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ULTRASONOGRAM OF THE AIRWAY AND TONGUE ASSESSMENT TO PREDICT DIFFICULT AIRWAY IN ADULTS - AN OBSERVATIONAL STUDY

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ABSTRACT

Background: Difficult airway management remains a major anaesthetic challenge with unpredictable occurrences and high morbidity. Ultrasound-based assessment, particularly tongue thickness measurement, offers a noninvasive, reliable, and objective alternative for predicting difficult airways. This study aimed to determine the accuracy of ultrasound as a noninvasive tool for assessing the airway. **Materials and Methods:** A hospital-based, cross-sectional, prospective observational study was conducted among 200 adults undergoing elective surgery under general anaesthesia at Government Tiruvannamalai Medical College and Hospital from April 2023 to April 2024. Preoperative assessment included Mallampati grading, interincisor gap, and thyromental distance. The ultrasonographic parameters measured were tongue thickness, skin-to-hyoid distance, skin-to-epiglottis distance, and skin-to-suprasternal notch. The laryngoscopic view was graded using the Cormack–Lehane classification. **Result:** Participants had a mean age of 38.8±14.4 years, and 145 (72.5%) had normal BMI. Easy airways were observed in 181 (90.5%) and difficult in 19 (9.5%). Mean BMI was higher in difficult airways (27.2±3.4) than in easy (23.3±2.6; p<0.001). Mean ultrasonographic measurements (cm) in difficult vs. easy airways were: tongue thickness 6.47±0.3 vs. 4.92±0.4; skin-to-epiglottis 2.53±0.1 vs. 1.63±0.2; skin-to-hyoid 0.83±0.09 vs. 0.66±0.12; and skin-to-suprasternal notch 0.91±0.1 vs. 0.69±0.1 (all p<0.001). Diagnostic accuracy: tongue thickness (sensitivity 100%, specificity 98.3%, PPV 86.4%, NPV 100%, accuracy 98.5%, AUC 0.994); skin-to-epiglottis (94.7%, 99.4%, 94.7%, 99.4%, 99%, AUC 0.995); suprasternal notch (94.7%, 89.5%, 48.6%, 99.4%, 90%, AUC 0.961); hyoid (78.9%, 76.8%, 26.3%, 97.2%, 77%, AUC 0.876). **Conclusion:** Ultrasound-based airway assessment is a reliable, accurate, and noninvasive method for predicting difficult intubation, with tongue thickness and skin-to-epiglottis distance showing the highest diagnostic value.

INTRODUCTION

Difficult airways pose a major concern in anaesthetic practice, occurring in approximately 5%–22% of patients. Among cases with difficult mask ventilation, 94% were unanticipated, and 93% of difficult intubations occurred unexpectedly, often leading to life-threatening complications during laryngoscopy. Predicting such difficulty remains challenging due to multiple dynamic anatomical and operator-dependent factors.[1] Unexpected difficult intubation remains a leading cause of anaesthesia-related morbidity and mortality.[2] Airway management is essential for maintaining oxygenation and ventilation, with difficult laryngoscopy and intubation reported in 1.5%–13% of cases and inadequate mask ventilation or failed intubation accounting for 28% of anaesthesia-related deaths.[3]

Preoperative prediction of a difficult airway is vital for ensuring patient safety and optimal preparation. Several bedside screening tests, such as the modified Mallampati test, hyomental distance, thyromental distance, interincisor gap, and neck circumference, are commonly used, but their diagnostic accuracy is limited by low sensitivity, interobserver variability, and reliance on patient cooperation.[4,5] Although imaging modalities like CT, MRI, and 3D reconstruction offer detailed anatomical visualisation, their routine use is restricted by high cost, radiation exposure, and limited accessibility.[1,6] The modified Mallampati test provides some predictive value by reflecting tongue volume but is limited in uncooperative or unconscious patients. Tongue thickness, an important determinant of airway difficulty, remains insufficiently evaluated using objective, practical methods.[5] Recent advances in imaging have established ultrasonography as a promising, noninvasive, radiation-free, and accessible tool. Point-of-care ultrasound (POCUS) enables real-time visualisation of airway anatomy, including tongue thickness, anterior neck soft tissue, and laryngeal structures and is increasingly applied in airway nerve blocks, vascular access, and the assessment of conditions such as obstructive sleep apnoea.[1]

POCUS has also been used in perioperative airway evaluation to assess dynamic changes in airway collapsibility and anatomy during induction, sedation, and positioning. Additionally, ultrasound allows the rapid identification of the cricothyroid membrane, aiding emergency airway access in "cannot intubate, cannot ventilate" scenarios. It can also confirm endotracheal tube placement and detect misplacements such as oesophageal or mainstem intubation crucial during resuscitation when capnography may be unreliable.[7-9]

Despite its advantages, ultrasonography lacks standardised parameters for predicting difficult airways, and current studies are constrained by heterogeneity, small sample sizes, and methodological variability.[2] The Cormack–Lehane (CL) grading system remains the gold standard for evaluating laryngoscopic difficulty, but it is invasive and unsuitable for preoperative use in conscious patients.[10] Consequently, ultrasound-based assessment offers a promising, objective, and reproducible alternative for preoperative airway evaluation.

Ultrasonography can quantify anatomical features, such as tongue thickness and anterior neck soft tissue, which may correlate with difficult laryngoscopy and intubation. Being portable, affordable, and safe, it has significant potential to enhance airway assessment and prediction accuracy. Measuring tongue thickness in the "sniffing" position using ultrasound may effectively reflect intrinsic upper airway characteristics while minimising patient effort.[4,5]

Aim

This study aimed to determine the accuracy of ultrasound as a noninvasive tool to assess the airway and its predictability in identifying difficult airways and to correlate ultrasound and clinical assessment of the airway.

MATERIALS AND METHODS

This hospital-based, cross-sectional, prospective observational study was conducted among 200 patients who underwent elective surgeries under general anaesthesia in the Department of Anesthesia at Government Tiruvannamalai Medical College and Hospital from April 2023 to April 2024. The study was approved by the Institutional Ethics Committee. Written informed consent was obtained from all patients before their inclusion in the study.

Inclusion Criteria

Patients with ASA PS grades 1, 2, and 3, both men and women, aged between 18 and 80 years, who were undergoing elective surgeries under general anaesthesia with direct laryngoscopy and endotracheal intubation were included.

Exclusion Criteria

Patients with mouth opening < 3 cm, edentulous, with head and neck anatomical pathologies that might have an unpredictable effect on the ultrasound assessment of the airway, and unable to extend their neck >30 °were excluded.

Methods

All patients underwent standard preoperative investigations, including complete blood count, coagulation profile, blood grouping, random blood sugar, liver and renal function tests, and case-specific assessments. A detailed airway evaluation was performed, focusing on the Modified Mallampati classification, interincisor gap, and thyromental distance.

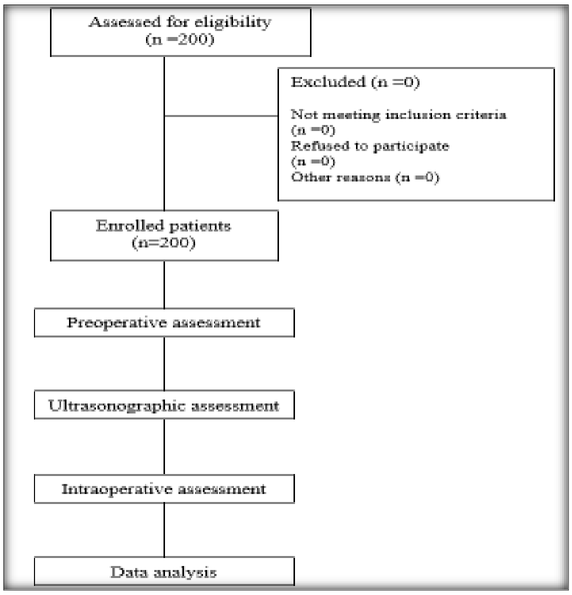
On the evening before the surgery, airway ultrasonography was performed in the Department of Anesthesiology. The soft tissue thickness of the anterior neck was measured at three levels: the hyoid bone, thyrohyoid membrane, and suprasternal notch, and tongue thickness was also recorded. All measurements were taken in the "sniffing position" using a low-frequency (2–5 MHz) curvilinear transducer. Demographic details, such as age, sex, height, and weight, were recorded.

On the day of surgery, the patients were transferred to the operating room, and general anaesthesia was administered by the attending anaesthesiologist. Airway equipment, including endotracheal tubes, Macintosh laryngoscopes, laryngeal mask airways, and emergency drugs, were kept ready. Fibreoptic equipment was prepared for anticipated difficult intubation.

During induction, the patients were monitored using ECG, NIBP, and pulse oximetry. All intubations were performed by anaesthesiologists with at least five years of experience using a Macintosh blade size 3. The best laryngeal view obtained on the first attempt without external manoeuvres was graded according to the Cormack–Lehane classification. Patients were continuously monitored intraoperatively and postoperatively for any complications, which were managed accordingly.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 23. Descriptive statistics (mean, SD, and range) were used for continuous variables, and frequencies and percentages were used for categorical variables. The Chi-square test was used to assess group differences. Diagnostic efficiency was evaluated using ROC curves and AUC, with sensitivity, specificity, PPV, and NPV calculated. A two-tailed p-value of <0.05 was considered significant.



RESULTS

The majority of participants were aged 26–40 years (40%), followed by 41–55 years (27%). Most patients were female (67.5%) and had a normal BMI (72.5%). The mean age of the participants was 38.8±14.4 years, and the mean Body Mass Index (BMI) was 23.7±2.8. According to airway assessment, 53.5% were classified as Mallampati grade 1 and 66.5% as Cormack–Lehane grade 1, indicating predominantly easy airways, with 90.5% of cases being easily intubated.

Ultrasonographic measurements showed that the skin-to-hyoid bone distance was 0.66–0.90 cm in 61.5% of the subjects, the skin-to-epiglottis distance was 1.30–1.80 cm in 67.5%, the skin-to-suprasternal notch distance was 0.66–0.90 cm in 59%, and the tongue thickness measured 4.10–5.00 cm in 62.5% of the participants. The mean skin-to-hyoid bone distance was 0.67±0.1 cm, while the skin-to-epiglottis distance was 1.71±0.3 cm. The skin-to-suprasternal notch distance was 0.72±0.1 cm, and the mean tongue thickness was 5.1±0.6 cm

Table 1: Distribution of demographic and ultrasonographic variables

Variable	Range / Category	Frequency (%)
Age groups (years)	18–25	41 (20.5%)
	26–40	80 (40%)
	41–55	54 (27%)
	56–70	19 (9.5%)
	>70	6 (3%)
Gender	Female	135 (67.5%)
	Male	65 (32.5%)
BMI categories	Underweight	5 (2.5%)
	Normal	145 (72.5%)
	Overweight	43 (21.5%)
	Obese	7 (3.5%)
Mallampati classification grading	1	107 (53.5%)
	2	74 (37%)
	3	19 (9.5%)
Cormack-Lehane classification grading	1	133 (66.5%)
	2	48 (24%)
	3	19 (9.5%)
Ease of intubation (by CL)	Easy airway	181 (90.5%)
	Difficult airway	19 (9.5%)
USG- Skin to Hyoid bone (cm)	0.40–0.65	73 (36.5%)
	0.66–0.90	123 (61.5%)
	0.91–1.20	4 (2.0%)
USG- Skin to Epiglottis (cm)	<1.30	6 (3%)
	1.30–1.80	135 (67.5%)
	1.81–2.30	41 (20.5%)
	2.31–2.70	18 (9%)
USG- Skin to Suprasternal notch (cm)	0.40–0.65	67 (33.5%)
	0.66–0.90	118 (59.0%)
	>0.90	15 (7.5%)
USG- Tongue thickness (cm)	4.10–5.00	125 (62.5%)
	5.10–6.00	53 (26.5%)
	6.10–7.00	22 (11%)

Skin-to-epiglottis distance showed the highest diagnostic performance, with a sensitivity of 94.7%, specificity of 99.4%, and an AUC of 0.995 (p < 0.001; 95% CI: 0.98–1.00) at a cut-off value of 2.22 cm. The tongue thickness parameter also exhibited excellent accuracy (98.5%) with perfect sensitivity (100%) and high specificity (98.3%) at a cut-off of 6.02 cm (AUC = 0.994; p < 0.001; 95% CI: 0.98–1.00). The skin-to-suprasternal notch distance achieved high sensitivity (94.7%) and specificity

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(89.5%) with an AUC of 0.961 (p < 0.001; 95% CI: 0.93–0.98). In comparison, the skin-to-hyoid distance demonstrated moderate accuracy (77%) with a sensitivity of 78.9% and specificity of 76.8% (AUC = 0.876; p < 0.001; 95% CI: 0.81–0.94). [Table 2]

Table 2: Diagnostic accuracy and ROC analysis of ultrasonographic parameters

USG Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	AUC	Cut-off (cm)	p value	95% CI
Skin to Hyoid	78.9	76.8	26.3	97.2	77	0.876	0.74	<0.001	0.81–0.94
Skin to Epiglottis	94.7	99.4	94.7	99.4	99	0.995	2.22	<0.001	0.98–1.00
Skin to Suprasternal Notch	94.7	89.5	48.6	99.4	90	0.961	0.81	<0.001	0.93–0.98
Tongue Thickness	100	98.3	86.4	100	98.5	0.994	6.02	<0.001	0.98–1.00

For skin-to-hyoid bone thickness, the optimal cutoff point was 0.74 cm, and the area under the curve was 0.876 (very good) in delineating easy and difficult airways. [Figure 2]

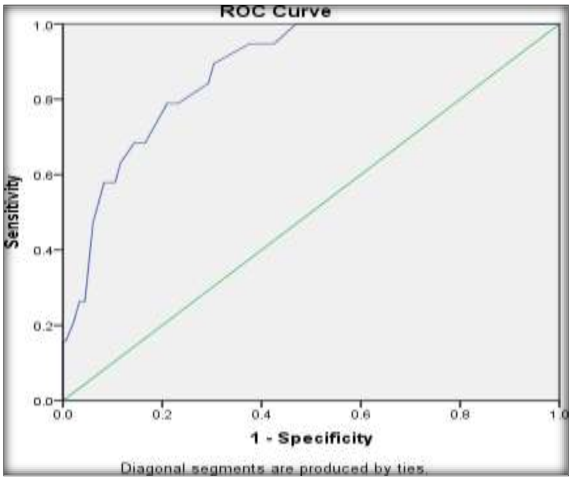

Figure 2: ROC curve for skin-to-hyoid bone distance in predicting difficult airway

For skin-to-epiglottis thickness, the optimal cutoff point was 2.22 cm, and the area under the curve was 0.995 (excellent) in delineating easy and difficult airways. [Figure 3]

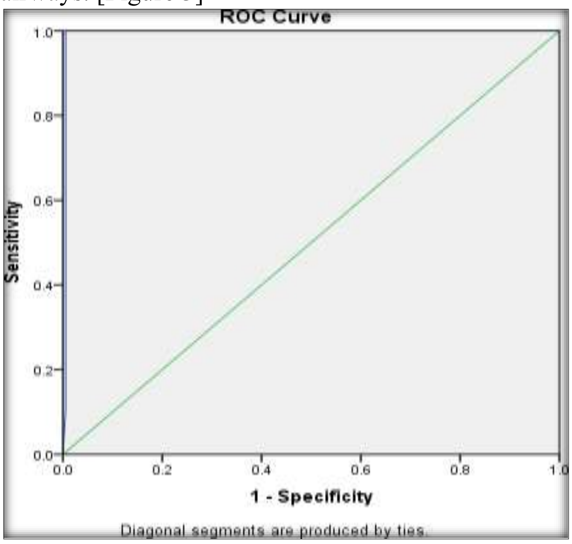

Figure 3: ROC curve for skin-to-epiglottis distance in predicting difficult airway

For skin-to-supraclavicular notch thickness, the optimal cutoff point was 0.81 cm, and the area under the curve was 0.961 (excellent) in delineating easy and difficult airways. [Figure 4]

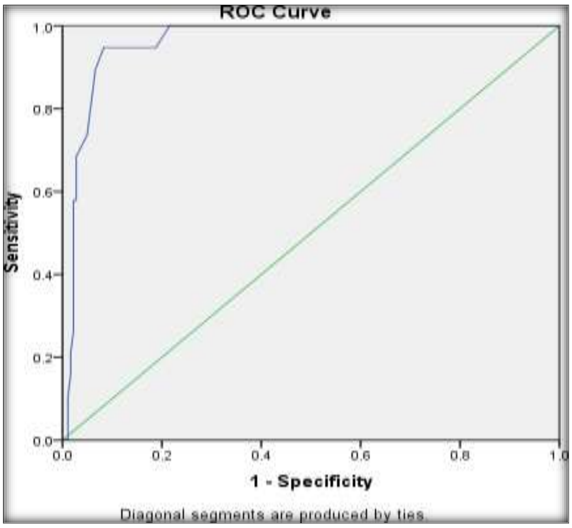

Figure 4: ROC curve for skin-to-suprasternal notch distance in predicting difficult airway

For tongue thickness, the optimal cutoff point was 6.02 cm, and the area under the curve was 0.994 (excellent) for delineating easy and difficult airways. [Figure 5]

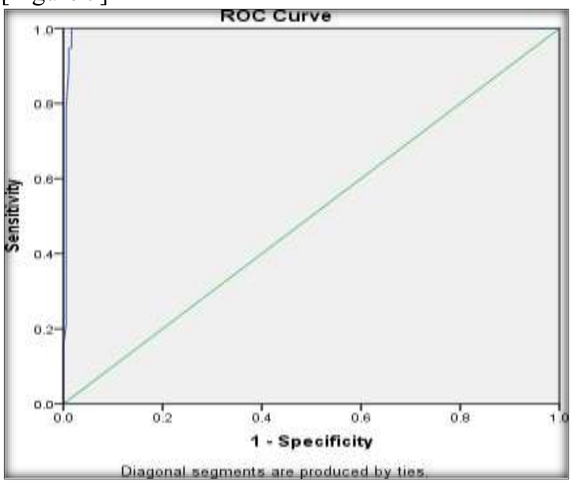

Figure 5: ROC curve for tongue thickness in predicting difficult airway

All ultrasonographic parameters and clinical grading systems were significantly associated with airway difficulty (p < 0.001). Most patients with higher skin-to-hyoid bone, skin-to-epiglottis, skin-to-suprasternal notch distances, and tongue thickness were in the difficult airway group. Similarly, a higher Cormack–Lehane grade was significantly associated with difficult intubation. [Table 3]

Table 3: Association between ultrasonographic and clinical parameters with airway difficulty

USG / Clinical parameter		Mallampati classification		p value
		Easy airway	Difficult airway	
Skin to Hyoid bone	Easy airway	138 (96.5%)	5 (3.5%)	<0.001
	Difficult airway	43 (75.4%)	14 (24.6%)	
Skin to Epiglottis	Easy airway	170 (93.9%)	11 (6.1%)	<0.001
	Difficult airway	11 (57.9%)	8 (42.1%)	
Skin to Suprasternal notch	Easy airway	155 (95.1%)	8 (4.9%)	<0.001
	Difficult airway	26 (70.3%)	11 (29.7%)	
Tongue thickness	Easy airway	167 (93.8%)	11 (6.2%)	<0.001
	Difficult airway	14 (63.6%)	8 (36.4%)	
Cormack Lehane grade	Easy airway	169 (93.4%)	12 (6.6%)	<0.001
	Difficult airway	12 (63.2%)	7 (36.8%)	

A significant association was observed between BMI and all ultrasonographic parameters and airway difficulty (p < 0.001). Patients with a higher BMI, greater skin-to-hyoid bone distance, skin-to-epiglottis distance, skin-to-suprasternal notch distance, and increased tongue thickness were more likely to have difficult airways. However, age and sex did not show a significant association (p = 0.19).[Table 4]

Table 4: Association between ultrasonographic and clinical parameters with demographic variables

Variable	Range / Category	Easy airway	Difficult airway	p value
Age group (years)	18–25	37 (90.2%)	4 (9.8%)	0.19
	26–40	77 (96.3%)	3 (3.8%)	
	41–55	46 (85.2%)	8 (14.8%)	
	56–70	16 (84.2%)	3 (15.8%)	
	>70	5 (83.3%)	1 (16.7%)	
Sex	Female	125 (92.6%)	10 (7.4%)	0.19
	Male	56 (86.2%)	9 (13.8%)	
BMI category	Underweight	5 (100%)	0 (0%)	<0.001
	Normal	139 (95.9%)	6 (4.1%)	
	Overweight	35 (81.4%)	8 (18.6%)	
	Obese	2 (28.6%)	5 (71.4%)	
USG- Skin to Hyoid bone (cm)	0.40–0.65	73 (100%)	0 (0%)	<0.001
	0.66–0.90	107 (87%)	16 (13%)	
	0.91–1.20	1 (25%)	3 (75%)	
USG- Skin to Epiglottis (cm)	<1.30	6 (100%)	0 (0%)	<0.001
	1.30–1.80	135 (100%)	0 (0%)	
	1.81–2.30	39 (95.1%)	2 (4.9%)	
	2.31–2.70	1 (5.6%)	17 (94.4%)	
USG- Skin to Suprasternal notch (cm)	0.40–0.65	67 (100%)	0 (0%)	<0.001
	0.66–0.90	110 (93.2%)	8 (6.8%)	
	>0.90	4 (26.7%)	11 (73.3%)	
USG- Tongue thickness (cm)	4.10–5.00	125 (100%)	0 (0%)	<0.001
	5.10–6.00	53 (100%)	0 (0%)	
	6.10–7.00	3 (13.6%)	19 (86.4%)	

Patients with a difficult airway had a higher mean age (44.7 ± 16.1 years) than those with an easy airway (38.3 ± 14.2 years, p = 0.06). The mean BMI was significantly higher in the difficult intubation group (27.2 ± 3.4 kg/m²) than in the easy intubation group (23.3 ± 2.6 kg/m², p < 0.001). Ultrasonographic measurements were also higher among difficult airway cases: skin-to-hyoid (0.83 ± 0.09 cm vs. 0.66 ± 0.12 cm), skin-to-epiglottis (2.53 ± 0.1 cm vs. 1.63 ± 0.2 cm), skin-to-suprasternal notch (0.91 ± 0.1 cm vs. 0.69 ± 0.1 cm), and tongue thickness (6.47 ± 0.3 cm vs. 4.92 ± 0.4 cm), all of which showed statistically significant differences (p < 0.001). [Table 5]

Table 5: Comparison of demographic and ultrasonographic parameters between easy and difficult airway groups

Variable	Easy airway	Difficult airway	Mean Difference	t value	p value	95% CI
Age (years)	38.3 ± 14.2	44.7 ± 16.1	-6.47	-1.86	0.06	-13.3 – 0.35
BMI (kg/m²)	23.3 ± 2.6	27.2 ± 3.4	-3.88	-6.06	<0.001	-5.55 – -2.20
Skin to Hyoid (cm)	0.66 ± 0.12	0.83 ± 0.09	-0.17	-6.02	<0.001	-0.23 – -0.11
Skin to Epiglottis (cm)	1.63 ± 0.2	2.53 ± 0.1	-0.9	-17.2	<0.001	-1.00 – -0.80
Skin to Suprasternal Notch (cm)	0.69 ± 0.1	0.91 ± 0.1	-0.21	-6.73	<0.001	-0.27 – -0.15
Tongue Thickness (cm)	4.92 ± 0.4	6.47 ± 0.3	-1.55	-15.5	<0.001	-1.75 – -1.35

DISCUSSION

In our study, most participants were within the younger to middle-age range, and females constituted the majority and females predominated in our study (67.5%). Similar age profiles were noted by Sajitha et al. (41.4 ± 12.6 years), Kadhim and Hamid (36 ± 6 years), and Anushaprasath et al. (40.7 ± 12.1 years) and female representation was reported (54.6%).10-12 Demographic variables such as age and gender were not significantly associated with difficult airway in our study (p = 0.19), consistent with the findings of Nair, who also reported no significant relationship between age (p = 0.63) or gender (p = 0.17) and airway difficulty.[13] These observations indicate a similar demographic pattern among studies assessing preoperative airway predictors.

In our study, most participants had a normal BMI, with an easy airway being the predominant finding on both clinical and laryngoscopic assessments. Similar observations were reported by Harjai et al., who found a significantly higher BMI in difficult-airway patients (p = 0.005). Bhagavan and Nelamangala documented comparable BMI distribution, with 72.9% normal, 22.9% overweight, and 4.2% underweight, while Sajitha et al., Chan et al., and Anushaprasath et al. reported mean BMI values of 23.8 ± 1.7, 24.5 ± 4.9, and 24.8 ± 4.6.14,4,11,15,10 Similarly, Sajitha et al., Chan et al., Parameswari et al., and Anushaprasath et al. noted easy airway rates of 93.4%, 86.7%, 88%, and 82.3% respectively, closely resembling our findings.[11,15,16,10] These results collectively demonstrate that a higher BMI is associated with a difficult airway, while a normal BMI is predominant among patients with easy intubation across studies.

In the present study, tongue thickness emerged as the most accurate and reliable ultrasonographic parameter, demonstrating excellent diagnostic performance for predicting difficult airways. Sajitha et al. reported tongue thickness sensitivity of 75%, specificity of 94.7%, PPV of 50%, and NPV of 98.2%, while Yao and Wang found sensitivity of 75%, specificity of 72%, PPV of 6%, and NPV of 99%. Parameswari et al. documented a sensitivity of 66.7% and specificity of 62.7%.[11,5,16] Compared to these studies, our findings show markedly higher sensitivity and comparable specificity, confirming the superior predictive value of tongue thickness as an ultrasonographic parameter for identifying difficult airways.

In our study, the skin-to-epiglottis distance also demonstrated excellent diagnostic ability, proving it to be a highly effective ultrasonographic parameter for predicting a difficult airway. Bashir et al. reported a sensitivity of 92%, specificity of 72%, and accuracy of 92%, whereas Parameswari et al. observed a sensitivity of 75% and specificity of 63.6%. Bhagavan and Nelamangala found a sensitivity of 75% and specificity of 89.7%, whereas Fernandez-Vaquero et al. documented a sensitivity of 91.3% and specificity of 96.9%. Carsetti et al. reported a sensitivity of 82% and specificity of 79%.[1,16,4,17,2] Compared with these studies, our findings demonstrate superior diagnostic performance, placing our results at the higher end of the reported range and showing the closest agreement with Fernandez-Vaquero et al., confirming the strong predictive value of the skin-to-epiglottis distance in difficult airway assessment.[17]

In the present study, the skin-to-suprasternal notch distance exhibited high diagnostic efficiency, indicating a strong predictive value for identifying a difficult airway. Bashir et al. reported comparatively lower values, with a sensitivity of 68%, specificity of 88%, and accuracy of 83%, whereas Fernandez-Vaquero et al. documented a sensitivity of 67.4% and specificity of 65.6%.[1,17] Compared with these findings, our study demonstrated clearly higher diagnostic indices, indicating the superior discriminatory power of the skin-to-suprasternal notch measurement in identifying difficult airways within our study population.

In our study, the skin-to-hyoid bone distance showed a moderate level of diagnostic reliability, serving as a useful but less robust ultrasonographic indicator for predicting difficult airways. Bashir et al. reported similar findings, with a sensitivity of 76%, specificity of 100%, and accuracy of 84%, whereas Parameswari et al. observed lower values, with a sensitivity of 58.3% and specificity of 56.8%. Fernandez-Vaquero et al. found a sensitivity of 80.4% and specificity of 60.1%, Carsetti et al. documented both sensitivity and specificity at 71%, and Bhagavan and Nelamangala reported the highest values with a sensitivity of 100% and specificity of 82.9%.[1,16,17,2,4] Our results fall within this reported range, though with a lower PPV (26.3%), likely due to the lower prevalence of difficult airway in our cohort.

The optimal ultrasound cutoff values identified in our study indicated well-defined thresholds for each parameter, with strong area-under-curve measures reflecting the excellent overall discriminative ability of ultrasonographic assessments. Comparable cut-offs and AUCs were reported by Bashir et al. (hyoid AUC = 0.801; epiglottis AUC = 0.772), Nair et al. (AUC = 0.79), Bhagavan and Nelamangala (hyoid cut-off > 0.64 cm, AUC = 0.97; epiglottis cut-off > 1.98 cm, AUC = 0.88), Nazir and Mehta (epiglottis cut-off 1.7 cm), and Sajitha et al. (tongue thickness cut-off > 6 cm, AUC = 0.879).[1,13,4,11,18] Overall, our ROC analysis, particularly for the epiglottis and tongue thickness, demonstrated excellent discriminative performance, aligning with or surpassing previous studies. Furthermore, all sonographic parameters showed significant correlations with Mallampati and Cormack–Lehane grades ($p < 0.05$), reinforcing their reliability as objective predictors of difficult airway in preoperative evaluation.

Limitations: This study was conducted at a single tertiary care centre with a limited sample size, which may have affected the generalisability of the findings. Additionally, the cross-sectional design and operator-dependent nature of ultrasound measurements could introduce observer bias and limit the longitudinal assessment.

CONCLUSION

Ultrasonographic airway assessment is a reliable and accurate tool for predicting difficult intubation. Among all parameters, tongue thickness and skin-to-epiglottis distance showed the highest diagnostic accuracies. Ultrasound offers a noninvasive, objective, and effective preoperative method for identifying patients at risk of difficult airway, enhancing patient safety and airway preparedness. Future multicentre studies with larger sample sizes and standardised measurement protocols are recommended to validate these findings and establish universal reference values.

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