

Research Article

Ultrasound Assessment of the Airway for Prediction of Difficult Intubation

Dr. Vaishalini Sankad¹, Dr. Sumangala², Dr. Asha K^{3*}

¹Senior Resident, Department of Anaesthesiology, Raichur Institute of Medical Sciences (RIMS), Raichur, Karnataka, India.

^{2,3*}Assistant Professor, Department of Anaesthesiology, Raichur Institute of Medical Sciences (RIMS), Raichur, Karnataka, India.

Corresponding Author: Dr. Asha K

Assistant Professor, Department of Anaesthesiology, Raichur Institute of Medical Sciences (RIMS), Raichur, Karnataka, India.

Received: 15.04.26, Revised: 17.05.26, Accepted: 19.06.26

ABSTRACT

Background: Prediction of difficult laryngoscopy remains challenging using conventional bedside airway tests alone. Airway ultrasonography provides objective anatomical measurements that may improve preoperative identification of difficult airways.

Methods: This prospective observational study included 80 adults undergoing elective surgery under general anaesthesia with endotracheal intubation. Conventional airway assessment and preoperative ultrasonography were performed. Ultrasonographic parameters included skin-to-epiglottis distance (DSE), skin-to-hyoid distance, anterior neck soft-tissue thickness, tongue thickness, hyomental distances, hyomental distance ratio (HMDR), and Pre-E/E-VC ratio. Cormack-Lehane Grades I-II were classified as easy and Grades III-IV as difficult laryngoscopy. Diagnostic performance was assessed using ROC analysis.

Results: Difficult laryngoscopy occurred in 15/80 (18.8%) patients. Compared with easy laryngoscopy, difficult cases had greater DSE (2.58 ± 0.38 vs 2.05 ± 0.32 cm; $p < 0.001$), anterior neck soft-tissue thickness (1.58 ± 0.29 vs 1.32 ± 0.25 cm; $p = 0.001$), and tongue thickness (5.67 ± 0.65 vs 5.15 ± 0.61 cm; $p = 0.004$), with lower HMDR (1.17 ± 0.07 vs 1.26 ± 0.08 ; $p < 0.001$). DSE > 2.30 cm showed an AUC of 0.87, with 80.0% sensitivity and 83.1% specificity, while HMDR < 1.20 showed an AUC of 0.84 with 80.0% sensitivity and specificity. DSE and HMDR remained independent predictors of difficult laryngoscopy.

Conclusion: Airway ultrasonography provides useful objective prediction of difficult laryngoscopy. DSE and HMDR may be valuable adjuncts to conventional preoperative airway assessment.

INTRODUCTION

Airway management is a fundamental component of anaesthetic practice, and successful tracheal intubation is essential for maintaining adequate oxygenation and ventilation during general anaesthesia. Difficult or failed intubation may result in serious complications, including airway trauma, hypoxaemia, aspiration, haemodynamic instability and, in severe situations, failure to maintain oxygenation.[1,2] Of particular concern is the unanticipated difficult airway, in which difficulty is encountered despite apparently reassuring preoperative findings.[3,4] Therefore, accurate identification of patients at risk of difficult laryngoscopy and tracheal intubation remains an important aspect of perioperative patient safety. Preoperative airway evaluation conventionally includes clinical parameters such as the modified Mallampati classification, inter-incisor distance, thyromental and sternomental distances, upper lip bite test, mandibular

protrusion and cervical spine mobility.[3,5] Although these tests are simple and widely used, none can reliably identify all patients with a difficult airway.[4,6] Airway difficulty is multifactorial and is influenced by patient anatomy, positioning, intubation technique, device used and operator experience.[3,6] Moreover, several bedside measurements are subject to interobserver variability. Consequently, difficult laryngoscopy or intubation may still occur in patients classified as having an apparently easy airway.[4,6] An important limitation of conventional assessment is its predominant reliance on external anatomical landmarks, which may not adequately represent the internal soft-tissue anatomy of the upper airway.[7] Airway ultrasonography has therefore emerged as a promising objective adjunct to bedside assessment.[7,8] Ultrasound is non-invasive, portable, repeatable and free from ionizing radiation, and allows real-time visualization and quantitative assessment of the tongue, hyoid

bone, epiglottis, thyroid cartilage and anterior neck soft tissues.[7,8]

Several ultrasonographic measurements have been investigated for prediction of difficult laryngoscopy and intubation, including skin-to-epiglottis distance (DSE), skin-to-hyoid distance, anterior neck soft-tissue thickness, tongue thickness, hyomental distance (HMD), hyomental distance ratio (HMDR), and the pre-epiglottic space to epiglottis-vocal cord ratio (Pre-E/E-VC).[8–10] These measurements provide objective information regarding anterior neck tissues, submandibular space and anatomical relationships that may influence visualization of the glottis during laryngoscopy.[9,10] Evidence suggests that increased anterior neck soft-tissue thickness and greater skin-to-epiglottis distance are associated with difficult laryngoscopy.[8,9] Measurements involving the hyoid and submandibular region, including HMD and HMDR, have also demonstrated potential predictive value.[9,10] Thus, ultrasonography may complement conventional clinical examination by providing quantitative information regarding airway anatomy that is otherwise difficult to assess objectively. However, considerable variation exists among studies regarding ultrasound techniques, parameters evaluated, patient positioning, definitions of difficult airway and proposed diagnostic cut-offs.[7–10] Patient characteristics and operator-dependent factors may further influence diagnostic performance, and no single ultrasonographic parameter or universally accepted threshold has yet been established. Therefore, the present study was undertaken to evaluate ultrasonographic assessment of the airway for prediction of difficult tracheal intubation and to determine the diagnostic utility of selected ultrasound-derived airway parameters as objective adjuncts to conventional preoperative airway assessment.

MATERIALS AND METHODS

This prospective observational diagnostic study was conducted in the Department of Anaesthesiology. A total of 80 patients, aged 18–65 years, of either sex, belonging to ASA physical status I–III and scheduled for elective surgery under general anaesthesia requiring endotracheal intubation were included.

Inclusion Criteria

Adult patients undergoing elective surgery under general anaesthesia with planned direct

laryngoscopy and oral endotracheal intubation who provided informed consent were included.

Exclusion Criteria

Patients with known difficult airway, craniofacial or upper-airway abnormalities, previous head and neck surgery or radiotherapy, cervical spine deformity or restricted neck movement, neck swelling, pregnancy, emergency surgery, or inability to cooperate with airway assessment were excluded.

Preoperative Clinical Airway Assessment

Demographic and anthropometric variables including age, sex, height, weight and BMI were recorded. Conventional airway assessment included modified Mallampati class, inter-incisor distance, thyromental distance, sternomental distance, upper lip bite test, mandibular protrusion and cervical spine mobility.

Ultrasonographic Airway Assessment

Preoperative airway ultrasonography was performed in the supine position using [ultrasound machine/model] and an appropriate linear/curvilinear transducer by an anaesthesiologist trained in airway ultrasound. The parameters measured included skin-to-epiglottis distance (DSE), skin-to-hyoid distance, anterior neck soft-tissue thickness, tongue thickness, hyomental distance in neutral (HMDn) and extended (HMDe) positions, hyomental distance ratio (HMDR), and Pre-E/E-VC ratio. HMDR was calculated as $HMDe/HMDn$. The anaesthesiologist performing laryngoscopy was blinded to the ultrasound findings.

Anaesthetic Technique

Standard monitoring was instituted, and patients were preoxygenated with 100% oxygen. General anaesthesia was induced according to the institutional protocol using an intravenous induction agent, opioid and neuromuscular blocker. Direct laryngoscopy was performed after adequate neuromuscular blockade.

Direct Laryngoscopy and Intubation

Direct laryngoscopy was performed using an appropriately sized Macintosh blade by an experienced anaesthesiologist. The laryngeal view was graded according to the Cormack–Lehane (CL) classification. The number of intubation attempts, external laryngeal manipulation, use of bougie/stylet, requirement for alternative airway devices and successful intubation were recorded.

Patient Grouping

Based on the laryngoscopic findings, patients were classified into two groups:

Group E (Easy laryngoscopy): CL Grade I or II.
Group D (Difficult laryngoscopy): CL Grade III or IV.

The number of patients in each group was determined by the observed laryngoscopic findings and was not predetermined.

Outcome Measures

The primary outcome was the diagnostic ability of ultrasonographic airway parameters to predict difficult laryngoscopy/intubation. Secondary outcomes included comparison of ultrasound parameters between Groups E and D and determination of their optimal cut-offs, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy.

Statistical Analysis

Data were analysed using SPSS version [26]. Normality was assessed using the Shapiro–Wilk test. Continuous variables were expressed as mean $\pm$ SD or median (IQR), and categorical variables as frequency and percentage. Groups were compared using the independent t-test/Mann–Whitney U test and Chi-square/Fisher's exact test, as appropriate. Diagnostic performance was assessed using ROC curves and AUC with 95% CI, with optimal cut-offs determined by the Youden index. Sensitivity, specificity, PPV, NPV and accuracy were calculated. Multivariable logistic regression was used to identify independent predictors of difficult laryngoscopy/intubation. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 80 patients were included, of whom 65 (81.3%) had easy laryngoscopy (Group E; Cormack–Lehane [CL] grades I–II) and 15 (18.8%) had difficult laryngoscopy (Group D; CL grades III–IV). The mean age was 41.9 ± 11.5 years, and 46 (57.5%) patients were male. Age, sex, and ASA physical status were comparable between the groups. However, mean BMI was significantly higher in Group D than Group E (27.2 ± 3.6 vs 24.8 ± 3.1 kg/m²; $p=0.011$). Overall, CL grades I, II, III, and IV were observed in 38.8%, 42.5%, 16.3%, and 2.5% of patients, respectively (Table 1). Patients with difficult laryngoscopy had significantly greater prevalence of Mallampati class III–IV compared with those with easy

laryngoscopy (53.3% vs 13.8%; $p=0.002$). Inter-incisor distance (4.0 ± 0.6 vs 4.5 ± 0.5 cm; $p=0.002$), thyromental distance (6.1 ± 0.8 vs 6.8 ± 0.7 cm; $p=0.001$), and sternomental distance (13.2 ± 1.5 vs 14.1 ± 1.4 cm; $p=0.029$) were significantly lower in Group D. Although ULBT class III and restricted neck mobility were more frequent in Group D, these differences did not reach statistical significance (Table 2).

Significant differences were observed in multiple ultrasonographic airway measurements between the groups. Skin-to-epiglottis distance (DSE) was significantly greater in Group D than Group E (2.58 ± 0.38 vs 2.05 ± 0.32 cm; $p<0.001$). Similarly, skin-to-hyoid distance (1.26 ± 0.24 vs 1.05 ± 0.20 cm; $p=0.001$), anterior neck soft-tissue thickness (1.58 ± 0.29 vs 1.32 ± 0.25 cm; $p=0.001$), tongue thickness (5.67 ± 0.65 vs 5.15 ± 0.61 cm; $p=0.004$), and Pre-E/E-VC ratio (1.66 ± 0.29 vs 1.34 ± 0.24 ; $p<0.001$) were significantly higher among patients with difficult laryngoscopy. Conversely, HMDn, HMDe, and HMdR were significantly lower in Group D, with particularly marked differences for HMDe (5.43 ± 0.57 vs 6.18 ± 0.59 cm; $p<0.001$) and HMdR (1.17 ± 0.07 vs 1.26 ± 0.08 ; $p<0.001$) (Table 3, Figure 1). Spearman correlation analysis demonstrated significant associations between CL grade and several clinical and ultrasonographic parameters. Among the ultrasound measurements, DSE showed the strongest positive correlation with increasing CL grade ($\rho=0.56$; $p<0.001$), followed by Pre-E/E-VC ratio ($\rho=0.46$; $p<0.001$), anterior neck soft-tissue thickness ($\rho=0.41$; $p<0.001$), and skin-to-hyoid distance ($\rho=0.39$; $p<0.001$). HMdR demonstrated the strongest negative correlation ($\rho=-0.52$; $p<0.001$), followed by HMDe ($\rho=-0.48$; $p<0.001$). Among conventional parameters, thyromental distance was negatively correlated with CL grade ($\rho=-0.38$; $p<0.001$), while BMI showed a positive correlation ($\rho=0.29$; $p=0.009$) (Table 4, Figure 2).

ROC analysis demonstrated that DSE had the highest diagnostic performance among the evaluated ultrasonographic parameters, with an AUC of 0.87. At an optimal cut-off of >2.30 cm, DSE provided 80.0% sensitivity, 83.1% specificity, 52.2% PPV, and 94.7% NPV. HMdR also showed good discriminatory ability (AUC=0.84); a cut-off of <1.20 yielded 80.0% sensitivity, 80.0% specificity, 48.0% PPV, and 94.5% NPV. The Pre-E/E-VC ratio had an AUC of 0.81 at a cut-off >1.50 , with 73.3%

sensitivity and 78.5% specificity. The remaining ultrasound parameters demonstrated AUCs ranging from 0.72 to 0.77 (Table 5, Figure 3). Difficult laryngoscopy was associated with significantly more challenging intubation characteristics. First-attempt intubation success was lower in Group D than Group E (53.3% vs 95.4%; $p<0.001$), whereas multiple intubation attempts (46.7% vs 4.6%; $p<0.001$), external laryngeal manipulation (60.0% vs 12.3%; $p<0.001$), and bougie/stylet use (53.3% vs 7.7%; $p<0.001$) were significantly more frequent. Alternative airway devices were also

required more often in Group D (13.3% vs 1.5%; $p=0.047$) (Table 6A).

On multivariable logistic regression, DSE >2.30 cm was independently associated with difficult laryngoscopy (adjusted OR [AOR] 5.42, 95% CI 1.42–20.68; $p=0.013$). HMDR <1.20 (AOR 4.31, 95% CI 1.16–16.05; $p=0.030$) and Mallampati class III–IV (AOR 3.76, 95% CI 1.01–14.02; $p=0.049$) were also independently associated with difficult laryngoscopy. In contrast, BMI ≥ 25 kg/m² was not independently associated with the outcome after adjustment (AOR 1.82, 95% CI 0.48–6.91; $p=0.378$) (Table 6B, Figure 4).

Table 1. Baseline Demographic and Laryngoscopic Characteristics of the Study Population

Parameter	Overall (N=80)	Group E (n=65)	Group D (n=15)	p-value	Statistical test
Age (years), mean $\pm$ SD	41.9 $\pm$ 11.5	41.2 $\pm$ 11.6	44.8 $\pm$ 10.9	0.277	Independent t-test
Male, n (%)	46 (57.5)	37 (56.9)	9 (60.0)	0.828	Chi-square test
Female, n (%)	34 (42.5)	28 (43.1)	6 (40.0)		
BMI (kg/m ²), mean $\pm$ SD	25.3 $\pm$ 3.3	24.8 $\pm$ 3.1	27.2 $\pm$ 3.6	0.011	Independent t-test
ASA I, n (%)	37 (46.3)	31 (47.7)	6 (40.0)	0.744	Fisher's exact test
ASA II, n (%)	36 (45.0)	29 (44.6)	7 (46.7)		
ASA III, n (%)	7 (8.8)	5 (7.7)	2 (13.3)		
CL Grade I, n (%)	31 (38.8)	31 (47.7)	0	—	—
CL Grade II, n (%)	34 (42.5)	34 (52.3)	0	—	—
CL Grade III, n (%)	13 (16.3)	0	13 (86.7)	—	—
CL Grade IV, n (%)	2 (2.5)	0	2 (13.3)	—	—

Group E: CL Grades I–II; Group D: CL Grades III–IV.

Table 2. Comparison of Conventional Airway Assessment Parameters

Parameter	Group E (n=65)	Group D (n=15)	p-value	Statistical test
Mallampati III–IV, n (%)	9 (13.8)	8 (53.3)	0.002	Fisher's exact test
Inter-incisor distance (cm), mean $\pm$ SD	4.5 $\pm$ 0.5	4.0 $\pm$ 0.6	0.002	Independent t-test
Thyromental distance (cm), mean $\pm$ SD	6.8 $\pm$ 0.7	6.1 $\pm$ 0.8	0.001	Independent t-test
Sternomental distance (cm), mean $\pm$ SD	14.1 $\pm$ 1.4	13.2 $\pm$ 1.5	0.029	Independent t-test
ULBT Class III, n (%)	3 (4.6)	3 (20.0)	0.068	Fisher's exact test
Restricted neck mobility, n (%)	4 (6.2)	3 (20.0)	0.116	Fisher's exact test

Table 3. Comparison of Ultrasonographic Airway Parameters between Easy and Difficult Laryngoscopy

Ultrasonographic parameter	Group E (n=65)	Group D (n=15)	p-value	Statistical test
Skin-to-epiglottis distance (cm)	2.05 $\pm$ 0.32	2.58 $\pm$ 0.38	<0.001	Independent t-test
Skin-to-hyoid distance (cm)	1.05 $\pm$ 0.20	1.26 $\pm$ 0.24	0.001	

Anterior neck soft-tissue thickness (cm)	1.32 ± 0.25	1.58 ± 0.29	0.001
Tongue thickness (cm)	5.15 ± 0.61	5.67 ± 0.65	0.004
HMDn (cm)	4.92 ± 0.51	4.63 ± 0.49	0.049
HMDe (cm)	6.18 ± 0.59	5.43 ± 0.57	<0.001
HMDR	1.26 ± 0.08	1.17 ± 0.07	<0.001
Pre-E/E-VC ratio	1.34 ± 0.24	1.66 ± 0.29	<0.001

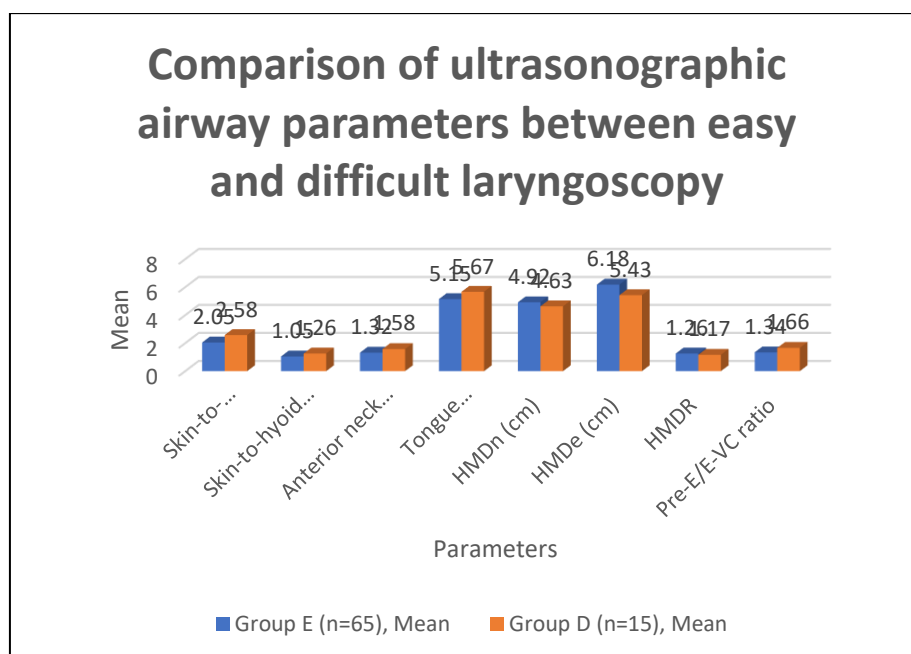


Figure 1. Comparison of Ultrasonographic Airway Parameters between Easy and Difficult Laryngoscopy

Table 4. Correlation of Clinical and Ultrasonographic Parameters with Cormack–Lehane Grade

Parameter	Correlation coefficient (ρ)	p-value	Statistical test
BMI	0.29	0.009	Spearman correlation
Inter-incisor distance	−0.34	0.002	
Thyromental distance	−0.38	<0.001	
Sternomental distance	−0.25	0.026	
Skin-to-epiglottis distance	0.56	<0.001	
Skin-to-hyoid distance	0.39	<0.001	
Anterior neck soft-tissue thickness	0.41	<0.001	
Tongue thickness	0.32	0.004	
HMDn	−0.23	0.041	
HMDe	−0.48	<0.001	
HMDR	−0.52	<0.001	
Pre-E/E-VC ratio	0.46	<0.001	

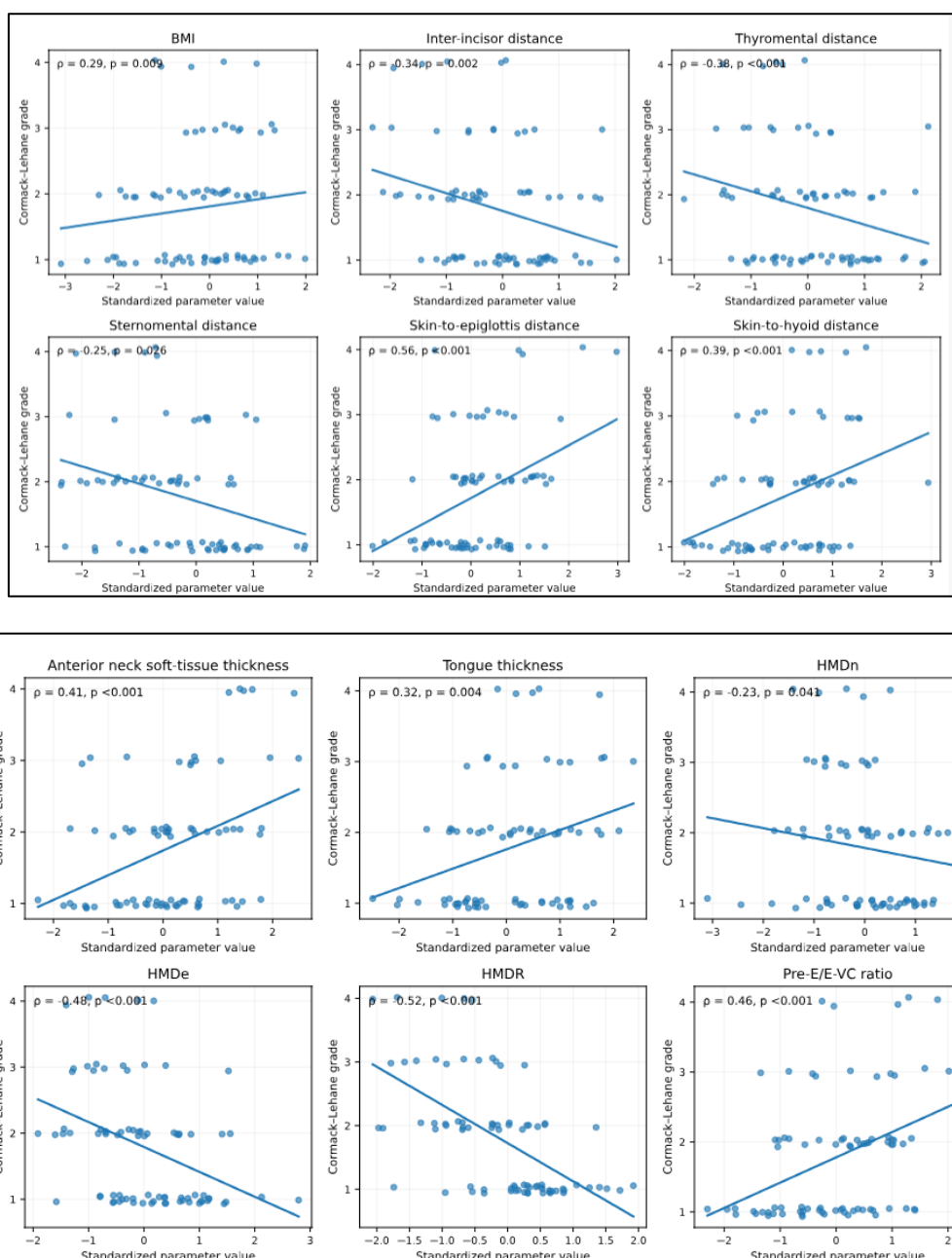


Figure 2. Correlation of Clinical and Ultrasonographic Parameters with Cormack-Lehane Grade

Table 5. Diagnostic Performance of Ultrasonographic Parameters for Predicting Difficult Laryngoscopy

Parameter	Optimal cut-off	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
DSE	>2.30 cm	0.87	80.0	83.1	52.2	94.7
Skin-to-hyoid distance	>1.15 cm	0.76	73.3	72.3	37.9	92.2
Anterior soft-tissue thickness	>1.45 cm	0.77	73.3	75.4	40.7	92.5
Tongue thickness	>5.45 cm	0.72	66.7	72.3	35.7	90.4
HMDR	<1.20	0.84	80.0	80.0	48.0	94.5
Pre-E/E-VC ratio	>1.50	0.81	73.3	78.5	44.0	92.7

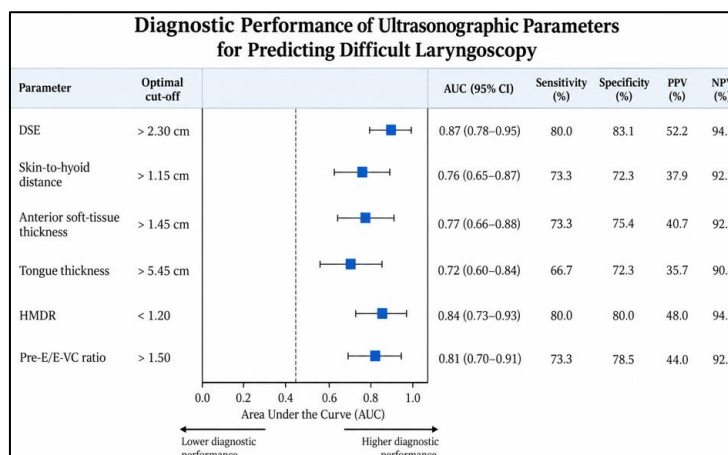


Figure 3. Diagnostic Performance of Ultrasonographic Parameters for Predicting Difficult Laryngoscopy

Table 6. Intubation Characteristics and Independent Predictors of Difficult Laryngoscopy

A. Intubation Characteristics

Parameter	Group E (n=65)	Group D (n=15)	p-value
First-attempt successful intubation	62 (95.4)	8 (53.3)	<0.001
>1 intubation attempt	3 (4.6)	7 (46.7)	<0.001
External laryngeal manipulation	8 (12.3)	9 (60.0)	<0.001
Bougie/stylet required	5 (7.7)	8 (53.3)	<0.001
Alternative airway device required	1 (1.5)	2 (13.3)	0.047

B. Multivariable Logistic Regression

Predictor	Adjusted OR	95% CI	p-value
DSE >2.30 cm	5.42	1.42–20.68	0.013
HMDR <1.20	4.31	1.16–16.05	0.030
Mallampati III–IV	3.76	1.01–14.02	0.049
BMI ≥25 kg/m ²	1.82	0.48–6.91	0.378

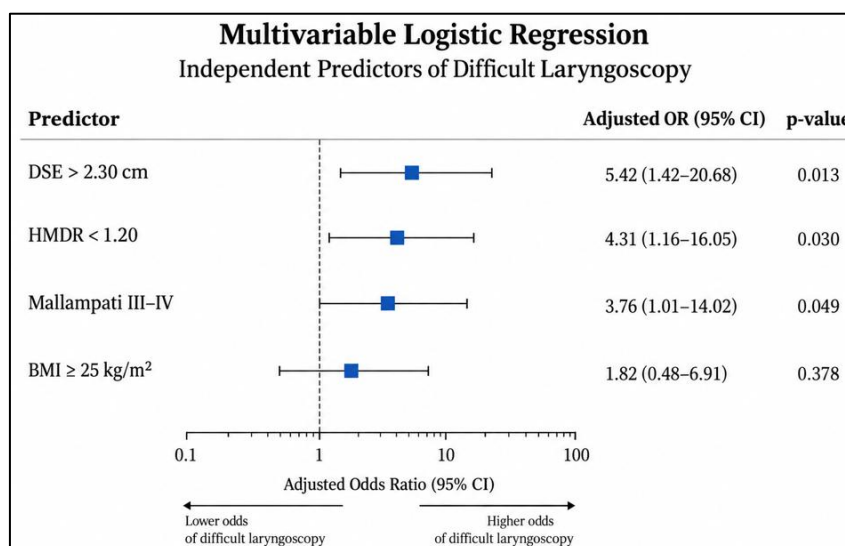


Figure 4. Intubation Characteristics and Independent Predictors of Difficult Laryngoscopy -Multivariable Logistic Regression

DISCUSSION

The present study evaluated clinical and ultrasonographic predictors of difficult laryngoscopy in 80 patients. Difficult laryngoscopy (CL Grade III–IV) occurred in 15

(18.8%) patients. Increased anterior airway soft-tissue measurements and reduced hyomental mobility were associated with difficult laryngoscopy, with DSE and HMDR showing the strongest diagnostic performance.

Difficult laryngoscopy occurred in 18.8% of our patients, comparable to the 18% (9/50) reported by Ezri et al.[11], while Komatsu et al.[12] reported a higher incidence of 31.3% (20/64) among obese patients. In our study, difficult laryngoscopy was associated with higher BMI (27.2 ± 3.6 vs 24.8 ± 3.1 kg/m²; $p=0.011$), Mallampati III–IV (53.3% vs 13.8%; $p=0.002$), and lower inter-incisor, thyromental and sternomental distances. Ezri et al.[11], however, found comparable BMI (44 ± 4.8 vs 43 ± 4.0 kg/m²; $p=0.47$), but significantly greater neck circumference in difficult cases (50 ± 3.8 vs 43.5 ± 2.2 cm; $p<0.001$).

Anterior neck soft-tissue thickness was significantly greater in our difficult group (1.58 ± 0.29 vs 1.32 ± 0.25 cm; $p=0.001$) and correlated positively with CL grade ($p=0.41$; $p<0.001$). Ezri et al.[11] similarly reported greater pretracheal soft-tissue thickness in difficult laryngoscopy (28.0 ± 2.7 vs 17.5 ± 1.8 mm; $p<0.001$). In contrast, Komatsu et al.[12] found slightly lower thickness in difficult cases (20.4 ± 3.0 vs 22.3 ± 3.8 mm; $p=0.049$) and did not find it to be an independent predictor. Differences in population, obesity and ultrasound measurement sites may explain these variations.

DSE was significantly greater in difficult laryngoscopy (2.58 ± 0.38 vs 2.05 ± 0.32 cm; $p<0.001$) and showed the strongest positive correlation with CL grade ($p=0.56$; $p<0.001$). Skin-to-hyoid distance was also greater (1.26 ± 0.24 vs 1.05 ± 0.20 cm; $p=0.001$; $\rho=0.39$, $p<0.001$), supporting the association between increased anterior airway depth and difficult glottic visualization.

Tongue thickness was greater in difficult laryngoscopy (5.67 ± 0.65 vs 5.15 ± 0.61 cm; $p=0.004$) and correlated with CL grade ($p=0.32$; $p=0.004$). Wojtczak[13], however, found no significant difference in tongue volume between difficult and easy intubation groups (137 ± 29 vs 168 ± 34 cm³). This difference may reflect variation in measurement methodology and the small sample size in Wojtczak's study.

HMD_e (5.43 ± 0.57 vs 6.18 ± 0.59 cm; $p<0.001$) and HMD_r (1.17 ± 0.07 vs 1.26 ± 0.08 ; $p<0.001$) were significantly lower in difficult laryngoscopy. HMD_r showed a strong inverse correlation with CL grade ($p=-0.52$; $p<0.001$). Wojtczak [13] similarly reported lower HMD_r in difficult versus easy intubation (1.02 ± 0.01 vs 1.14 ± 0.02 ; $p<0.002$). Petrisor et al. [14] found that an HMD_r cut-off of 1.23 predicted difficult laryngoscopy with 100%

sensitivity and 90.5% specificity, supporting HMD_r as a useful ultrasound predictor.

DSE >2.30 cm showed the highest diagnostic performance in our study, with an AUC of 0.87, sensitivity of 80.0%, specificity of 83.1%, PPV of 52.2% and NPV of 94.7%. HMD_r <1.20 showed an AUC of 0.84 with 80.0% sensitivity and 80.0% specificity, while Pre-E/E-VC >1.50 showed an AUC of 0.81, sensitivity of 73.3% and specificity of 78.5%. Petrisor et al.[14] and Egger et al. [15] reported even higher performance for HMD_r at a cut-off of 1.23 (sensitivity 100%, specificity 90.5%), although differences in study population and sample size may account for variation in thresholds.

On multivariable analysis, DSE >2.30 cm (AOR 5.42; 95% CI 1.42–20.68; $p=0.013$), HMD_r <1.20 (AOR 4.31; 95% CI 1.16–16.05; $p=0.030$), and Mallampati III–IV (AOR 3.76; 95% CI 1.01–14.02; $p=0.049$) independently predicted difficult laryngoscopy, whereas BMI ≥ 25 kg/m² did not (AOR 1.82; $p=0.378$). Overall, these findings support DSE and HMD_r as useful objective adjuncts to conventional airway assessment, while the differing observations of Ezri et al.[11], Komatsu et al.[12], Wojtczak[13], and Petrisor et al.[14] indicate that ultrasound cut-offs may vary across populations.

CONCLUSION

Airway ultrasonography was useful for predicting difficult laryngoscopy, with DSE and HMD_r demonstrating the best diagnostic performance. Increased DSE and reduced HMD_r were independently associated with difficult laryngoscopy. Ultrasound may therefore serve as a useful objective adjunct to conventional preoperative airway assessment.

Limitations

The study was limited by its relatively small sample size, single-centre design, and small number of difficult laryngoscopy cases. Ultrasound measurements are operator-dependent, and the identified cut-offs require validation in larger multicentre populations.

REFERENCES

1. Cook TM, Macdougall-Davis SR. Complications and failure of airway management. Br J Anaesth. 2012;109 Suppl 1:i68-85.
2. 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;106:617-31.
3. O'Dell K. Predictors of difficult intubation and the otolaryngology perioperative consult. *Anesthesiol Clin*. 2015;33:279-90.
4. Shirgoska B, Netkovski J. Predicting difficult airway in apparently normal adult and pediatric patients. *Pril (Makedon Akad Nauk Umet Odd Med Nauki)*. 2013;34:155-9.
5. Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology*. 2013;118:251-70.
6. Crawley S, Dalton A. Predicting the difficult airway. *BJA Educ*. 2015;15:253-7.
7. Bajracharya G, Truong A, Truong D, Cata J. Ultrasound-assisted evaluation of the airway in clinical anesthesia practice: past, present and future. *Int J Anesthesiol Pain Med*. 2015;1:1-10.
8. Kristensen MS. Ultrasonography in the management of the airway. *Acta Anaesthesiol Scand*. 2011;55:1155-73.
9. Petrișor C, Dîrzu D, Trancă S, Hagău N, Bodolea C. Preoperative difficult airway prediction using suprahyoid and infrahyoid ultrasonography derived measurements in anesthesiology. *Med Ultrason*. 2019;21:83-8.
10. Wojtczak JA. Submandibular sonography: assessment of hyomental distances and ratio, tongue size, and floor of the mouth musculature using portable sonography. *J Ultrasound Med*. 2012;31:523-8.
11. Ezri T, Gewürtz G, Sessler DI, Medalion B, Szumuk P, Hagberg C, et al. Prediction of difficult laryngoscopy in obese patients by ultrasound quantification of anterior neck soft tissue. *Anaesthesia*. 2003;58:1111-4.
12. Komatsu R, Sengupta P, Wadhwa A, Akça O, Sessler DI, Ezri T, et al. Ultrasound quantification of anterior soft tissue thickness fails to predict difficult laryngoscopy in obese patients. *Anaesth Intensive Care*. 2007;35:32-7.
13. Wojtczak JA. Submandibular sonography: assessment of hyomental distances and ratio, tongue size, and floor of the mouth musculature using portable sonography. *J Ultrasound Med*. 2012;31:523-8.
14. Petrișor C, Szabo R, Constantinescu C, Prie A, Hagau N. Ultrasound-based assessment of hyomental distances in neutral, ramped, and maximum hyperextended positions, and derived ratios, for the prediction of difficult airway in the obese population: a pilot diagnostic accuracy study. *Anesthesiol Intensive Ther*. 2018;50:110-6.
15. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ*. 1997;315:629-34.