

Ultrasound-guided anterior neck soft tissue measurements in the prediction of difficult laryngoscopy: A prospective observational study

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ABSTRACT

Introduction: Difficult laryngoscopy remains a significant challenge in anesthetic practice, occurring in 1.5% to 13% of cases. Point-of-care ultrasound has emerged as a potential tool for predicting difficult laryngoscopy. This study evaluated the utility of ultrasound measurements of anterior neck soft tissue thickness in predicting difficult laryngoscopy. **Methods:** This prospective observational study included 140 adult patients (ASA I-II) undergoing elective surgery requiring general anesthesia and endotracheal intubation. Modified Mallampati Grade, thyromental distance, inter-incisor gap, neck circumference, and body mass index were recorded and ultrasound measurements of distance from skin to hyoid bone (DSHB), skin to epiglottis midway between hyoid and thyroid cartilage (DSEM), and skin to anterior commissure (DSAC) were obtained preoperatively. Laryngoscopy view was graded using the Modified Cormack-Lehane classification. Receiver operating characteristic curve analysis was performed to determine the diagnostic accuracy of each parameter. **Results:** Out of 140 patients, 33(23.6%) had difficult laryngoscopy. DSEM demonstrated superior predictive performance with an area under the curve (AUC) of 0.867, sensitivity of 90.9%, and specificity of 79.4% at a cutoff of 1.69 cm ($p<0.001$). DSHB showed an AUC of 69.8% with moderate sensitivity (51.5%) and specificity (74.8%). Among clinical parameters, neck circumference ($p=0.016$), thyromental distance ($p=0.007$), inter-incisor gap ($p=0.005$), and Modified Mallampati grading ($p=0.006$) were significantly associated with difficult laryngoscopy. **Conclusions:** Ultrasound measurement of DSEM is a reliable predictor of difficult laryngoscopy with excellent sensitivity and good specificity. The high negative predictive value (96.6%) makes DSEM particularly useful for ruling out difficult airways in routine cases.

Keywords: Airway assessment, difficult laryngoscopy, intubation, ultrasound.

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INTRODUCTION

Airway management is a fundamental skill in anesthesia. Difficult laryngoscopy still occurs in 1.5% to 13% cases despite technological advancement.¹ Airway-related complications contribute significantly to anesthesia-related morbidity and mortality.² Accurate preoperative airway assessment is essential.

Traditional tools like Modified Mallampati classification, thyromental distance, inter-incisor gap, are simple to perform. But no single test reliably predicts difficult intubation, most demonstrating sensitivity below 60%.^{3,4} Ultrasound has emerged as a promising adjunct, providing real-time, non-invasive, quantitative measurements of anterior neck soft tissue thickness.⁵⁻⁷ Increased anterior neck soft tissue thickness impede laryngoscope insertion and obstruct the view of laryngeal structures during laryngoscopy.^{8,9} Key landmarks studied include hyoid bone, pre-epiglottic space, and anterior commissure, and these influence the ease of laryngoscopy.¹⁰⁻¹²

The purpose of this study was to evaluate the utility of ultrasound measurements (distance from skin to hyoid bone, epiglottis, and

anterior commissure) in predicting difficult laryngoscopy among elective surgical patients.

METHODS

This prospective observational study was conducted over six months (July 2025 to January 2026) in the Department of Anesthesiology at Devdaha Medical College and Research Institute, Rupandehi, Nepal, following approval from the Institutional Review Committee (Ref. No. 1721/081/082). The study included patients scheduled for elective surgery under general anesthesia with endotracheal intubation; American Society of Anesthesiologists (ASA) physical status I or II; age between 18 and 65 years regardless of body mass index (BMI). Patients with history of facial, cervical, pharyngeal, or epiglottic surgery or trauma; emergency surgery; age less than 18 years or greater than 65 years; and refusal to participate were excluded from the study.

Prevalence of difficult laryngoscopy of 10% was derived from a previous study by Lin et al.¹³ The prevalence of difficult laryngoscopy ranges from 1.5 to 13% as previously stated. Based on Cochran's sample size formula using a prevalence of difficult laryngoscopy of 10%, a confidence level of 95%, and a margin of error of 5%, a minimum sample size of 138 patients was calculated. To account for potential exclusions, we enrolled 140 patients in our study.

Pre-operative assessment

All patients underwent detailed pre-operative evaluation by an anesthesiologist blinded to the study objectives on the day before surgery. Clinical parameters recorded using standardized techniques included: Modified Mallampati Grading (assessed with the patient in sitting position, mouth fully open, tongue protruded maximally without phonation, graded I-IV); thyromental distance (measured from the thyroid notch to the mentum with the neck fully extended); inter-incisor gap (maximum distance between upper and lower incisors with mouth fully open); neck circumference (measured at the level of the thyroid cartilage); and body mass index (calculated from height and weight measurements).

Ultrasound measurements were performed by the principal investigator using a Siemens ultrasound machine with a 13-6 MHz linear array probe. All measurements were obtained with the patient in the supine position and the head and neck in neutral alignment. The probe was placed transversely across the anterior surface of the neck at three specific levels: hyoid bone level (minimal distance from hyoid bone to skin surface, DSHB); thyrohyoid membrane level (distance from skin to epiglottis midway between

hyoid bone and thyroid cartilage, DSEM); and anterior commissure level (minimal distance from skin to anterior commissure, DSAC). All measurements were recorded in centimeters to two decimal places. All patients were kept Nil Per Os (NPO) for a minimum of six hours for solids and two hours for clear liquids prior to the scheduled surgery, in accordance with standard fasting guidelines. Preoperative anxiolytic premedication with tablet alprazolam 0.25 mg orally was administered the evening prior to surgery selectively to patients who were anxious or hypertensive, as deemed appropriate by the attending anesthesiologist following preoperative evaluation. Laryngoscopy and Intubation

On the day of surgery, patients were transferred to the operating room and standard monitoring was performed. After pre-oxygenation, intravenous premedication comprising midazolam (0.04 mg/kg) and fentanyl (2 µg/kg) was administered prior to induction of anesthesia. Subsequently anesthesia was induced with intravenous propofol (2 to 3 mg/kg). Muscle relaxation achieved with vecuronium (0.1 mg/kg IV) and ventilation was done with oxygen and isoflurane 1.2% for 3 minutes. Direct laryngoscopy was performed by an experienced anesthesiologist who was not involved in the preoperative assessment and was blinded to both clinical and ultrasound findings.

Laryngoscopy was performed using an appropriately sized curved Macintosh blade. Laryngeal view was graded according to the Modified Cormack-Lehane classification. (Table 1)¹⁴ Easy laryngoscopy was defined as Cormack-Lehane Grade I or IIa, while difficult laryngoscopy was defined as Grade IIb, III, or IV. Additional data collected included intubation time, number of intubation attempts, requirement for adjuncts, and intubation success or failure.

Table 1: Modified Cormack-Lehane Laryngoscopy grading system

| Grade | Laryngoscopy View | Description |
|-----------|--------------------------------|---|
| Grade I | Full view of glottis | Complete visualization of the vocal cords |
| Grade IIa | Partial view of glottis | Partial view of the glottis/vocal cords |
| Grade IIb | Arytenoids only | Only arytenoid visible |
| Grade III | Epiglottis only | Only epiglottis visible; no part of the glottis seen |
| Grade IV | Neither glottis nor epiglottis | Neither glottis nor epiglottis visible; only soft palate seen |

Statistical analysis

Data was entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 21.0. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Comparison between easy

and difficult laryngoscopy groups was performed using independent samples t-test for continuous variables and chi-square test for categorical variables. Receiver operating characteristic (ROC) curve analysis was conducted to evaluate the discriminative power of clinical and ultrasound parameters. The area under the curve (AUC) with 95% confidence intervals was calculated for each parameter. Optimal cutoff values were determined using Youden's index. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for all parameters. A p-value less than 0.05 was considered statistically significant.

RESULTS

A total of 140 patients were included in the study. The demographic distribution showed a female predominance 96(68.6%) compared to males 44(31.4%). The most common surgical indication was cholelithiasis 66(47%), followed by renal calculus 25(17.9%). Of the 140 patients, 107(76.4%) had easy laryngoscopy (Cormack-Lehane grades I-IIa), while 33(23.6%) experienced difficult laryngoscopy (Cormack-Lehane grades IIb, III, and IV). The overall intubation success rate was 100%. (Table 2)

Table 2: Classification and frequency of laryngoscopy views

| Cormack-Lehane Grade | Laryngoscopic View | Number of Patients n(%) | Difficulty Category n(%) |
|----------------------|--------------------------------|-------------------------|--------------------------|
| Grade I | Full glottis view | 62(44.28) | 107(76.42) |
| Grade IIa | Partial glottis view | 45(32.14) | Easy |
| Grade IIb | Only arytenoids visible | 25(17.85) | |
| Grade III | Only epiglottis visible | 8(5.71) | Difficult |
| Grade IV | Neither glottis nor epiglottis | 0 | |

The majority of patients 116(82.9%) were successfully intubated on the first attempt, while 22(15.7%) required a second attempt and 2(1.4%) required three attempts. Intubation aids, primarily stylets, were used in 42(30.0%) of cases. The BURP (Backward Upward Rightward Pressure) maneuver was employed in 46(32.9%) of cases. Gender distribution showed a statistically significant association with difficult laryngoscopy (p=0.016). Among female patients, 82.3% had easy laryngoscopy and 17.7% had difficult laryngoscopy, whereas among male patients, only 63.6% had easy laryngoscopy while 36.4% experienced difficult laryngoscopy. Among clinical airway assessment parameters, Modified Mallampati Grade showed a strong association with difficult laryngoscopy (p=0.006). Neck circumference was significantly larger in the difficult laryngoscopy group (38.14 ± 3.52 cm) compared to the easy group (36.47 ± 3.41 cm, p=0.016). Thyromental distance was significantly shorter in patients with difficult laryngoscopy (6.61 ± 0.85 cm) compared to those with easy laryngoscopy

(7.03 ± 0.76 cm, p=0.007). Similarly, inter-incisor gap was significantly reduced in the difficult laryngoscopy group (4.40 ± 0.79 cm) versus the easy group (4.86 ± 0.81 cm, p=0.005). Ultrasound-guided measurements demonstrated significant associations with difficult laryngoscopy. The distance from skin to hyoid bone (DSHB) was significantly greater in patients with difficult laryngoscopy (0.90 ± 0.22 cm) compared to easy laryngoscopy (0.74 ± 0.18 cm, p<0.001). The distance from skin to epiglottis at mid-thyrohyoid membrane level (DSEM) showed the most pronounced difference. Patients with difficult laryngoscopy had a mean DSEM of 1.89 ± 0.23 cm, compared to 1.55 ± 0.20 cm in the easy laryngoscopy group (p<0.001). The distance from skin to anterior commissure (DSAC) showed a trend toward greater thickness in the difficult group (0.90 ± 0.17 cm) versus the easy group (0.84 ± 0.18 cm), but this difference did not reach statistical significance (p=0.083). Intubation time was significantly prolonged in the difficult laryngoscopy group. The mean time from laryngoscope insertion to removal was 49.64 ± 20.07 seconds in the difficult group compared to 24.91 ± 9.38 seconds in the easy group (p<0.001). (Table 3)

Table 3: Comparison of parameters between easy and difficult laryngoscopy groups

| Parameter | Laryngoscopy (Mean ± SD) | | p-value | |
|------------------------------|--------------------------|------------------|-----------|---------|
| | Easy (n=107) | Difficult (n=33) | | |
| Demographic variables | | | | |
| Gender | Female | 79(82.3%) | 17(17.7%) | 0.016* |
| | Male | 28(63.6%) | 16(36.4%) | |
| Height (cm) | 160.25 ± 6.11 | 161.31 ± 8.23 | | 0.729 |
| Weight (kg) | 64.11 ± 11.98 | 68.33 ± 9.60 | | 0.14 |
| BMI (kg/m ²) | 25.01 ± 4.80 | 26.11 ± 4.73 | | 0.328 |
| MPG (Mallampati Grading) | I | 43(82.7%) | 9(17.3%) | 0.006* |
| | II | 52(82.5%) | 11(17.5%) | |
| | III | 10(45.5%) | 12(54.5%) | |
| | IV | 2(66.7%) | 1(33.3%) | |
| Clinical Parameters | | | | |
| Neck Circumference (cm) | 36.47 ± 3.41 | 38.14 ± 3.52 | | 0.016* |
| Thyromental Distance (cm) | 7.03 ± 0.76 | 6.61 ± 0.85 | | 0.007* |
| Inter-Incisor Gap (cm) | 4.86 ± 0.81 | 4.40 ± 0.79 | | 0.005* |
| Ultrasound Parameters | | | | |
| DSHB (cm) | 0.74 ± 0.18 | 0.90 ± 0.22 | | <0.001* |
| DSEM (cm) | 1.55 ± 0.20 | 1.89 ± 0.23 | | <0.001* |
| DSAC (cm) | 0.84 ± 0.18 | 0.90 ± 0.17 | | 0.083 |
| Intubation Outcome | | | | |
| Intubation Time | 24.91 ± 9.38 | 49.64 ± 20.07 | | <0.001* |
| Intubation attempts | 1 attempt | 103(96.26%) | 13(39.4%) | <0.001* |
| | 2 attempts | 4(3.74%) | 18(54.6%) | |
| | 3 attempts | 0 (0%) | 2(6%) | |

*p-value<0.05 denotes statistical significance

Among all parameters studied DSEM demonstrated the highest diagnostic accuracy. With an optimal cutoff value of 1.69 cm, DSEM achieved a sensitivity of 90.9%,

specificity of 79.4%, PPV of 57.7%, NPV of 96.6%, and AUC of 0.867(p<0.001). DSHB showed moderate diagnostic accuracy with an AUC of 0.698(p=0.001). Using a cutoff value of 0.855 cm, DSHB achieved a sensitivity of 51.5%, specificity of 74.8%, PPV of 38.6%, and NPV of 83.3%. Among clinical parameters, thyromental distance showed modest predictive ability with an AUC of 0.657(p=0.006). Modified Mallampati Grade achieved an AUC of 0.64 (p=0.016), with sensitivity of 39.4% and specificity of 88.8%. Inter-incisor gap had an AUC of 0.645 (p=0.012). DSAC showed the poorest diagnostic performance with an AUC of only 0.601 (p=0.081), which did not reach statistical significance. (Table 4, Figure 1)

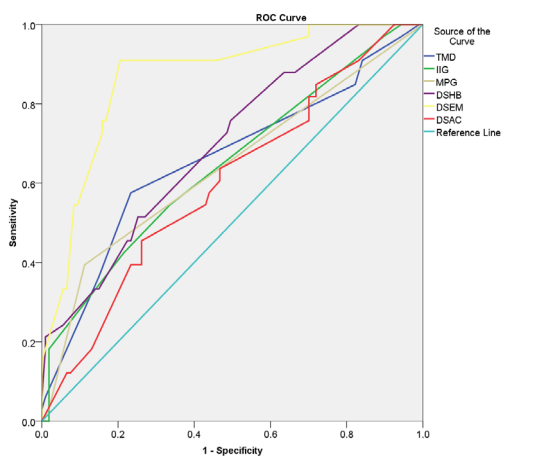


Figure 1: ROC curve for ultrasound and clinical parameters

Table 4: Diagnostic accuracy of parameters for predicting difficult laryngoscopy

| Parameters | Sensitivity | Specificity | PPV | NPV | Cut-off value | AUC | p-value |
|------------|-------------|-------------|------|------|---------------|-------|---------|
| TMD | 57.6 | 76.6 | 43.2 | 85.4 | 6.75 | 0.657 | 0.006 |
| MPG | 39.4 | 88.8 | 52.0 | 82.6 | 3.0 | 0.64 | 0.016 |
| IIG | 54.5 | 66.4 | 33.3 | 82.6 | 4.75 | 0.645 | 0.012 |
| DSHB | 51.5 | 74.8 | 38.6 | 83.3 | 0.8550 | 0.698 | 0.001 |
| DSEM | 90.9 | 79.4 | 57.7 | 96.6 | 1.69 | 0.867 | <0.001* |
| DSAC | 45.5 | 73.8 | 34.9 | 81.4 | 0.9050 | 0.601 | 0.081 |

*p-value<0.05 denotes statistical significance; Abbreviations: TMD, thyromental distance; MPG, Modified Mallampati Grade; IIG, inter-incisor gap; DSHB, distance from skin to hyoid bone; DSEM, distance from skin to epiglottis at mid-thyrohyoid membrane; DSAC, distance from skin to anterior commissure; PPV, positive predictive value; NPV, negative predictive value; AUC, area under the curve.

DISCUSSION

In our prospective observational study of 140 patients, the observed prevalence of difficult laryngoscopy was 23.6% which is higher than the prevalence quoted. This may be attributable to our use of the Modified Cormack-Lehane classification with Grade IIb included in the difficult laryngoscopy category — a broader definition than the CL Grade III-IV threshold used in many referenced studies. The study demonstrated that ultrasound measurement of

the distance from skin to epiglottis at the mid-thyrohyoid membrane level (DSEM) is a highly accurate predictor of difficult laryngoscopy, achieving an area under the curve of 0.867, sensitivity of 90.9%, and specificity of 79.4% at an optimal cutoff value of 1.69 cm. The excellent negative predictive value of 96.6% makes DSEM particularly valuable for identifying patients at low risk for difficult laryngoscopy.

Our findings align closely with various studies investigating ultrasound-based airway assessment. Carsetti et al. reported an AUC of 0.87 for DSEM in predicting difficult laryngoscopy.¹⁵ Our findings are broadly consistent with those of Koundal et al. (2019) in a similar Indian cohort, who reported a DSEM cutoff of ≥ 1.615 cm (sensitivity 89.7%, specificity 64.8%).¹⁶ The minor differences in cutoff value and specificity may be attributed to variations in the definition of difficult laryngoscopy (we included Cormack-Lehane Grade IIb as difficult, whereas Koundal et al. used Grade \geq III), as well as differences in gender distribution. Nevertheless, both studies confirm that DSEM is a highly sensitive ultrasound parameter for predicting difficult laryngoscopy in South Asian populations, outperforming traditional clinical tests. Pinto et al. evaluated 74 patients in Portugal and demonstrated that a DSEM cutoff of 2.75 cm predicted difficult laryngoscopy with a sensitivity of 64.7% and specificity of 77.1%, confirming the diagnostic value of this measurement in a European population; the higher cutoff value compared to our cohort (1.69 cm) is consistent with known ethnic variation in anterior neck soft tissue thickness between European and South Asian populations.¹⁷ Wu et al. studied on 203 Chinese population and demonstrated that DSEM achieved an AUC of 0.90 (95% CI: 0.85–0.94, p<0.0001) with a cut-off of 1.78 cm, sensitivity of 100% and specificity of 66.3%, demonstrating very high sensitivity but lower specificity in a Chinese population.⁹

The superior predictive performance of DSEM can be explained by anatomical and biomechanical principles of direct laryngoscopy.¹⁸ DSEM quantifies soft tissue depth at the pre-epiglottic space, a region occupied by adipose and loose connective tissue. Excessive tissue accumulation at this level widens the distance the laryngoscope blade must traverse to engage the epiglottis, mechanically impeding adequate glottic exposure.¹⁹

Our findings regarding traditional clinical airway assessment parameters confirm their limited individual predictive accuracy. The Modified Mallampati classification demonstrated an AUC of 64.0% with very low sensitivity (39.4%) but high specificity (88.8%), consistent with large meta-analyses.²⁰⁻²² These findings indicate that while high Mallampati grades are moderately specific for difficulty,

most difficult laryngoscopy occurs in patients with Mallampati Grades I or II.

An important finding in our study was the association between male gender and increased difficult intubation rates (36.4% vs. 17.7% in females, $p=0.016$). Males typically have larger tongue volumes, more prominent mandibles, greater neck circumferences, and different pharyngeal dimensions.²³⁻²⁴ This suggests that male patients may warrant more careful preoperative assessment.

The high diagnostic accuracy of DSEM has important clinical implications. Patients with DSEM below 1.69 cm can be identified preoperatively as very likely to have easy intubation. Patients with elevated DSEM can be flagged as high-risk, prompting enhanced preparation including ensuring availability of difficult airway equipment.¹ Due to its non-invasive approach, quick application, and high predictive accuracy, ultrasound-guided airway evaluation (especially measurement of the DSEM) should be considered for incorporation into standard preoperative assessment protocols.

This single-center study in a South Asian population may limit generalizability to other ethnic groups with different anthropometric characteristics. The study population consisted entirely of ASA I-II patients undergoing elective surgery; results may differ in higher-risk populations, emergency settings, or obstetric patients.²⁵ Principal investigator performed all measurements which may limit generalizability.

CONCLUSIONS

Ultrasound measurement of DSEM is a reliable predictor of difficult laryngoscopy with excellent sensitivity and good specificity. The high negative predictive value (96.6%) makes DSEM particularly useful for ruling out difficult airways in routine cases.

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AUTHORS' CONTRIBUTIONS

SK: Conceptualization, data collection, data analysis, manuscript writing. PA: supervision, critical revision, literature review. RS: Data collection, statistical analysis, manuscript review. SB: Data collection, manuscript review. All authors read and approved of the final manuscript.

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