DOI: 10.62838/jccm-2026-0054

Ultrasound-measured tongue thickness: a marker of difficult mask ventilation, prospective observational study

Seetepalli Venkata Naga Sai Krishna, Rama Rani Krishna Bhat*, Sushma Thimmaiah Kanakalakshmi, Laxmi Shenoy, Malavika Kulkarni, Aparna Satish

Department of Anaesthesiology, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India

Abstract

Background: Unanticipated difficult airways pose major issues for anesthesiologists every time they encounter them. Mask ventilation is a basic skill that can help in any emergency scenario. Our primary goal was to verify the role of upper airway ultrasound, mainly tongue thickness, as a parameter for predicting difficult mask ventilation.

Methods: We conducted a prospective observational study involving 125 patients scheduled for elective surgical procedures requiring general anesthesia and endotracheal intubation. Preoperative clinical assessment and ultrasound assessment of tongue thickness in the submental mid-sagittal plane were performed to predict a difficult airway. We compared the parameters associated with difficulties encountered during airway management, including mask ventilation and intubation.

Results: The thickness of the base of the tongue was greater than 4.06 cm, confirming difficulty in mask ventilation, and the thickness of the body of the tongue was greater than 5.36 cm, confirming difficulty in intubation. Ultrasound plays a major supporting role in assessing difficulties.

Conclusions: Preoperative ultrasound airway assessment provides valuable insights into airway management. This can be incorporated into routine clinical practice alongside standard clinical assessment to minimize adverse events associated with airway management.

Keywords: Airway management, ultrasonography, mask ventilation, tongue thickness

Received: 26 may 2026 / Accepted: 24 september 2026

Published under CC BY 4.0 license

Introduction

Airway management is a crucial step in the safe practice of anesthesia. Airway, if not effectively managed, may lead to a spectrum of adverse outcomes ranging from hypoxemia to severe neurological sequelae and even death[1]. The estimated incidence of significant complications during anesthesia linked to airway management is approximately 46 events per million anesthetics administered, with a fatality rate of 5.6 per million[1]. Such statistics underscore the need for robust, proactive strategies to identify and manage patients at risk of encountering difficult airway scenarios. A difficult airway is a clinical situation in which difficulty or failure, including face mask ventilation, laryngoscopy, supraglottic airway ventilation, tracheal intubation, or extubation, is experienced by a physician trained in anesthesia care. Difficult mask ventilation (DMV) is characterized by the inability to provide adequate ventilation because of one or more of the following problems: inadequate mask seal, excessive gas leakage, and excessive resistance to the ingress or egress of gas by a trained anesthesia provider[2]. Difficult tracheal intubation (DI) is defined as the requirement for multiple laryngoscopy attempts or alternative techniques to achieve successful endotracheal intubation[2]. A comprehensive approach to avoid this situation is to assess the airway preoperatively. Many traditional clinical assessments for predicting difficult airways, including the Mallampati score, thyromental distance, inter-incisor gap, and neck mobility, are used [3]. However, these traditional clinical methods frequently demonstrate significant limitations in accurately predicting difficult airways [4,5]. This evidence indicates the need for more dependable and objective assessment techniques. Consequently, ultrasound assessment is emerging as a reliable, noninvasive, and objective methodology in clinical settings. Although numerous studies have examined the utility of ultrasound in airway assessment, significant gaps in our current understanding remain [3,6,7].Many studies are limited by small sample sizes, which restricts how their findings can be generalized to broader populations[8,9]. Some studies have focused primarily on anterior neck soft tissues, whereas the

* Correspondence to: Dr. Rama Rani Krishna Bhat, Department of Anaesthesiology, Kasturba Medical College, Manipal Academy of Higher Education, Manipal, India, E-mail: rama.rani@manipal.edu

available literature on the thickness of the tongue and its role in predicting airway difficulties remains sparse [10,11]. Most existing research has focused primarily on difficult intubations [12] and has given less attention to difficult mask ventilation [13,14]. Our study aims to address these gaps and define tongue thickness as a difficult airway parameter in routine standard-of-care practice to improve diagnostic accuracy.

Methods

This single-center, prospective, observational study was conducted at a tertiary care teaching hospital, over six months from August 2024 to February 2025. One hundred twenty-five adult patients who underwent elective surgical procedures under general anesthesia were enrolled. The study was conducted after approval was obtained from the Institutional Ethics Committee (IEC). Ethical committee approval number: IEC2:491/2023. Clinical trials registry India a number: CTRI/2024/02/063217. Patients aged more than 18 years with an American Society of Anesthesiologists physical status ≤3 who underwent elective surgery under general anesthesia and whose primary mode of tracheal intubation was direct laryngoscopy were included. Patients who were at risk of aspiration and required rapid sequence induction and who had upper airway deformities, trauma, or tumors were excluded. All patients recruited for the study were informed about inclusion, and written consent was obtained before the procedure.

A standard preanesthetic check-up was performed a day before the surgery, including clinical parameters for predicting the DMV and DI. These parameters include the inter-incisor distance, modified Mallampati test, thyro-mental distance, mandibular protrusion, presence of a beard, abnormal dentition, history of neck irradiation, and snoring. Before induction in the preoperative area, an ultrasound assessment was performed via ultrasound (Sonosite™) with a low-frequency (2–5 MHz) curvilinear probe. The patient was kept in the supine position with the neck stretched. To obtain uniform tongue status, the patient was asked to keep their mouth closed and touch the tongue tip gently to the incisors without phonation. The probe was placed under the chin in the mid-sagittal plane and adjusted to obtain a full outline of the tongue and soft tissues clearly on the screen (Figure 1a), and tongue thickness (TT) was measured at four points. These points were designated Points A, B, C, and D (Figure 1b).

Point A: Midway between the mentum and hyoid, a vertical measurement from the skin to the hard palate was taken (body of the tongue).

Point B: Midway between the mentum and hyoid, a vertical measurement from the skin to the tongue soft tissue demarcation was taken (body of the tongue).

Point C: Just above the hyoid region, a vertical measurement from the skin to the hard palate was taken (at the base of the tongue).

Point D: Just above the hyoid region, a vertical measurement from the skin to the tongue soft tissue demarcation was measured (base of the tongue).

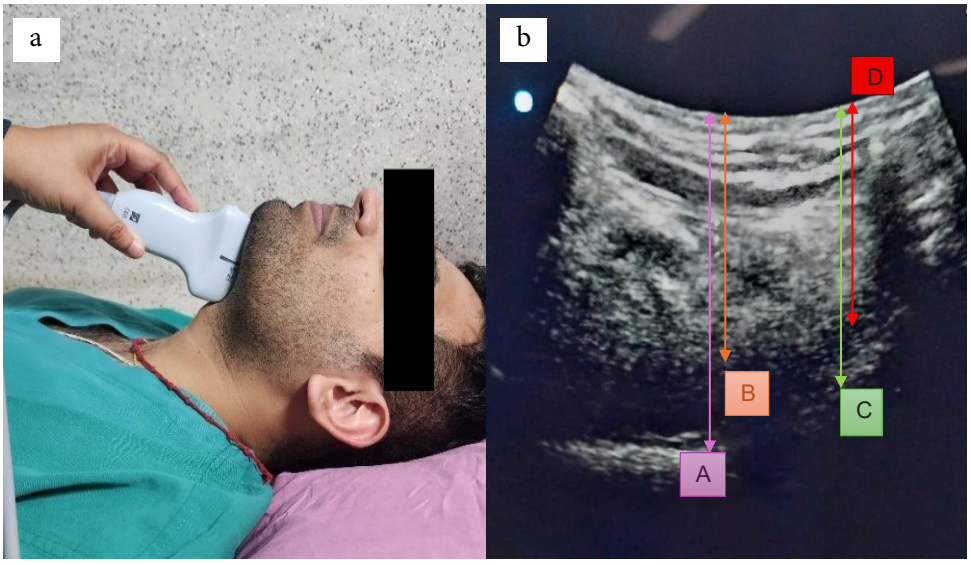


Figure 1: a) orientation of curvilinear probe in submental mid-sagittal region for assessing tongue thickness b) the sonoanatomy of the tongue in the mid-sagittal plane with various measured points depicted.

The relative difference between the points measured at the body and base of the tongue, i.e., A-B and C-D, reflecting the air–soft tissue interface, is considered the palatoglossal space.

The ultrasound assessment was performed by a single anesthesiologist with 5 years of experience in POCUS to avoid interobserver bias. Three values for each of the measurements were noted, and the average value was taken.

The consultant anesthesiologist performed bag-mask ventilation and intubation, and difficulty was graded. The patient was shifted to the operating theatre, standard ASA monitors were attached, and baseline vital signs were recorded. Preoxygenation with 100% oxygen was performed on the patient for at least 3 minutes. General anesthesia was induced via the standard institutional protocol, and the patients were relaxed with an appropriate dose of muscle relaxant. At the proper depth of anesthesia and after adequate muscle relaxation, mask ventilation and intubation were performed.

Mask ventilation was graded via the Warters grading scale for mask ventilation [15]. This grading system is based on achieving a target tidal volume of 5 ml/kg. If the target tidal volume of 5 ml/kg is not achieved and the provider cannot generate a peak inspiratory pressure of > 30 cm H_2O, additional points are assigned. As the score increases, the difficulty increases. For clinical correlation, difficulty is categorized into scores <3 (easy mask ventilation) and scores ≥3 (difficult mask ventilation).

Difficulty in intubation was determined by the intubation difficulty scale (IDS)[16]. The IDS is based on seven parameters, including the number of attempts, operators, alternative techniques, glottic exposure, laryngeal pressure, and vocal cord position. Each parameter is scored, and the total IDS score is calculated, ranging from 0 (ideal intubation) to values indicative of increasing difficulty. A score of infinity is assigned to impossible intubations. The IDS provides an objective measurement of intubation difficulty. A score of more than 0 was considered to indicate any difficulty in intubation in this study.

Statistical analysis:

On the basis of reports in the literature[14], the sensitivity of ultrasound for the prediction of difficult airways is approximately 85%. Assuming an expected sensitivity (S) of 0.85, a prevalence of difficult airway of 10% in our study population, a confidence interval width of 20%, and a two-sided type I error (α) of 5% (Z = 1.96), the sample size was calculated using the formula for estimating the sensitivity of a diagnostic test:

where S is the anticipated sensitivity, P is the prevalence of the target condition, and W is the desired confidence interval width.

Substituting the values:

Accordingly, the minimum required sample size was 123 participants. To account for rounding and to ensure adequate statistical precision, a total sample size of 125 patients was included in the study. The statistical package for social sciences (SPSS) for Windows v23 (IBM Corp, New York, USA) was used for statistical

$$n = \frac{Z_{1-\alpha/2}^2 \times S(1-S)}{P \times W^2}$$

analysis. A p-value < 0.05 was considered statistically significant. Receiver operating characteristic (ROC) curve analysis was used to assess the diagnostic accuracy of the ultrasound parameters. The area under the curve (AUC), optimal cutoff value, sensitivity, specific-

$$n = \frac{(1.96)^2 \times 0.85 \times (1-0.85)}{0.10 \times (0.20)^2} = 122.5$$

ity, positive predictive value, negative predictive value, and accuracy were calculated.

Results:

One hundred twenty-five patients from the South Indian population were enrolled and analyzed in our study. The demographic distribution was representative of the regional patient population encountered in our clinical setting. All recruited patients were analyzed, and no dropouts were found.

The demographic data, clinical assessment details, and ultrasound measurements obtained throughout the study are summarized in Table 1.

Difficulty in mask ventilation was encountered in 36 (28.8%) patients. Overall, throughout the study, 50 (40%) patients were found to have some degree of difficulty with intubation.

To compare the diagnostic accuracy of various clinical and ultrasound parameters in predicting difficult mask ventilation, i.e., Warters score of mask ventilation<3 and score ≥3, a receiver operating characteristic (ROC) curve was plotted, and analysis was performed

Table 1: Demographic and airway assessment parameters of the study population

Parameter	Mean ± SD/N (%)
Age (Years)	47.65 ± 14.58
Gender	
Male	63 (50.4%)
Female	62 (49.6%)
BMI (kg/m²)	24.35 ± 4.48
ASA-PS	
I	72 (57.6%)
II	44 (35.2%)
III	9 (7.2%)
Mallampati Score	
Class 1	29 (23.2%)
Class 2	58 (46.4%)
Class 3	36 (28.8%)
Class 4	2 (1.6%)
Mandibular Protrusion	
Present	122 (97.6%)
Limited	3 (2.4%)
Beard (Present)	7 (5.6%)
Dentition	
Normal	99 (79.2%)
Absent/Missed/Broken Tooth	22 (17.6%)
Edentulous	4 (3.2%)
History of Snoring (Present)	49 (39.2%)
Neck Irradiation History (Yes)	1 (0.8%)
Clinical measurements	
Thyromental distance (cm)	6.66 ± 0.94
Inter Incisor Distance (cm)	5.37 ± 0.64
Neck Circumference (cm)	36.10 ± 2.59
Warters scoring of Mask Ventilation	
Score-1	75 (60.0%)
Score-2	14 (11.2%)
Score-3	21 (16.8%)
Score-4	13 (10.4%)
Score-5	2 (1.6%)
Warters Score-Category of Mask Ventilation	
<3 (Easy mask ventilation)	89 (71.2%)
≥3(Difficult mask ventilation)	36 (28.8%)
IDS Degree of Difficulty	
Easy	75 (60.0%)
Slight Difficulty	44 (35.2%)
Major Difficulty	6 (4.8%)
IDS- Any Difficulty (Yes)	50 (40.0%)
Ultrasound tongue thickness at points	
Point A (cm)	5.42 ± 0.58
Point B (cm)	4.60 ± 0.57
Point C (cm)	4.37 ± 0.66
Point D (cm)	3.69 ± 0.66

BMI- Body mass index, kg/m2- kilogram per meter square, ASA-PS- American Society of Anesthesiologists physical status, cm- centimeter, IDS- Intubation difficulty scale

Table 2: Comparison of the diagnostic performance of various predictors in predicting the ease of face mask ventilation (Warters score of mask ventilation<3 and score ≥3)

Predictor	Cutoff	AUROC (95%CI)	p-value	Sn (%)	Sp (%)	PPV (%)	NPV (%)	Accuracy (%)
BMI (kg/m²)	27.131	0.562 (0.444-0.68)	0.279	33	82	43	75	68
Thyromental distance (cm)	5	0.596 (0.483-0.709)	0.076	17	97	66.7	74.1	73.6
Inter Incisor Distance (cm)	5	0.601 (0.488-0.713)	0.057	69	53	37.3	81.0	57.6
Neck Circumference (cm)	38	0.651 (0.540-0.761)	0.008	47	80	48.6	78.9	70.4
Point A (cm)	5.59	0.641 (0.530-0.752)	0.014	67	61	40.7	81.8	62.4
Point B (cm)	5.02	0.586 (0.473-0.699)	0.134	36	83	46.4	76.3	69.6
Point C (cm)	4.61	0.652 (0.540-0.761)	0.008	58	72	45.7	81.0	68
Point D (cm)	4.06	0.664 (0.55-0.77)	0.004	42	85	53.6	78.4	72.8

*AUROC: Area under the ROC curve; CI: Confidence interval; Sn: Sensitivity; Sp: Specificity; PPV: positive predictive value; NPV: negative predictive value

for each variable.

For each parameter, sensitivity (true positive rate) was plotted against 1-specificity (false positive rate) across a range of cutoff values. The area under the ROC curve (AUROC) was calculated to quantify the overall diagnostic performance, with an AUROC closer to 1.0 indicating better discriminative ability. The Youden Index (J = sensitivity + specificity – 1) was used to determine the optimal cutoff values, identifying the threshold with the maximum combined sensitivity and specificity. These cutoffs were then used to calculate each parameter's diagnostic indices—sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy.

Among the clinical parameters, neck circumference (cutoff: 38 cm) had the highest diagnostic performance, with an AUROC of 0.651, sensitivity of 47%, and specificity of 80%. The inter-incisor distance and thyromental distance had lower AUROC values (0.601 and 0.596, respectively), suggesting limited utility in isolation for predicting difficult mask ventilation.

Ultrasound-derived tongue thickness measurements showed better overall discriminative ability. Point D (cutoff: 4.06 cm) had the highest AUROC of 0.664, with a specificity of 85%, indicating a strong negative predictive value. Point A (cutoff: 5.59 cm) demonstrated the highest sensitivity (67%) among the sonographic measurements, with an AUROC of 0.641. These findings suggest that ultrasonographic tongue thickness, especially at points A and D, has greater predictive utility than traditional clinical airway parameters in identifying patients at risk for difficult mask ventilation.

Similarly, to compare the diagnostic accuracy of various clinical and ultrasound parameters, receiver operating characteristic (ROC) curves were plotted to predict any difficulty in intubation, i.e., an intubation difficulty score of more than 0. Analysis was performed for each variable, and the AUROC was calculated.

Among the clinical predictors, inter-incisor distance and neck circumference had AUROCs of 0.600 and 0.602, respectively, with modest discriminative ability ($p = 0.042$ and 0.052). Thyromental distance showed limited utility, with an AUROC of 0.545 and low specificity (27%), despite high sensitivity (86%).

Ultrasound parameters, particularly tongue thickness at Point A, demonstrated the highest diagnostic performance, with an AUROC of 0.693 ($p < 0.001$) and a sensitivity and specificity of 82% and 56%, respectively.

Multivariate logistic regression analysis was performed for both mask ventilation and intubation to assess the contribution of tongue thickness to each outcome (Point D for difficult mask ventilation; Point A for difficult intubation) after adjustment for BMI, neck circumference, thyromental distance, and inter-incisor distance. Adjusted odds ratios and Wald 95% confidence intervals are reported per original measurement unit.

Tongue thickness remained an independent predic-

Table 3: Comparison of the diagnostic performance of various predictors of difficulty with respect to intubation- Any difficulty: Yes vs no

Predictor	Cutoff	AUROC (95%CI)	p- value	Sn (%)	Sp (%)	PPV (%)	NPV (%)	Accuracy (%)
BMI (kg/m²)	27.131	0.583 (0.477-0.688)	0.119	36	87	64	67	66
Thyromental distance (cm)	7	0.545 (0.441-0.649)	0.369	86	27	43.9	74.1	50.4
Inter Incisor Distance (cm)	5.5	0.600 (0.497-0.702)	0.042	68	51	47.9	70.4	57.6
Neck Circumference (cm)	35	0.602 (0.500-0.705)	0.052	86	31	45.3	76.7	52.8
Point A (cm)	5.36	0.693 (0.597-0.790)	<0.001	82	56	55.4	82.4	66.4
Point B (cm)	4.67	0.671 (0.573-0.770)	0.001	62	69	57.4	73.2	66.4
Point C (cm)	4.31	0.586 (0.483-0.689)	0.105	64	56	49.2	70.0	59.2
Point D (cm)	3.74	0.565 (0.461-0.668)	0.223	58	59	48.3	67.7	58.4

*AUROC: area under the ROC curve; CI: confidence interval; Sn: sensitivity; Sp: specificity; PPV: positive predictive value; NPV: negative predictive value

Table 4: Multivariable logistic regression for difficult mask ventilation

Variable	Adjusted OR	95% CI	p- value
Tongue thickness – Point D (cm)	3.229	1.469 – 7.097	0.004
Neck circumference (cm)	1.232	0.960 – 1.581	0.101
Inter-incisor distance (cm)	0.514	0.234 – 1.132	0.098
Thyromental distance (cm)	0.725	0.425 – 1.239	0.240
BMI (kg/m²)	0.988	0.869 – 1.123	0.852

*OR: odds ratio; CI : confidence interval

Table 5: Multivariable logistic regression for difficult intubation

Variable	Adjusted OR	95% CI	p -value
Tongue thickness – Point A (cm)	3.960	1.649 – 9.510	0.002
Inter-incisor distance (cm)	0.446	0.221 – 0.900	0.024
Neck circumference (cm)	1.015	0.815 – 1.263	0.897
Thyromental distance (cm)	0.884	0.556 – 1.404	0.601
BMI (kg/m²)	1.011	0.899 – 1.137	0.852

*OR: odds ratio; CI : confidence interval

tor of both outcomes after adjustment. For difficult mask ventilation, Point D was independently associated with difficulty (adjusted OR 3.23, 95% CI 1.47–7.10, p=0.004); neck circumference, inter-incisor distance, thyromental distance, and BMI were not independently significant (p=0.10, p=0.10, p=0.24, p=0.85, respectively). For difficult intubation, Point A was independently associated with difficulty (adjusted OR 3.96, 95% CI 1.65–9.51, p=0.002), as was inter-incisor distance (adjusted OR 0.45 per cm, 95% CI 0.22–0.90, p=0.024); neck circumference, thyromental distance, and BMI were not independently significant.

Discussion

The insights of this prospective observational study favor the use of ultrasound-measured tongue thickness as an adjunctive parameter in airway assessment alongside clinical parameters for better airway predictability.

In the era of supraglottic airway devices, the ability to maintain oxygenation through effective mask ventilation ensures the safety of patients. This technique remains irreplaceable, reinforcing its relevance in modern anesthesiology training and practice; one should not neglect the basic skill of mask ventilation[17].

A total of 125 patients were enrolled. None of the

patients experienced impossible mask ventilation or intubation. However, we found that 28.8% and 40% of the study population experienced DMV and DI, respectively.

For the prediction of the DMV, tongue thickness measured at the base (from the skin to the soft tissue demarcation of the tongue) demonstrated the highest area under the ROC curve (AUC = 0.664, p = 0.004). A cutoff value of 4.06 cm yielded a sensitivity of 42% and a specificity of 85%. Comparable findings were reported by Bianchini et al. (2021)[14], who identified tongue base thickness >5 cm as a predictor of DMV with a sensitivity of 85% and specificity of 60%. In contrast to our present study, they used a transverse plane approach with the probe positioned in the submental region. A more methodologically aligned study is that of Kundra et al. (2025) [18], who assessed tongue thickness in the sagittal plane, identical to the technique used in our study. They reported that a tongue thickness >4.1 cm predicted DMV with a sensitivity of 69.4% and specificity of 71.1%. Our analysis also demonstrated comparable findings, with Point A showing a cutoff value of 5.59 cm, yielding a sensitivity of 67% and specificity of 61%, with an AUROC of 0.641 (p = 0.014). Therefore, the findings cannot be generalized but can be interpreted as indicating that with a greater thickness of the base of the tongue, difficulty in mask ventilation can be anticipated.

We also compared tongue thickness with difficult intubation, and we found that tongue thickness measured from the skin to the hard palate (Point A) had the highest predictive value (AUC = 0.693, p < 0.001). A threshold of 5.36 cm demonstrated a sensitivity of 82% and specificity of 56%. Yao et al. (2014–2016) [12], in a study conducted in a Chinese population, concluded that increased tongue thickness was an independent predictor of difficult laryngoscopy and tracheal intubation, with a cutoff >6.1 cm, yielding a sensitivity of 75% and specificity of 72%.

We also explored the relative difference between the points at the body and base of the tongue, i.e., A-B and C-D (the palatoglossal space), as a predictive marker. However, no statistically significant association was found between DMV and DI in our cohort. In contrast, Kundra et al. (2025) [18] reported that obliteration of the palatoglossal space was a valuable indicator for predicting the DMV.

When the predictive performance of ultrasound-derived tongue thickness and conventional clinical airway assessment parameters was compared, ultrasound measurements demonstrated marginally higher AUROC values than the individual clinical predictors. Furthermore, multivariable logistic regression analysis showed that tongue thickness measured at the base (Point D) for difficult mask ventilation and at the body (Point A) for difficult intubation remained independently associated with their respective outcomes after adjustment for established clinical predictors. These findings suggest that ultrasonographic tongue thickness provides predictive information beyond that explained by anthropometric measures such as BMI, neck circumference, and thyromental distance. Although the incremental improvement in diagnostic performance was modest, ultrasound may complement conventional airway assessment by providing objective anatomical information that is not captured by routine clinical examination alone. Incorporating ultrasound-derived tongue thickness into preoperative airway evaluation may therefore improve risk stratification, although further validation in larger multicentre studies is warranted.

Our study also has several limitations: a relatively small sample size may have reduced statistical power, and the absence of a universally accepted cutoff for tongue thickness limits comparability. Also, ultrasound measurements were performed by a single experienced operator; therefore, interobserver variability was not assessed. However, airway ultrasound for tongue thickness has a relatively short learning curve, and previous studies have demonstrated good reproducibility after appropriate training. We also did not include multidomain protocols such as Difficult Airway Evaluation with Sonography (DARES[19]), where hyomental distance and anterior soft tissue thickness parameters were included. DARES mainly explores difficult intubations, so its applicability can be limited to this study. More extensive, multicentric studies with broader populations and additional sonographic markers are needed to validate and extend these findings.

Conclusion:

Ultrasound-measured tongue thickness demonstrates moderate discriminative ability for predicting difficult mask ventilation and difficult intubation. Hence, ultrasonographic assessment of tongue thickness performed along with conventional preoperative airway evaluation may have a potential role in airway assessment.

Acknowledgments:

We thank our institution, mentors, and participants for their support.

Ethics: Research was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

Funding sources -This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

Conflicts of interest:

None

Authors' contributions

Dr. SVNSK- acquisition of data, data analysis

Dr. RRKB- conception, design of the study, acquisition of data, data analysis, and interpretation

Dr. STK- drafting of the article

Dr. LS- literature review

Dr. MK- critical review for important intellectual content

Dr. AS-- literature review

References

1. Cook TM, Woodall N, Frerk C, Fourth National Audit Project. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: anaesthesia. Br J Anaesth. 2011 May;106(5):617–31.
2. Apfelbaum JL, Hagberg CA, Connis RT, Abdelmalak BB, Agarkar M, Dutton RP, et al. 2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway*. Anesthesiology. 2022 Jan 1;136(1):31–81.
3. Ellard L, Wong DT. Preoperative Airway Evaluation. Curr Anesthesiol Rep. 2020 Mar;10(1):19–27.
4. Lee A, Fan LTY, Gin T, Karmakar MK, Ngan Kee WD. A Systematic Review (Meta-Analysis) of the Accuracy of the Mallampati Tests to Predict the Difficult Airway: Anesth Analg. 2006 Jun;102(6):1867–78.
5. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology. 2005 Aug;103(2):429-37.
6. Nakazawa H, Uzawa K, Tokumine J, Lefor AK, Motoyasu A, Yorozu T. Airway ultrasound for patients anticipated to have a difficult airway: Perspective for personalized medicine. World J Clin Cases. 2023 Mar 26;11(9):1951–62.
7. Carsetti A, Sorbello M, Adrario E, Donati A, Falcetta S. Airway Ultrasound as Predictor of Difficult Direct Laryngoscopy: A Systematic Review and Meta-analysis. Anesth Analg [Internet]. 2022;134(4). Available from: https://journals.lww.com/anesthesia-analgesia/fulltext/2022/04000/airway_ultrasound_as_predictor_of_difficult_direct.15.aspx
8. Adi O, Fong CP, Sum KM, Ahmad AH. Usage of airway ultrasound as an assessment and prediction tool of a difficult airway management. Am J Emerg Med. 2021 Apr;42:263.e1-263.e4.
9. Fulkerson JS, Moore HM, Anderson TS, Lowe RF. Ultrasonography in the preoperative difficult airway assessment. J Clin Monit Comput. 2017 Jun;31(3):513–30.
10. Sotoodehnia M, Rafiemanesh H, Mirfazaelian H, Safaie A, Baratloo A. Ultrasonography indicators for predicting difficult intubation: a systematic review and meta-analysis. BMC Emerg Med. 2021 Dec;21(1):76.
11. Pinto J, Cordeiro L, Pereira C, Gama R, Fernandes HL, Assunção J. Predicting difficult laryngoscopy using ultrasound measurement of distance from skin to epiglottis. J Crit Care. 2016 Jun;33:26–31.
12. Yao W, Wang B. Can tongue thickness measured by ultrasonography predict difficult tracheal intubation? Br J Anaesth. 2017 Apr;118(4):601–9.
13. Roth D, Pace NL, Lee A, Hovhannisyan K, Warenits AM, Arrich J, et al. Bedside tests for predicting difficult airways: an abridged Cochrane diagnostic test accuracy systematic review. Anaesthesia. 2019 Jul;74(7):915–28.
14. Bianchini A, Nardozi L, Nardi E, Scuppa MF. Airways ultrasound in predicting difficult face mask ventilation. Minerva Anestesiol [Internet]. 2021 Feb [cited 2025 Feb 2];87(1). Available from: https://www.minervamedica.it/index2.php?show=R02Y2021N01A0026
15. Warters RD, Szabo TA, Spinale FG, DeSantis SM, Reves JG. The effect of neuromuscular blockade on mask ventilation. Anaesthesia. 2011;66(3):163–7.
16. Adnet F, Borron SW, Racine SX, Clemessy JL, Fournier JL, Plaisance P, et al. The Intubation Difficulty Scale (IDS) : Proposal and Evaluation of a New Score Characterizing the Complexity of Endotracheal Intubation. Anesthesiology. 1997 Dec 1;87(6):1290–7.
17. Ramachandran SK, Kheterpal S. Difficult mask ventilation: does it matter? Anaesthesia. 2011;66(s2):40–4.
18. Sekhar S, Kundra P, Mohan VK, Senthilnathan M, Ramesh A. Ultrasonographic evaluation of palatoglossal space to predict difficult mask ventilation – A prospective observational study. Indian J Anaesth. 2025 Mar;69(3):315.
19. Lin J, Bellinger R, Shedd A, Wolfshohl J, Walker J, Healy J, et al. Point-of-Care Ultrasound in Airway Evaluation and Management: A Comprehensive Review. Diagnostics. 2023 Apr 25;13(9):1541.