaluation. Ultrasonography offers a non-invasive, radiation-free, and bedside approach for visualizing upper airway structures with minimal patient preparation. It enables real-time assessment of anatomical landmarks such as the tongue, hyoid bone, epiglottis, and vocal cords. Furthermore, ultrasound has demonstrated utility in various airway-related procedures, including confirmation of endotracheal tube placement, identification of the cricothyroid membrane, and guidance for tracheostomy. Advances in ultrasound technology have enhanced image resolution and tissue penetration, thereby improving visualization of critical airway structures.

Ultrasound-based airway assessment has shown considerable potential in predicting difficult intubation by quantifying anterior neck soft-tissue characteristics. Among various parameters, the distance from the skin to the epiglottis (DSE) and the distance from the skin to the hyoid bone (DSHB) have emerged as significant predictors of difficult intubation.[7] Additionally, its non-ionizing nature makes ultrasonography a safer alternative to imaging modalities such as computed tomography (CT) and X-rays, particularly in vulnerable populations such as obstetric patients.[2]

Although significant progress has been made in predicting anticipated difficult airways, the occurrence of unanticipated difficult intubation in ASA I and II patients with seemingly normal clinical airway assessments continues to pose a major clinical challenge. This prospective observational study was therefore undertaken to assess the role of ultrasonographic airway evaluation in such cases, particularly where conventional clinical predictors may offer false reassurance. The study further seeks to correlate various ultrasound-based airway measurements with Cormack–Lehane (C–L) grading observed during direct laryngoscopy, in order to evaluate the potential of ultrasound as an adjunctive tool for identifying difficult airways not detected by routine clinical examination. Conventional predictors such as the Modified Mallampati score, TMD, and ULBT, while widely used, are limited by subjectivity, inter-observer variability, and susceptibility to patient factors including cooperation, obesity, and cervical mobility – making them unreliable precisely in the patients who most need accurate screening. Ultrasonography, by providing objective and quantifiable measurements of anterior neck soft tissue, offers a fundamentally different approach. The primary aim of this study is to determine the correlation between ultrasonographic airway measurements – specifically DSE and DSHB – and C–L grading in this population. The secondary objective is to compare the predictive accuracy of these parameters with conventional bedside methods, with the goal of identifying a reliable screening tool for the unanticipated difficult airway.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted after obtaining approval from the Institutional Ethics Committee and Scientific Committee (Ref: KJSMCRC/567/2023-2024). Written informed consent was obtained from all participants prior to enrollment. The study was carried out over a period of 12 months, from March 2023 to February 2024, in patients scheduled for elective surgical procedures under general anesthesia requiring endotracheal intubation.

Study Population

A total of 189 patients belonging to the American Society of Anaesthesiologists (ASA) physical status I and II, aged between 18 and 60 years, of either gender, were included in the study. Patients with ASA physical status III and IV, those aged less than 18 years or more than **60** years, and individuals with a body mass index greater than 35 kg/m² were excluded. Additionally, patients with oral or neck malignancies, maxillofacial or cervical abnormalities, facial trauma, cervical spine instability, as well as pregnant and pediatric patients were excluded from the study.

Preoperative Assessment

All patients underwent a detailed preoperative evaluation, which included routine airway assessment and recording of demographic variables such as age, gender, and body weight. Routine laboratory investigations were carried out as per the guidelines of the Indian Society of Anaesthesiologists (ISA). Clinical airway assessment was performed using standard bedside predictors. Modified Mallampati score was assessed by evaluating the oropharyngeal structures visible upon maximal mouth opening, with the patient in the upright position. It was classified into four grades: Grade I, where the faucial pillars, soft palate, and uvula are visible; Grade II, where the faucial pillars and soft palate are visible but the uvula is masked by the base of the tongue; Grade III, where only the soft palate is visible; and Grade IV, where the soft palate is not visible.

The TMD was measured as the distance from the mentum to the thyroid notch with the neck fully extended, with values less than 6 cm considered suggestive of difficult intubation. The ULBT was classified into three categories based on the ability of the lower incisors to bite the upper lip: Class I, complete coverage of the upper lip mucosa; Class II, partial visibility of the mucosa; and Class III, inability to bite the upper lip. Classes II and III were considered predictors of difficult intubation.

Ultrasonographic Airway Assessment

Preoperative ultrasonographic evaluation of the airway was performed in all patients in the preoperative area. The patients were positioned supine with the head placed in the sniffing position using a slightly compressible pillow. A high-frequency linear ultrasound probe (6–12 MHz), with a penetration depth of 2–3 cm suitable for superficial structures, was used for the assessment. The probe was placed transversely over the anterior aspect of the neck to visualize airway structures and measure soft tissue thickness. Two parameters that were recorded are DSHB and the DSE. All measurements were documented in the data collection sheet.

Intraoperative Procedure and Laryngoscopic Assessment

Upon arrival in the operating room, standard non-invasive monitoring, including electrocardiography, pulse oximetry, non-invasive blood pressure, and capnography, was instituted. After adequate preoxygenation, general anesthesia was induced using intravenous midazolam (0.03 mg/kg), fentanyl (1–2 µg/kg), propofol (2–2.5 mg/kg), and atracurium (0.6–1 mg/kg). Direct laryngoscopy was performed in the sniffing position using a Macintosh blade of appropriate size (3 or 4) by an experienced anesthesiologist who was blinded to the preoperative ultrasound findings. The laryngoscopic view was graded according to the C–L classification, where Grade I indicated full visualization of the glottis, Grade II partial visualization, Grade III visualization of only the epiglottis, and Grade IV visualization of only the soft palate. Grades III and IV were considered indicative of difficult laryngoscopy and intubation. Endotracheal intubation was subsequently performed using appropriately sized tubes, and all intraoperative findings were recorded.

Statistical Analysis

Statistical analysis was performed using appropriate methods. Pearson's correlation coefficient was applied to evaluate the relationship between ultrasonographic parameters (DSE and DSHB) and the C–L grade. Ordinal logistic regression analysis was used to assess the influence of ultrasonographic measurements and clinical predictors, including Modified Mallampati score, TMD, ULBT, age, gender, BMI, and ASA status, on the occurrence of difficult intubation. Receiver Operating Characteristic (ROC) curve analysis was performed to determine the optimal cut-off value for DSE using the area under the curve (AUC) and Youden's index, and the corresponding sensitivity and specificity were calculated.

RESULTS

A total of 189 patients aged 18–60 years, belonging to ASA physical status I and II, of either gender, and scheduled for elective surgeries under general anesthesia with endotracheal intubation were included in this prospective observational study. The demographic and clinical characteristics of the study participants are summarized in Table 1. The majority of patients belonged to the 46–60 years age group, followed by those aged 31–45 years, while a smaller proportion were in the 18–30 years category. There was a predominance of male participants compared to females. Most patients were classified as ASA Grade II, with a smaller proportion in Grade I. In terms of body mass index, the majority of participants were in the overweight range (25.1–30.0 kg/m²), followed by those with normal BMI and a smaller proportion in the obese category (30.1–35.0 kg/m²).

Table 1: Demographic and Clinical Characteristics of Study Participants (n = 189)

Variable	Category	Frequency (n)	Percentage (%)
Age Group	18–30 years	23	12%
	31–45 years	80	42%

	46–60 years	86	46%
Gender	Male	112	59%
	Female	77	41%
ASA Grade	Grade I	54	29%
	Grade II	135	71%
BMI (kg/m²)	18.5–25.0	36	19%
	25.1–30.0	108	57%
	30.1–35.0	45	24%

The distribution of clinical airway assessment parameters, ultrasonographic measurements, and Cormack–Lehane grading is presented in Table 2. A greater proportion of patients were classified as Modified Mallampati Grade II compared to Grade I. Similarly, the majority of patients were categorized as Class I on the Upper Lip Bite Test, followed by Class II, with only a small proportion falling into Class III. Laryngoscopic assessment revealed that most patients had a Cormack–Lehane Grade II view, followed by Grade I, while higher grades (III and IV), indicative of difficult laryngoscopy, were relatively infrequent. On ultrasonographic evaluation, the mean distance from skin to epiglottis was higher than the distance from skin to hyoid bone, indicating relatively greater soft tissue thickness at the epiglottic level.

Table 2: Distribution of Cormack–Lehane Grading, Clinical Airway Assessment Parameters, and Ultrasonographic Measurements (n = 189)

Variable	Category / Parameter	Value
Modified Mallampati Score (MMS), N (%)	Grade I	81 (43%)
	Grade II	108 (57%)
Upper Lip Bite Test (ULBT), N (%)	Class I	98 (52%)
	Class II	75 (40%)
	Class III	16 (8%)
Cormack–Lehane Grade, N (%)	Grade I (Full view)	42 (22%)
	Grade II (Partial view)	128 (68%)
	Grade III (Epiglottis only)	13 (7%)
	Grade IV (Soft palate only)	6 (3%)
Ultrasound Measurements (Mean ± SD)	DSHB (cm)	0.82 ± 0.13
	DSE (cm)	1.50 ± 0.23

Note: Units for ultrasound measurements corrected to centimetres (cm) for consistency with cut-off values reported throughout the text.

The correlation between ultrasonographic parameters and C–L grading is presented in Table 3. A strong and statistically significant correlation between DSE and DSHB was observed in patients with C–L Grade III, indicating their potential utility in predicting difficult intubation. In contrast, no significant correlation was observed for lower grades (I and II) or for Grade IV. It is notable that the absence of significant correlation in Grade IV may be partly attributed to the small sample size (n = 6) in this subgroup, limiting statistical power. On ordinal logistic regression analysis, DSE emerged as the most significant predictor of difficult intubation, demonstrating a markedly higher odds ratio compared to other variables. BMI also showed a significant positive association with difficult intubation, suggesting increased risk with higher BMI. In contrast, a TMD greater than 6.5 cm was associated with a reduced likelihood of difficult intubation, indicating its protective role. Other clinical predictors, including Modified Mallampati score, ULBT, ASA grade, and gender, did not demonstrate significant predictive value, while age showed only a marginal association. The regression model demonstrated moderate explanatory power, as indicated by the model fit statistics. Further evaluation using ROC curve analysis revealed that the predictive performance improved when higher C–L grades (III/IV) were considered as the outcome, with excellent discriminative ability observed.

Table 3: Correlation of Ultrasonographic Parameters with Cormack–Lehane Grading, and Comparison of Predictive Accuracy Using Ordinal Logistic Regression and ROC Analysis

Analysis Type	Variable / Comparison	Statistic	Value	p-value	Interpretation
Correlation	CL Grade I (DSE vs DSHB)	r^2	0.30	0.05	Not significant
	CL Grade II (DSE vs DSHB)	r^2	0.16	0.08	Not significant
	CL Grade III (DSE vs DSHB)	r^2	0.72	0.006	Strong significant correlation
	CL Grade IV (DSE vs DSHB) (n=6; insufficient sample size for reliable interpretation- cannot be compared with Grade1-3)	r^2	0.44	0.39	Not significant
Ordinal Logistic Regression (Secondary Objective)	DSE	OR	27.99	<0.005	Strong predictor
	DSHB	OR	2.89	0.503	Not significant

	Mallampati (II)	OR	1.19	0.615	Not significant
	ULBT	OR	1.02	0.954	Not significant
	TMD >6.5 cm	OR	0.19	0.027	Protective (easier intubation)
	Gender (Male)	OR	0.96	0.919	Not significant
	ASA Grade II	OR	1.90	0.128	Not significant
	Age	OR	1.05	0.055	Borderline
	BMI	OR	1.23	0.002	Significant predictor
	Model Fit	LR Chi-square	82.06	—	Moderate model fit
		Pseudo R^2	0.24	—	Moderate explanatory power
ROC Analysis	Outcome 1	AUC	0.19	—	Poor
	Outcome 2	AUC	0.69	—	Moderate
	Outcome 3 (CL III/IV vs I/II)	AUC	0.88	—	Excellent prediction

Abbreviations: DSE – Distance from Skin to Epiglottis; DSHB – Distance from Skin to Hyoid Bone; CL – Cormack–Lehane; OR – Odds Ratio; CI – Confidence Interval; ULBT – Upper Lip Bite Test; TMD – Thyromental Distance; ASA – American Society of Anaesthesiologists; BMI – Body Mass Index; AUC – Area Under the Curve; SD – Standard Deviation; r^2 – Coefficient of Determination.

The diagnostic performance of the DSE at various cut-off values is presented in Table 4. A progressive increase in specificity with a corresponding decrease in sensitivity was observed as the cut-off value increased. Among the evaluated thresholds, a DSE cut-off of 1.8 cm demonstrated the highest Youden's index, indicating the most optimal balance between sensitivity and specificity for predicting difficult intubation. Lower cut-off values were associated with higher sensitivity but reduced specificity, whereas higher cut-off values improved specificity at the expense of sensitivity.

Table 4: Determination of Optimal Cut-off Value of DSE for Predicting Difficult Intubation

DSE Cut-off (cm)	Sensitivity (%)	Specificity (%)	Youden's Index (J)
1.5	90	60	0.50
1.6	85	70	0.55
1.7	80	80	0.60
1.8	74	89	0.63
1.9	68	93	0.61
2.0	60	96	0.56

DISCUSSION

In this prospective observational study involving 189 ASA I and II patients with no obvious preoperative predictors of difficult intubation, we evaluated the role of ultrasonographic airway assessment in predicting unanticipated difficult intubation and compared its performance with conventional clinical airway predictors. Difficulty in intubation was defined based on the C–L grading system, with Grades III and IV considered indicative of difficult laryngoscopy. The incidence of difficult laryngoscopy in our study was approximately 10%, consistent with published rates for unanticipated difficulty in apparently normal patients, with no cases of failed intubation.

The primary objective of this study was to determine the correlation between ultrasonographic airway measurements – specifically DSE with DSHB – and the C–L grade. Our findings demonstrated a strong and statistically significant correlation between these parameters in patients with C–L Grade III, suggesting that increased anterior neck soft tissue thickness is associated with a higher likelihood of difficult intubation. Similar observations have been reported in previous studies, where increased pretracheal soft tissue thickness was associated with poor laryngoscopic view. The absence of significant correlation in Grades I and II is expected given the low soft tissue burden in those cases. In Grade IV, the lack of correlation is most likely attributable to the very small sample size (n = 6), which limits statistical power, and should be interpreted with caution rather than as a distinct clinical finding.

A key aspect of our study was the determination of an optimal DSE cut-off value. We identified 1.8 cm as the optimal threshold, demonstrating the best balance between sensitivity and specificity. This finding closely aligns with the study by Parameswari et al. (2017), which also reported a cut-off of 1.8 cm in an Indian population,[8] supporting the reproducibility of this threshold in similar demographic settings. In contrast, Wu et al. (2014) reported a lower cut-off value of 1.78 cm with very high sensitivity in a Chinese population,[9] whereas Pinto et al. (2016) and Falcetta et al. (2018) reported higher thresholds of 2.75 cm and 2.54 cm in Portuguese and Italian populations respectively.[10,11] Martinez et al. (2021) reported an even higher cut-off of 3 cm in a Spanish population,[12] while Fernández-Vaquero et al. (2023) observed a value of 2.48 cm in a Caucasian population.[13]

These variations in cut-off values across studies can be attributed to several factors. Firstly, differences in patient populations, including ethnicity and body habitus, play a significant role, as anatomical variations in airway structures are well documented. Secondly, the technique of ultrasound measurement, including probe positioning and identification of anatomical landmarks, may introduce variability. Thirdly, operator experience is a critical factor, as

studies involving more experienced clinicians tend to demonstrate higher diagnostic accuracy. Finally, differences in head positioning during measurement significantly influence results. Most earlier studies performed ultrasound in the neutral position,[9-11] whereas our study, along with Martinez (2021),[12] and Fernández-Vaquero (2019),[13] utilized the sniffing position. Since the sniffing position more closely replicates the conditions during direct laryngoscopy, it may provide more clinically relevant and accurate measurements, thereby enhancing the predictive value of ultrasonographic parameters.

In terms of diagnostic performance, the sensitivity and specificity observed in our study were comparable to those reported in the literature, with some variability across studies. Wu et al. (2014) reported very high sensitivity (100%) with lower specificity, suggesting a tendency to overpredict difficult intubation.[9] In contrast, studies by Pinto et al. (2016), Parameswari et al. (2017), and Falcetta et al. (2018) demonstrated a more balanced profile.[8,10,11] In our study, the sensitivity of DSE (73.7%) was comparable to that reported by Parameswari et al,[8] (75%) and intermediate between lower values reported by Martinez et al,[12] (56.3%) and higher values observed in Wu et al. (2014)[9] and Fernández-Vaquero et al. (2019),[13] The specificity (89.5%) in our study was higher than that reported by Wu et al,[9] and Pinto et al,[10] and comparable to that of Falcetta et al,[11] and Fernández-Vaquero et al,[13] These findings indicate that DSE provides a balanced predictive performance, with relatively higher specificity, suggesting better ability to correctly identify patients without difficult intubation.

When compared with conventional bedside airway assessment methods, our results identified DSE as the most significant predictor of difficult intubation, outperforming traditional indices such as the Modified Mallampati score, ULBT, and ASA grading. This finding is particularly noteworthy given the study population, in which all patients had apparently normal preoperative airway assessments, yet approximately 10% demonstrated a Grade III or IV laryngoscopic view. The lack of statistical significance observed with the Mallampati score and ULBT is not merely methodological but highlights a critical clinical limitation—these tools are inherently less effective in identifying unanticipated difficult airways, as they often yield falsely reassuring results. In contrast, DSE provides an objective assessment of anterior neck soft tissue, capturing anatomical features that are not appreciable on routine clinical examination. These findings are consistent with prior studies demonstrating the limited sensitivity and subjectivity of conventional airway predictors. Our results therefore underscore the potential of ultrasonography to bridge this important diagnostic gap.

Thyromental distance retained its clinical relevance, with values greater than 6.5 cm being associated with easier intubation. This finding is in agreement with established literature, supporting its continued use as a simple bedside screening tool. Additionally, body mass index (BMI) emerged as a significant predictor in our study, consistent with prior reports indicating that increased soft tissue mass in obese individuals contributes to airway difficulty. Age showed only a marginal association, suggesting that while anatomical changes with aging may influence airway characteristics, its predictive value remains limited.

The overall predictive performance of our model was moderate, indicating that while ultrasonographic parameters significantly contribute to airway assessment, difficult intubation is a multifactorial phenomenon influenced by a combination of anatomical and physiological factors. However, ROC curve analysis demonstrated excellent discriminative ability when difficult intubation was defined as C–L Grade III/IV, with an area under the curve (AUC) of 0.88 (95% CI: 0.78-0.98). This finding is comparable to or better than several previously reported studies, further supporting the robustness of ultrasonographic assessment.

Taken together, our findings highlight the growing role of ultrasonography as a valuable adjunct in airway evaluation. Compared to conventional methods, it offers a more objective, reproducible, and non-invasive means of assessing airway anatomy. The identification of a reliable DSE cut-off value further enhances its clinical applicability. Incorporating ultrasound into routine preoperative airway assessment protocols may improve the prediction of difficult intubation and allow for better planning and preparedness, ultimately improving patient safety. This study is subject to certain limitations. Being a single-center observational study, the findings may have limited generalizability and do not establish causality. The predominance of patients with lower Mallampati grades, along with older and overweight individuals (ASA II), may introduce selection bias. Additionally, only selected ultrasonographic and clinical parameters were evaluated, and other potential predictors of difficult intubation may not have been considered.

CONCLUSION

In this prospective observational study of 189 ASA I and II patients undergoing elective surgery under general anesthesia, ultrasonographic airway assessment, particularly the measurement of the DSE, emerged as a reliable predictor of difficult laryngoscopy. DSE demonstrated superior predictive performance compared to conventional bedside airway assessment methods, highlighting the advantage of ultrasound as an objective, non-invasive tool for preoperative airway evaluation. The strong diagnostic performance observed in our study supports the potential integration of ultrasonography into routine clinical practice to enhance airway assessment and improve patient safety. However, variability in ultrasonographic measurements across different populations reflects the need for further

validation through large, multi-center studies with standardized protocols. Future research should focus on refining predictive models and exploring multimodal approaches to further improve airway risk stratification and perioperative management.

Conflict of interest statement: Authors declare no conflict of interest.

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