

Point-of-Care Ultrasound-Based Tongue Thickness for Predicting Difficult Laryngoscopy: Comparison with the Modified Mallampati Score

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Research Article

Keywords: Difficult laryngoscopy, airway ultrasonography, tongue thickness, Modified Mallampati classification, Cormack-Lehane grade, preoperative airway evaluation

Posted Date: October 22nd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11075260/v1>

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Additional Declarations: No competing interests reported.

Abstract

Background & Aims: Difficult laryngoscopy may remain unanticipated despite routine preoperative airway assessment. The Modified Mallampati Score (MMS) is widely used but has limited sensitivity. Point-of-care ultrasound (POCUS) provides an objective assessment of airway anatomy. This study evaluated POCUS-measured tongue thickness for predicting difficult laryngoscopy and compared its diagnostic performance with MMS using Cormack–Lehane (CL) grade as the reference standard.

Patients and Methods: This prospective observational study included 150 adults with American Society of Anesthesiologists physical status I–III undergoing elective surgery under general anesthesia with tracheal intubation. Preoperative assessment included MMS and submental POCUS measurement of tongue thickness using a curvilinear probe. CL grades III–IV defined difficult laryngoscopy. Receiver operating characteristic (ROC) analysis was used to assess discrimination, and the maximum Youden index determined the optimal tongue-thickness cutoff. Sensitivity, specificity, predictive values, likelihood ratios, and diagnostic accuracy were calculated.

Results: Difficult laryngoscopy occurred in 55/150 patients (36.7%). The area under the ROC curve was 0.92 for tongue thickness and 0.79 for MMS. A tongue-thickness cutoff of 5.82 cm yielded 78.2% sensitivity, 97.9% specificity, 95.6% positive predictive value, 88.6% negative predictive value, and 90.7% accuracy. MMS demonstrated 56.4% sensitivity, 98.9% specificity, and 83.3% accuracy.

Conclusion: POCUS-measured tongue thickness showed good discrimination for difficult laryngoscopy and greater observed sensitivity than MMS while maintaining high specificity. A cutoff of 5.82 cm may complement conventional airway assessment; however, external validation is required before routine clinical use.

Introduction

A difficult laryngoscopic view that is not anticipated before induction can result in multiple intubation attempts, hypoxemia, airway trauma, or failure to establish an airway. For this reason, contemporary guidance places considerable weight on assessment and planning before anesthesia begins.^{1,2} Even so, bedside examination cannot reliably identify every patient who will prove difficult to visualize.

MMS is still one of the most commonly used bedside assessments: it is fast, costs nothing, and needs no device. Its weakness is that sensitivity is modest and the assigned class can change with posture, phonation, effort, technique, and the examiner's judgment.^{3,4} These sources of variation have prompted interest in airway measurements that depend less on patient cooperation or visual interpretation.

POCUS provides a bedside image of the upper airway without radiation exposure.^{5,6} Investigators have assessed several sonographic features, among them tongue thickness, the skin-to-epiglottis distance, hyomental distance, anterior neck soft tissue, and ratios derived from these measurements.^{7,8} Across

reviews, the overall signal is promising, but estimates differ because landmarks, scanning methods, study populations, and outcome thresholds have not been uniform.^{7,8}

The tongue is a plausible structure to examine because a larger tongue may occupy more of the oropharyngeal space available during direct laryngoscopy.⁹ Prospective studies have found greater tongue thickness in patients with poor laryngoscopic views, suggesting that it may add information to the usual clinical assessment.^{10,11}

This study primarily assessed how well POCUS-derived tongue thickness predicted difficult laryngoscopy, with CL grade as the reference, and compared its diagnostic performance with MMS. We also sought the tongue-thickness value that most effectively separated difficult and easy views within the study sample.

Subjects and Methods

Study design and participants

This prospective observational investigation ran from May 2022 to April 2023 at a tertiary teaching hospital. The Institutional Ethics Committee approved the protocol (approval number withheld for blinded review), and each participant gave written informed consent. The work followed the Declaration of Helsinki, and the report was prepared with reference to STARD 2015 and STROBE guidance.

Eligible participants were 18 to 55 years old, had an American Society of Anesthesiologists (ASA) physical status of I, II, or III, and were scheduled for elective surgery requiring general anesthesia and tracheal intubation. The approved protocol specified a target of 150 participants, based on the expected occurrence of difficult laryngoscopy and the anticipated diagnostic performance of airway ultrasound.

We did not include emergency cases or patients scheduled for maxillofacial or neck operations. Other exclusions were previous irradiation, burns, swelling, or trauma involving the head or neck; limited neck movement; trismus; and inability to communicate.

Preoperative airway assessment

An experienced anesthesiologist completed the preoperative airway examination. To assign MMS, the participant remained seated upright, opened the mouth as widely as possible, and fully protruded the tongue without speaking. The observed class (I-IV) was documented. Classes III and IV constituted a positive test; classes I and II constituted a negative test.

For the ultrasound examination, a 2–5 MHz curvilinear probe connected to a Sonosite M-Turbo system was used. The participant lay supine with the neck extended, and the probe was positioned on the submental midline to obtain a sagittal image. Only light probe pressure was used so that the soft tissues were not compressed. While the participant breathed quietly, the operator measured the greatest vertical

tongue dimension between the dorsal surface and submental skin, using the prespecified landmarks (Fig. 1). Values were entered in centimeters.

Figure 1. Point-of-care ultrasonographic measurement of tongue thickness. (A) Submental placement of a curvilinear transducer with the patient supine and neck extended. (B) Mid-sagittal ultrasound image showing the landmarks used for vertical tongue-thickness measurement.

One experienced anesthesiologist acquired every scan according to the same protocol. Consequently, this study provides no estimate of agreement between different operators.

Anesthesia and laryngoscopic assessment

Following preoxygenation, the institutional induction regimen was administered intravenously: fentanyl 2 micrograms/kg, propofol 2 mg/kg, and cisatracurium 0.15 mg/kg. Direct laryngoscopy was performed by an anesthesiologist with more than 5 years of airway-management experience.

The clinician performing laryngoscopy had no access to either the MMS class or ultrasound measurement. CL grade was assigned from the first view, before external laryngeal pressure was applied. If an optimization maneuver or airway adjunct became necessary, it was introduced only after that grade had been recorded. Grades I and II were grouped as easy laryngoscopy, whereas grades III and IV were grouped as difficult laryngoscopy.

Statistical analysis

All analyses were carried out in IBM SPSS Statistics 29.0 (IBM Corp, Armonk, NY). Continuous data with an approximately normal distribution are summarized by mean and standard deviation (SD); skewed continuous data by median and interquartile range (IQR); and categorical data by frequency and percentage. There were no missing data for variables included in the final analysis.

Differences between the easy- and difficult-laryngoscopy groups were tested with an independent-samples t test for normally distributed variables and a Mann-Whitney U test otherwise. The chi-square test was used for categorical variables. Where relevant, effect estimates are reported with 95% confidence intervals (CIs).

Discrimination for MMS and tongue thickness was examined with receiver operating characteristic (ROC) curves. We selected the tongue-thickness threshold that produced the largest Youden index. At that value, we calculated sensitivity, specificity, positive and negative predictive values (PPV and NPV), overall accuracy, and positive and negative likelihood ratios (LR + and LR-). Exact binomial 95% CIs accompany sensitivity and specificity.

Exploratory analyses considered diabetes, hypertension, and sex. Several diagnostic cells contained few observations, so sensitivity and specificity were compared separately within each subgroup pair using

two-sided Fisher exact tests. Because the subgroup work was exploratory, we did not adjust for multiple testing. A two-sided P value below 0.05 denoted statistical significance, and exact P values are shown.

Results

Among 181 people screened, 21 did not undergo ultrasound: 5 declined participation, 6 were due for maxillofacial or neck surgery, 4 had a history of head or neck radiotherapy, 3 had limited neck movement or trismus, and 3 required emergency surgery. Ultrasound images from another 10 participants were unsuitable for measurement. Thus, 150 participants remained in the analysis (Fig. 2).

Figure 2. Flow of participants from screening and exclusion through ultrasound assessment to the final analytic cohort.

There were 84 men (56.0%) and 66 women (44.0%) in the final cohort. The mean age was 41.1 ± 9.5 years, and mean tongue thickness was 5.52 ± 0.53 cm. CL grade III or IV was observed in 55 participants (36.7%), who formed the difficult-laryngoscopy group (Table 1).

Table 1
Baseline Demographic and Clinical Profile of the Participants (N = 150)

Variable	Category	n (%)
Age, y	≤ 30	24 (16.0)
	31–40	40 (26.7)
	41–50	64 (42.7)
	> 50	22 (14.7)
Sex	Male	84 (56.0)
	Female	66 (44.0)
BMI, kg/m ²	Normal	74 (49.3)
	Overweight	64 (42.7)
	Obese	12 (8.0)
ASA physical status	I	37 (24.7)
	II	68 (45.3)
	III	45 (30.0)
MMS	I	37 (24.7)
	II	81 (54.0)
	III	32 (21.3)
Diabetes mellitus	Present	78 (52.0)
	Absent	72 (48.0)
Hypertension	Present	72 (48.0)
	Absent	78 (52.0)
BMI, body mass index; ASA, American Society of Anesthesiologists; MMS, Modified Mallampati Score.		

Average tongue thickness differed by 0.71 cm between groups: 5.97 ± 0.33 cm for difficult laryngoscopy and 5.26 ± 0.44 cm for easy laryngoscopy (95% CI, 0.58–0.83; $P = 6.44 \times 10^{-21}$). MMS was likewise higher in the difficult group (median 3 [IQR 2–3] versus 2 [IQR 1–2]; $P = 3.66 \times 10^{-11}$). Hypertension occurred in 36 of 55 difficult cases (65.5%) and 36 of 95 easy cases (37.9%; $P = 0.0011$). The groups did not differ significantly in age, diabetes, or sex (Table 2).

Table 2
Comparison of Clinical Characteristics Between Easy and Difficult Laryngoscopy Groups

Variable	Easy laryngoscopy (n = 95)	Difficult laryngoscopy (n = 55)	Difference (95% CI)	P value
Age, years	41.43 ± 9.37	40.51 ± 9.86	-0.92 (- 4.17 to 2.33)	0.575
Male sex	51/95 (53.7)	33/55 (60.0)	6.3% (- 10.1 to 22.7)	0.453
Diabetes mellitus	50/95 (52.6)	28/55 (50.9)	-1.7% (- 18.3 to 14.9)	0.839
Hypertension	36/95 (37.9)	36/55 (65.5)	27.6% (11.7 to 43.5)	0.001
MMS	2 (1-2)	3 (2-3)	—	< 0.001
Tongue thickness, cm	5.26 ± 0.44	5.97 ± 0.33	0.71 (0.58 to 0.83)	< 0.001
Data are presented as mean ± SD, median (IQR), or n/N (%), as appropriate. Differences were calculated as difficult minus easy and are expressed as mean differences for continuous variables and absolute percentage-point differences for categorical variables. CL grades I–II were classified as easy laryngoscopy and grades III–IV as difficult laryngoscopy. Continuous variables were compared using the independent-samples <i>t</i> test or Mann–Whitney U test, as appropriate; categorical variables were compared using the chi-square test. CI, confidence interval; CL, Cormack–Lehane; IQR, interquartile range; MMS, Modified Mallampati Score; SD, standard deviation.				

Using MMS III-IV as the positive category gave a sensitivity of 56.4% (95% CI, 42.3%-69.7%) and a specificity of 98.9% (95% CI, 94.3%-100.0%). The corresponding PPV, NPV, and accuracy were 96.9%, 79.7%, and 83.3%; LR + was 53.55 and LR- was 0.44.

ROC analysis selected a tongue-thickness threshold of at least 5.82 cm. This point yielded 78.2% sensitivity (95% CI, 65.0%-88.2%) and 97.9% specificity (95% CI, 92.6%-99.7%). PPV was 95.6%, NPV was 88.6%, and accuracy was 90.7%, with an LR + of 37.14 and an LR- of 0.22 (Table 3).

Table 3
Performance of MMS and Tongue Thickness for Detecting Difficult Laryngoscopy

Assessment method	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, %	NPV, %	Accuracy, %	LR+	LR-
MMS classes III-IV	56.4 (42.3–69.7)	98.9 (94.3–100.0)	96.9	79.7	83.3	53.55	0.44
POCUS tongue thickness $\geq$ 5.82 cm	78.2 (65.0–88.2)	97.9 (92.6–99.7)	95.6	88.6	90.7	37.14	0.22
Difficult laryngoscopy corresponds to CL grade III or IV. The cutoff for tongue thickness is the value with the maximum Youden index. Exact binomial 95% CIs are provided for sensitivity and specificity. MMS, Modified Mallampati Score; POCUS, point-of-care ultrasound; PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR-, negative likelihood ratio.							

The AUC estimates were 0.92 for tongue thickness and 0.79 for MMS. The maximum Youden index occurred at 5.82 cm, where sensitivity and specificity were 78.2% and 97.9%, respectively (Fig. 3). We did not conduct a formal paired test of the two AUCs.

Figure 3. Receiver operating characteristic curves for tongue thickness and MMS. AUCs were 0.92 and 0.79, respectively. The optimal tongue-thickness cutoff was 5.82 cm, corresponding to 78.2% sensitivity and 97.9% specificity

In the exploratory subgroup analysis, sensitivity for tongue thickness was 82.1% in participants with diabetes and 74.1% in those without it ($P = 0.528$). The corresponding values were 80.6% versus 73.7% for hypertension ($P = 0.733$) and 84.8% versus 68.2% for men and women ($P = 0.188$). Specificity lay between 95.6% and 100%, and none of the subgroup contrasts was statistically significant (Table 4).

Table 4
Exploratory Performance of POCUS Tongue Thickness Within Participant Subgroups

Subgroup	n	Sensitivity, % (95% CI)	P value*	Specificity, % (95% CI)	P value†
Diabetes mellitus	78	82.1 (63.1–93.9)	0.528	100.0 (92.9–100.0)	0.222
No diabetes mellitus	72	74.1 (53.7–88.9)	—	95.6 (84.9–99.5)	—
Hypertension	72	80.6 (64.0–91.8)	0.733	97.2 (85.5–99.9)	1.000
No hypertension	78	73.7 (48.8–90.9)	—	98.3 (90.9–100.0)	—
Male	84	84.8 (68.1–94.9)	0.188	98.0 (89.6–100.0)	1.000
Female	66	68.2 (45.1–86.1)	—	97.7 (88.0–99.9)	—
Calculations use a tongue-thickness threshold of at least 5.82 cm and define difficult laryngoscopy as CL grade III or IV. Sensitivity and specificity include exact binomial 95% CIs. *P values test sensitivity within each paired subgroup; †P values test specificity. Comparisons used two-sided Fisher exact tests. These analyses were exploratory and were not adjusted for multiple testing. POCUS, point-of-care ultrasound; CL, Cormack-Lehane.					

Discussion

In this study, tongue thickness measured by POCUS separated difficult from easy laryngoscopy with an AUC of 0.92. At the selected 5.82-cm point, sensitivity was 78.2%, specificity was 97.9%, and overall accuracy was 90.7%. MMS preserved very high specificity but missed more difficult views. These findings place tongue thickness as an additional anatomical measurement for airway assessment, not as a replacement for the clinical examination.

The 56.4% sensitivity of MMS in our sample reflects a familiar limitation of single bedside tests. In an earlier meta-analysis, individual clinical predictors were generally not sensitive enough to rule out difficulty on their own.³ A more recent synthesis in adults without obvious airway abnormalities also found substantial variation among standard prediction methods.⁴ Here, MMS III or IV was strongly associated with a difficult view, but an MMS I or II did not offer the same reassurance.

Ultrasound approaches the question from anatomy rather than external examination, allowing upper-airway structures to be seen at the bedside.^{5,6} Reported measurements include tongue thickness, skin-to-epiglottis distance, hyomental distance, and anterior neck soft-tissue thickness.^[7] Comparisons across studies remain difficult, however, because positioning, probe location, landmarks, acquisition methods, and even the definition of a difficult view vary.^{7,8}

A recent synthesis of upper-airway POCUS provides useful context for our threshold. It brought together 60 studies and more than 10,000 patients across a wide set of ultrasound variables. Among studies of tongue thickness, difficult laryngoscopy was associated with an average increase of about 0.57 cm, and most reported thresholds were between 5.9 and 6.1 cm.⁸ Our value of 5.82 cm is near, but not identical

to, that range. Because relatively few datasets address tongue thickness, a cutoff developed in one cohort should not be assumed to transfer unchanged to another.

Prospective tongue-thickness studies agree on the direction of the association, although their diagnostic estimates are not the same. One elective-surgery study found a higher sensitivity but a lower specificity than we observed.¹⁰ In our data, sensitivity was 78.2% and specificity was 97.9%. Differences in case selection, sample size, patient positioning, probe pressure, measurement points, laryngoscopic grading, and the method used to choose a cutoff could account for part of this spread. Still, thicker tongues have repeatedly been associated with less favorable glottic views.

Another prospective investigation assessed tongue thickness alongside the tongue-thickness-to-thyromental-distance ratio and skin-to-epiglottis distance.¹¹ Its findings suggest that tongue thickness carries information, but that information may be more useful when combined with other airway measurements. Our results point in the same direction: an AUC of 0.92 shows strong discrimination, yet 78.2% sensitivity would leave roughly one difficult laryngoscopy in five undetected if tongue thickness were used by itself.

Studies from India using different sonographic landmarks have reached a related conclusion. Measurements of anterior neck soft tissue have yielded AUCs near 0.9, while some conventional bedside assessments performed less well.¹² Our AUCs were 0.92 for tongue thickness and 0.79 for MMS. The comparison is consistent with a role for direct imaging in preoperative risk estimation, but it does not prove that one test is statistically superior to the other.

In a Central Indian prospective cohort, maximum tongue thickness and several other ultrasound airway variables were associated with difficult laryngoscopy.¹³ The threshold for maximum tongue thickness in that work was below ours. Earlier Indian research also reported an association between sonographic airway dimensions and laryngoscopic grade.¹⁴ The lack of a common cutoff is clinically important. Population characteristics and body habitus may shift the measurement, as may neck position, transducer angle and pressure, the chosen landmarks, and the operator's experience.

Research is therefore moving beyond a single dimension toward ratios and multivariable tools. Tongue height relative to oral-cavity height has been studied together with anterior neck soft tissue in patients who were not expected to have a difficult airway.¹⁵ Other investigators have compared several ultrasound measures with established clinical predictors.¹⁶ Combined clinical-ultrasound scores and ultrasound-based nomograms have also been described.^{17,18} Such approaches may better reflect the many anatomical and clinical factors that contribute to a poor laryngoscopic view.

The likelihood ratios clarify how tongue thickness might be used. At 5.82 cm, the combination of 97.9% specificity, 95.6% PPV, and an LR + of 37.14 substantially raised the probability of a difficult view in this cohort. The LR- was 0.22, compared with 0.44 for MMS. Although the lower value is helpful, it does not

safely rule out difficulty. Tongue thickness therefore appears better suited to refining risk after routine assessment than to serving as the only screening test.

The 36.7% frequency of difficult laryngoscopy was higher than is commonly expected in elective practice. Published frequencies depend on the patients selected, the definition applied, the laryngoscopy technique, and operator experience.^{3,19} This matters because prevalence directly affects PPV and NPV. In settings with fewer difficult views, the PPV found in our study could be appreciably lower.

Diabetes, hypertension, and sex did not significantly modify sensitivity or specificity in the exploratory analyses. The male-female sensitivity estimates were visibly different, but the intervals were broad and the statistical comparison was negative. With the available subgroup sizes, these results are best viewed as signals for future study; they do not demonstrate equal performance across the groups.

Although tongue thickness produced the larger AUC, the two ROC curves arose from the same participants and were not formally compared as paired curves. Accordingly, the data show a higher observed discrimination for tongue thickness, not confirmed head-to-head superiority over MMS. That cautious interpretation also matches the study's purpose, which was to characterize diagnostic performance rather than test a prespecified superiority hypothesis.

POCUS can be repeated at the bedside, does not expose the patient to radiation, and is noninvasive. These practical advantages do not remove the need for operator training or a tightly reproducible scanning method. Recent commentary has made a similar point: airway POCUS is promising, but its place in universal screening remains uncertain until validation is broader.²⁰

Several aspects strengthen this study. Data were collected prospectively, the scan followed a prespecified technique, and the laryngoscopist remained unaware of both MMS and ultrasound findings. We reported several complementary measures of diagnostic performance rather than relying on one summary value. The cohort also contributes evidence from elective surgical practice in India, a setting in which locally validated sonographic thresholds are still scarce.

The results should nevertheless be read in light of important constraints. This was a modest, single-center cohort, limiting the extent to which the findings can be generalized. The same participants were used both to derive and to assess the 5.82-cm threshold, so its apparent performance may be optimistic. Because one experienced operator performed every scan, between-operator reproducibility could not be studied. We excluded emergency surgery and several established airway abnormalities. CL grade itself depends on the laryngoscopist and describes the view obtained, not every aspect of difficult airway management. Finally, the subgroup comparisons were exploratory and too small to establish effect modification.

The next step is prospective testing of the 5.82-cm cutoff in larger, independent multicenter cohorts. Those studies should measure both repeatability within an operator and agreement between operators. They should also determine whether body habitus, sex, ethnicity, diabetes, or craniofacial anatomy shifts

the useful threshold. Prediction models combining tongue thickness with other ultrasound features and routine clinical findings will require internal validation followed by evaluation in external populations.

Conclusion

In adults undergoing elective surgery, sonographic tongue thickness showed good discrimination for difficult laryngoscopy and greater observed sensitivity than MMS while maintaining high specificity. A value of 5.82 cm could support conventional airway assessment, but sensitivity was inadequate for the measurement to be used alone. Independent validation and evidence of measurement reproducibility are needed before this cutoff can be adopted routinely.

Abbreviations

ASA - American Society of Anesthesiologists

AUC - area under the receiver operating characteristic curve

BMI - body mass index

CI - confidence interval

CL - Cormack-Lehane

IQR - interquartile range

LR+ - positive likelihood ratio

LR- - negative likelihood ratio

MMS - Modified Mallampati Score

NPV - negative predictive value

POCUS - point-of-care ultrasound

PPV - positive predictive value

ROC - receiver operating characteristic

SD - standard deviation

TT - tongue thickness

Declarations

Presentation at a Scientific Meeting

This study was presented as a scientific poster during the Decennial Celebration of the MAHE–FAIMER International Institute for Leadership in Interprofessional Education, held on 24 October 2024 at Manipal Academy of Higher Education, Manipal, India.

Ethical Approval

The study was approved by the Lakeshore Ethics Committee . Lakeshore Hospital & Research Centre Ltd. Approval Number: LHRC/EC-2022-1/06, Date of approval: 19 April 2022. Additional Reference: LHRC/LARC/04/06/22

Clinical trial number: Not applicable. This was a prospective observational diagnostic-accuracy study with no assignment of participants to an intervention.

Source of Funding

The authors declare that no external funding was received for this study.

Conflict of Interest

The authors declare no conflicts of interest relevant to this manuscript.

Data Availability Statement

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Declaration of Generative AI and AI-Assisted Technologies

The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used in the writing, analysis, interpretation, or preparation of this manuscript. All scientific content was conceived, developed, analysed, and reviewed entirely by the authors, who accept full responsibility for the integrity and accuracy of the work.

CRediT Authorship Contribution Statement

Dr. Jawabulla Vazhayil:

Conceptualization, Methodology, Investigation, Data Collection, Data Curation, Statistical Analysis, Data Interpretation, Resources, Project Administration, Supervision, Writing – Review & Editing.

Dr. Aysha Linsy:

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Methodology, Formal Analysis, Validation, Data Curation, Statistical Analysis, Data Interpretation, Writing – Original Draft, Writing – Review & Editing, Visualization.

Dr. Sanjan Asanaru Kunju:

Conceptualization, Methodology, Formal Analysis, Data Curation, Statistical Analysis, Visualization, Writing – Original Draft, Writing – Review & Editing

Dr. Renny Chacko:

Conceptualization, Supervision, Methodology, Validation, Resources

Acknowledgements

The authors thank the Department of Anesthesiology, Lakeshore Hospital, Kochi for facilitating the conduct of this study. The authors also acknowledge all patients who voluntarily participated in this research.

Consent to Participate

Written informed consent was obtained from all participants prior to enrolment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, and participant confidentiality was maintained throughout the study.

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Figures

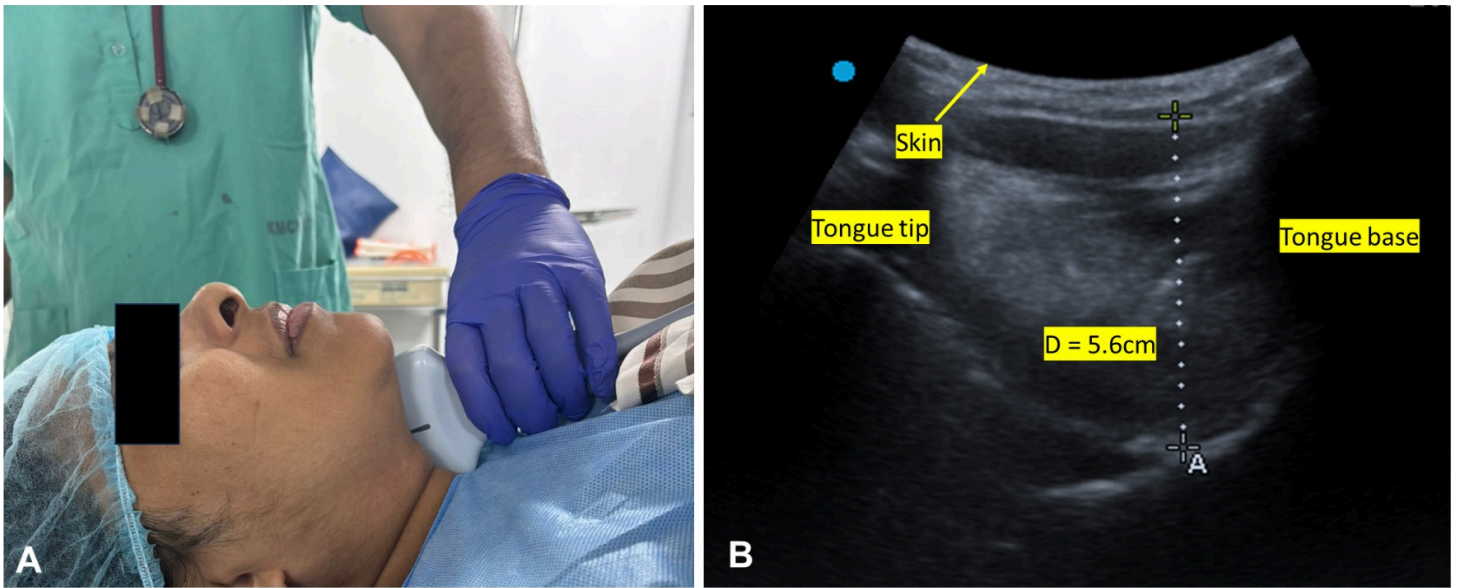


Figure 1

Point-of-care ultrasonographic measurement of tongue thickness. (A) Submental placement of a curvilinear transducer with the patient supine and neck extended. (B) Mid-sagittal ultrasound image showing the landmarks used for vertical tongue-thickness measurement.

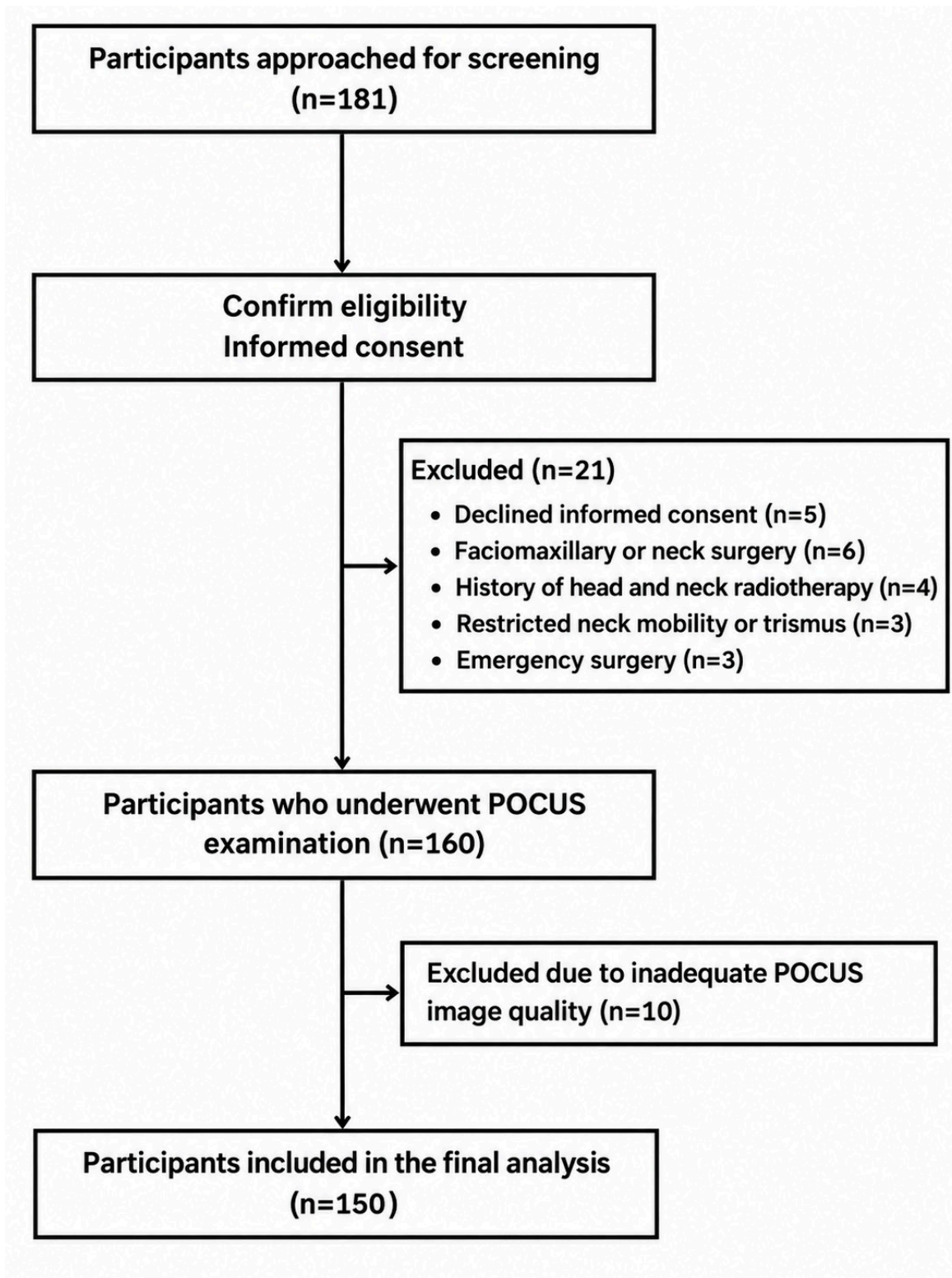


Figure 2

Flow of participants from screening and exclusion through ultrasound assessment to the final analytic cohort.

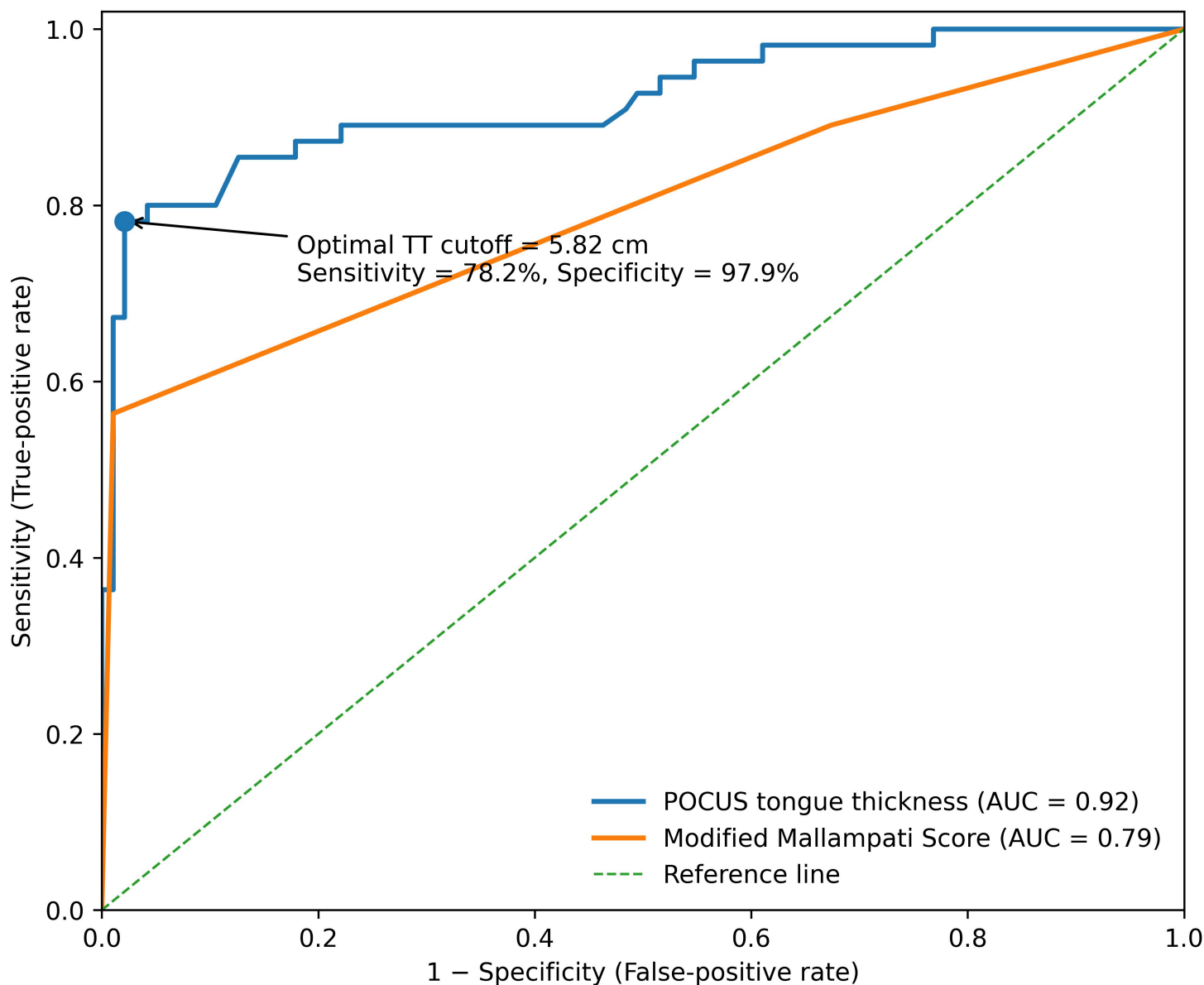


Figure 3

Receiver operating characteristic curves for tongue thickness and MMS. AUCs were 0.92 and 0.79, respectively. The optimal tongue-thickness cutoff was 5.82 cm, corresponding to 78.2% sensitivity and 97.9% specificity