



Original Article

Clinical and Radiological Predictors of Difficult Laryngoscopy and Intubation: A Prospective Observational Study

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ABSTRACT

Background: Unanticipated difficult laryngoscopy and intubation remain important preventable contributors to perioperative airway morbidity. Bedside airway tests are widely used, yet their predictive performance varies across populations. Radiological airway measurements have been explored as adjuncts, but their value in routine preoperative assessment remains uncertain.

Objectives: To evaluate and compare clinical and lateral radiographic predictors of difficult laryngoscopy and intubation among adult patients undergoing elective surgery under general anaesthesia.

Methods: This prospective observational study included 60 patients aged 18-60 years, belonging to American Society of Anaesthesiologists physical status I-II, scheduled for elective surgery requiring endotracheal intubation. Preoperative clinical assessment included modified Mallampati class, inter-incisor gap, thyromental distance, sternomental distance, and Wilson sum risk score. Lateral radiographic variables included anterior mandibular depth, posterior mandibular depth, effective mandibular length, atlanto-occipital distance, mandibulo-hyoid distance, radiological thyromental distance, and distance between the temporomandibular joint and inferior edge of C4. Difficult intubation was defined by Cormack-Lehane grade III or IV.

Results: Difficult intubation was observed in 12 patients. Modified Mallampati classification showed the highest sensitivity among clinical predictors, followed by thyromental distance, sternomental distance, and inter-incisor gap. Thyromental distance and Wilson sum risk score showed 100% specificity. Among radiological variables, atlanto-occipital distance showed the strongest diagnostic performance, with high sensitivity and specificity. Most other radiographic measurements showed weaker standalone discrimination. Age was significantly associated with difficult intubation, whereas sex was not.

Conclusion: Clinical airway tests, particularly modified Mallampati class, thyromental distance, sternomental distance, and inter-incisor gap, were useful predictors of difficult intubation. Atlanto-occipital distance was the most informative radiological predictor. Combined clinical and radiological assessment provides a more complete preoperative airway evaluation than isolated measurements.

Keywords: Difficult intubation; difficult laryngoscopy; airway assessment; Cormack-Lehane grading; Mallampati classification; thyromental distance.

INTRODUCTION

Safe airway control is a core responsibility in anaesthetic practice, and tracheal intubation under direct laryngoscopy continues to be a common method for securing the airway during general anaesthesia. Current difficult airway guidelines emphasise systematic preoperative assessment, preparation of rescue devices, and prompt use of alternative strategies

when laryngoscopy or ventilation is problematic [1]. The clinical concern is not limited to failed intubation. Poor glottic exposure can produce repeated attempts, airway trauma, hypoxaemia, haemodynamic instability, aspiration risk, and delayed surgery. The Cormack-Lehane classification remains a practical intraoperative grading system for the laryngoscopic view and is widely used in research to define difficult laryngoscopy [2].

Prediction of difficult intubation is challenging because airway anatomy is influenced by several interacting factors, including oral cavity size, mandibular mobility, submandibular space, cervical spine extension, body habitus, and laryngeal position. The Mallampati test and its Samssoon and Young modification are simple bedside tools that assess oropharyngeal visibility and tongue-palate disproportion [3,4]. Thyromental distance, sternomental distance, inter-incisor gap, and multicomponent scores such as the Wilson sum risk score were developed to improve prediction beyond a single clinical observation [5-7]. Nevertheless, previous studies and meta-analyses have shown that no isolated test has consistent accuracy across all settings, and that sensitivity is often sacrificed when specificity is high [12,13].

Radiological airway assessment offers a different perspective because lateral cervical imaging can quantify mandibular depth, atlanto-occipital space, hyoid position, and relationships between the mandible, larynx, and cervical spine. These variables are biologically plausible predictors because direct laryngoscopy requires alignment of airway axes, adequate mouth opening, forward displacement of the mandible, and sufficient submandibular space for tongue accommodation. Earlier work on clinical-radiological models suggested that imaging variables could strengthen multivariate prediction, although their usefulness as independent screening tools remains uncertain [8,14]. In routine practice, a feasible approach is to identify which clinical and radiological variables show the best discrimination in the local surgical population.

The present study was conducted with the objective of evaluating and comparing selected clinical and lateral radiographic variables for prediction of difficult laryngoscopy and intubation in adult elective surgical patients. The clinical predictors assessed were modified Mallampati class, inter-incisor gap, thyromental distance, sternomental distance, and Wilson sum risk score. The radiological predictors assessed were anterior mandibular depth, posterior mandibular depth, effective mandibular length, atlanto-occipital distance, mandibulo-hyoid distance, radiological thyromental distance, and distance between the superior temporomandibular joint and inferior edge of the C4 vertebra.

METHODOLOGY

Study design and setting

This prospective observational study was conducted in the Department of Anaesthesiology, Gandhi Medical College and Hospital, Secunderabad, from September 2022 to February 2024. The study was designed to compare preoperative airway assessment findings with the laryngoscopic view obtained during standardised general anaesthesia. Institutional ethics committee clearance was obtained, and written informed consent was taken from all participants before surgery.

Study population

The study included 60 adult patients aged 18-60 years of either sex, belonging to American Society of Anaesthesiologists physical status I or II, scheduled for elective surgery requiring general anaesthesia with endotracheal intubation. Patients undergoing emergency surgery or rapid sequence induction were excluded. Other exclusion criteria were edentulous status or absence of upper and lower incisors, obvious oral or neck malformation, upper airway tumours, and pregnancy.

Preoperative airway assessment

All participants underwent routine pre-anaesthetic evaluation, general physical examination, laboratory investigations, electrocardiography, and chest radiography as clinically indicated. Clinical airway assessment included modified Mallampati classification as described by Samssoon and Young, inter-incisor gap, thyromental distance, sternomental distance, and Wilson sum risk score [3-5,10,11]. Modified Mallampati classes III and IV, inter-incisor gap below 4 cm, thyromental distance below 6 cm, sternomental distance below 12 cm, and Wilson score above 2 were considered indicators of difficult intubation. Radiological assessment was performed on lateral neck radiographs by a radiologist blinded to the clinical assessment. The radiographic measurements were anterior mandibular depth, posterior mandibular depth, effective mandibular length, atlanto-occipital distance, mandibulo-hyoid distance, thyromental distance, and distance between the superior temporomandibular joint and inferior edge of C4 [8,14].

Anaesthesia and laryngoscopy protocol

A difficult airway cart was kept ready before induction. Patients received standard premedication and monitoring, including electrocardiography, non-invasive blood pressure, and pulse oximetry. After preoxygenation with 100% oxygen for three minutes, anaesthesia was induced with intravenous propofol 2 mg/kg and succinylcholine 1.5 mg/kg. Laryngoscopy was performed in the sniffing position using an appropriate Macintosh blade. The laryngoscopic view was graded using the Cormack-Lehane system [2]. When exposure was poor, optimal external laryngeal manipulation, change of blade, McCoy blade, stylet, or gum elastic bougie was used according to clinical need [1].

Outcome definition and statistical analysis

The primary outcome was difficult intubation, defined as Cormack-Lehane grade III or IV. Grades I and II were categorised as easy intubation. Diagnostic performance was evaluated using true positive, false positive, true negative, and false negative counts. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for each predictor. Continuous variables were summarised as mean and standard deviation. Categorical variables were summarised as frequency and percentage. Association between predictors and difficult intubation was evaluated using cross-tabulation and univariate analysis, with $p < 0.05$ considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee of Gandhi Medical College and Hospital, Secunderabad, before study initiation. Written informed consent was secured from all participants, and confidentiality, voluntary participation, and ethical conduct were maintained throughout the study period.

RESULTS

A total of 60 patients were included in the final analysis. The mean age of the study population was 37.72 ± 10.72 years. The largest proportion of patients belonged to the 31-40 years age group, followed by the 41-50 years age group. Males constituted 53.3% of the cohort and females constituted 46.7%. The demographic profile is presented in Table 1.

Table 1. Demographic profile of the study population

Variable	Category	Number	Percentage
Age group	18-20 years	3	5.0
	21-30 years	13	21.7
	31-40 years	21	35.0
	41-50 years	16	26.7
	51-60 years	7	11.7
	Total		60
Mean age	Mean +/- SD	37.72 +/- 10.72 years	
Sex	Male	32	53.3
	Female	28	46.7
	Total	60	100.0

The laryngoscopic view was Cormack-Lehane grade I in 31 patients and grade II in 17 patients. Grade III was observed in 10 patients and grade IV in 2 patients. Therefore, difficult intubation, defined as grade III or IV, was present in 12 patients, giving an incidence of 20.0%. The distribution of laryngoscopic grades is shown in Table 2.

Table 2. Cormack-Lehane laryngoscopic grading

Cormack-Lehane grade	Number	Percentage	Interpretation
Grade I	31	51.7	Easy intubation
Grade II	17	28.3	Easy intubation
Grade III	10	16.7	Difficult intubation
Grade IV	2	3.3	Difficult intubation
Total	60	100.0	

Age showed a significant association with difficult intubation. The mean age was higher among patients with difficult intubation than among those with easy intubation. Half of the difficult intubations occurred in the 41-50 years age group. Sex was not significantly associated with difficult intubation. The age-wise and sex-wise distribution according to intubation difficulty is shown in Table 3.

Table 3. Age and sex distribution according to intubation difficulty

Variable	Category	Easy intubation n (%)	Difficult intubation n (%)	p value
Age group	18-20 years	3 (6.2)	0 (0.0)	0.041
	21-30 years	11 (22.9)	2 (16.7)	
	31-40 years	19 (39.6)	2 (16.7)	
	41-50 years	10 (20.8)	6 (50.0)	
	51-60 years	5 (10.4)	2 (16.7)	
Mean age	Mean +/- SD	36.31 +/- 10.64	43.33 +/- 9.45	0.041
Sex	Male	27 (56.2)	5 (41.7)	0.365
	Female	21 (43.8)	7 (58.3)	

Among the clinical predictors, modified Mallampati classification demonstrated the highest sensitivity and negative predictive value. Thyromental distance showed 91.7% sensitivity and 100% specificity, with a positive predictive value of 100%. Inter-incisor gap and sternomental distance also showed high diagnostic performance. Wilson sum risk score was highly specific but had lower sensitivity. The diagnostic performance of clinical predictors is summarised in Table 4.

Table 4. Diagnostic performance of clinical predictors for difficult intubation

Clinical predictor	TP	FP	TN	FN	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Modified Mallampati class	10	2	48	0	100	96.0	83.3	100
Inter-incisor gap	10	1	47	2	83.3	97.9	90.9	95.9
Thyromental distance	11	0	48	1	91.7	100	100	97.9
Sernomental distance	10	3	46	1	90.9	93.9	76.9	97.9
Wilson sum risk score	7	0	49	4	63.6	100	100	93.3

TP: true positive; FP: false positive; TN: true negative; FN: false negative; PPV: positive predictive value; NPV: negative predictive value.

Among radiological variables, atlanto-occipital distance showed the strongest performance, with 91.7% sensitivity, 93.8% specificity, 78.6% positive predictive value, and 97.8% negative predictive value. Other radiological parameters, including anterior mandibular depth, posterior mandibular depth, mandibulo-hyoid distance, and the TMJ-C4 distance, showed lower discrimination when used alone. The diagnostic performance of radiological predictors is shown in Table 5.

Table 5. Diagnostic performance of radiological predictors for difficult intubation

Radiological predictor	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Anterior mandibular depth	72.7	51.0	25.1	89.3
Posterior mandibular depth	50.0	52.0	17.2	83.9
Effective mandibular length	63.6	67.4	30.4	89.2
Atlanto-occipital distance	91.7	93.8	78.6	97.8
Mandibulo-hyoid distance	45.5	59.2	20.0	82.9
Radiological thyromental distance	72.7	90.2	61.5	93.9
TMJ to inferior edge of C4 distance	54.6	55.1	21.4	84.4

Univariate analysis of clinical variables showed significant differences between easy and difficult intubation groups for age, modified Mallampati class, inter-incisor gap, thyromental distance, sternomental distance, and Wilson sum risk score. Gender was not statistically significant. Among radiological variables, only the atlanto-occipital distance showed a statistically significant difference between the two groups. The detailed univariate findings are presented in Table 6.

Table 6. Univariate comparison of clinical and radiological variables

Variable	Easy intubation	Difficult intubation	p value
Age (years)	36.31 +/- 10.64	43.33 +/- 9.45	0.041
Gender - male/female	27/21	5/7	0.365
Modified Mallampati class I/II/III/IV	40/2/4/0	0/8/2/2	<0.001
Inter-incisor gap (cm)	5.41 +/- 0.29	4.53 +/- 0.44	<0.001
Thyromental distance (cm)	8.25 +/- 0.78	6.49 +/- 0.94	<0.001
Sernomental distance (cm)	18.76 +/- 1.67	13.85 +/- 2.75	<0.001

Variable	Easy intubation	Difficult intubation	p value
Wilson sum risk score	0 (1-0)	2 (0-4)	<0.001
Anterior mandibular depth (cm)	4.44 +/- 0.42	4.57 +/- 0.39	0.329
Posterior mandibular depth (cm)	2.61 +/- 0.39	2.65 +/- 0.35	0.717
Effective mandibular length (cm)	10.35 +/- 0.86	10.83 +/- 0.97	0.101
Occiput-C1 spinous process distance (cm)	1.01 +/- 0.25	0.53 +/- 0.14	<0.001
Mandibulo-hyoid distance (cm)	1.41 +/- 0.39	1.47 +/- 0.41	0.329
Radiological thyromental distance (cm)	8.18 +/- 0.82	7.89 +/- 0.64	0.265
TMJ to inferior edge of C4 distance (cm)	8.39 +/- 0.28	8.39 +/- 0.29	0.946

DISCUSSION

This prospective observational study evaluated commonly used bedside tests and selected lateral radiographic measurements for predicting difficult laryngoscopy and intubation. The incidence of difficult intubation was 20.0% when Cormack-Lehane grades III and IV were used as the operational definition. This proportion is higher than rates reported in several large general surgical series, where differences in population structure, sample size, definition of difficulty, and operator factors influence incidence estimates [9,12]. The finding reinforces the need for routine airway assessment even in patients without obvious external airway deformity.

Among clinical predictors, the modified Mallampati classification performed best, with complete sensitivity and a high negative predictive value. This supports its value as a rapid screening tool, although previous meta-analyses have shown variable accuracy when the test is used alone [3,12,13]. The strong performance in the present cohort likely reflects strict technique, uniform patient positioning, and use of grades III and IV as the abnormal threshold. Thyromental distance also showed excellent diagnostic utility, with high sensitivity and complete specificity. This result is anatomically plausible because a shorter thyromental distance indicates reduced submandibular space, limiting tongue displacement during laryngoscopy [6,7].

Sternomental distance and inter-incisor gap showed good sensitivity and specificity. Sternomental distance represents a composite estimate of mandibular space and head-neck extension, and its usefulness has been described in previous clinical studies [10,11]. Inter-incisor gap reflects mouth opening and temporomandibular mobility, both essential for blade insertion and manipulation. Wilson sum risk score was highly specific but less sensitive, indicating that a high score identifies a high-risk patient, while a low score cannot exclude all difficult laryngoscopies. This agrees with earlier concerns that multicomponent bedside scores improve structure but still leave residual prediction error [5,7,12].

The radiological component showed a clear pattern. Atlanto-occipital distance was the only radiographic variable with strong diagnostic performance and statistical significance in univariate analysis. Reduced atlanto-occipital space limits head extension and impairs alignment of the oral, pharyngeal, and laryngeal axes during direct laryngoscopy. Other radiographic measures, including mandibular depths, effective mandibular length, mandibulo-hyoid distance, and radiological thyromental distance, were weak as isolated predictors. This observation is consistent with work suggesting that imaging variables are more useful when integrated into multivariate models rather than applied as standalone screening tools [8,14].

The clinical implication is practical. A simple preoperative assessment combining modified Mallampati class, mouth opening, thyromental distance, sternomental distance, and Wilson score can identify many patients at risk. Lateral radiographic atlanto-occipital distance adds information on cervical extension where imaging is available. No single test should be treated as definitive. A combined approach permits early preparation of adjuncts such as optimal external laryngeal manipulation, bougie, McCoy blade, videolaryngoscope, or fiberoptic equipment, consistent with modern difficult airway recommendations.

Limitations

The study was conducted at a single tertiary-care centre with a modest sample size, limiting subgroup analysis. Only elective ASA I-II patients aged 18-60 years were included, so findings do not extend to emergency cases, pregnancy, paediatric patients, severe obesity, or major airway pathology. Radiological assessment used lateral X-ray measurements only, without ultrasound, computed tomography, or interobserver reliability testing across independent observers.

CONCLUSION

In this prospective study, difficult intubation occurred in one-fifth of adult elective surgical patients. Modified Mallampati classification, thyromental distance, sternomental distance, inter-incisor gap, and Wilson sum risk score were useful clinical predictors, with modified Mallampati class showing the highest sensitivity and thyromental distance showing excellent specificity. Among radiological measurements, atlanto-occipital distance was the most informative standalone predictor, while other mandibular and hyoid measurements showed limited independent value. These findings support a combined preoperative airway assessment strategy rather than reliance on any single bedside or radiological measure. Early recognition of abnormal predictors helps the anaesthesiologist prepare appropriate adjuncts and reduce avoidable airway-related complications in routine elective surgical anaesthesia and patient risk.

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