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Research Article

Role of Preoperative Radiological Assessment in Predicting Difficult Airway Management during General Anesthesia

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ABSTRACT

Background: Difficult airway management continues to be a significant cause of perianesthetic complications under general anesthesia. While conventional bedside airway exams are helpful, they may not be sufficient to detect internal anatomical abnormalities which can lead to difficult laryngoscopy and tracheal intubation. Radiological evaluation before surgery might be useful to provide objective parameters of airway structures, and help predict airway difficulty.

Objective: To evaluate the role of preoperative radiological airway assessment in predicting difficult airway management during general anesthesia.

Methods: This prospective observational study was conducted at Islamabad Diagnostic Centre, Islamabad, from January 2025 to June 2025 and included 85 adult patients undergoing elective procedures under general anesthesia with endotracheal intubation. The Mallampati classification, thyromental distance, sternomental distance, inter-incisor distance, neck circumference and cervical extension were performed as a part of the pre-operative clinical assessment of the airway. Radiological parameters measured were skin to epiglottis distance, tongue thickness, pre-epiglottis space, hyomental distance, hyomental distance ratio and mandibular length. Intraoperative airway difficulty was evaluated by Cormack-Lehane grade, number of intubations, intubation time, first-pass success and need for adjunct airway devices. The predictive performance was calculated using ROC curve analysis and multivariable logistic regression.

Results: Difficult airway management was observed in 19 (22.4%) patients, while 66 (77.6%) had an easy airway. Patients with difficult airways had significantly greater skin-to-epiglottis distance (25.8 ± 3.6 vs 20.4 ± 3.2 mm; $p < 0.001$) and tongue thickness (59.3 ± 6.1 vs 52.1 ± 5.7 mm; $p < 0.001$), together with lower hyomental distance and hyomental distance ratio. Skin-to-epiglottis distance showed the highest predictive accuracy, with an AUC of 0.86, sensitivity of 84.2%, and specificity of 80.3% at a cut-off of >23.5 mm. Tongue thickness and hyomental distance ratio showed AUCs of 0.82 and 0.80, respectively. Increased skin-to-epiglottis distance, increased tongue thickness, and Mallampati class III-IV remained independent predictors of difficult airway management.

Conclusion: Preoperative radiological assessment can provide valuable objective information for prediction of difficult airway management. Skin-to-epiglottis distance showed the strongest predictive ability and may be particularly useful when combined with conventional bedside airway examination.

Keywords: Difficult Airway, Radiological Assessment, General Anesthesia, Tracheal Intubation, Skin-To-Epiglottis Distance, Airway Prediction.

INTRODUCTION

Airway management is a basic skill of a safe general anaesthetic and an undiagnosed difficult airway before induction can result in significant peri-operative complications. Hypoxemia, air way injury, aspiration, cardiovascular instability, emergency surgical airway, and even permanent neurological damage or death may occur in the event of difficult laryngoscopy or tracheal intubation.

Therefore, correct identification of patients with a higher risk for airway problems is an integral component in the anesthetic assessment and can enable the preparation of other airway devices and the appropriate management strategies (1, 2).

There are several tests routinely performed to assess the risk of difficult laryngoscopy and intubation. They are the modified Mallampati classification, thyromental distance, sternomental distance, inter-incisor distance, neck circumference, upper lip bite test, and an assessment of the cervical spine mobility. These are inexpensive and simple tests, but also have a lot of variation in the diagnostic accuracy. There is no single bedside test that has proven to be sufficiently sensitive and specific to reliably predict all airways that are difficult. The intricate structure of the upper airway and the varying distribution of soft-tissues can be the reason why some patients who are difficult to intubate have normal external measurements (3, 4).

A radiological assessment allows an opportunity to assess anatomical features that are not adequately seen at a routine physical examination. The measurements like skin to epiglottis distance, tongue thickness, pre-epiglottic soft tissue space, hyomental distance, mandibular dimensions and space of the pharyngeal airway can represent the anatomical relationship between tongue, epiglottis, mandible and surrounding tissues. Thickening of the soft tissues in the anterior part of the neck and/or an enlarged tongue can obscure the glottis, whereas if the hyomental or mandibular length is shorter, it may mean that there is less room to move the tongue during laryngoscopy. These anatomical characteristics can thus serve as a predictor of airways difficulties prior to an anesthesia (5, 6).

The recent development of imaging technology has led to a growing interest in using objective radiological or ultrasonographic measurements of the airway during the preoperative assessment. Radiological assessment should be particularly helpful in obese patients, craniofacial abnormalities, cervical spine disease, and in patients with poor airway assessment at the bedside. Besides being used to identify patients at risk, objective imaging measurements could lead to clinically meaningful cut-offs and the inclusion of these values in multivariable prediction models. The relative value of individual radiological parameters, however, is variable and their practical use in combination with the classical clinical airway tests, still needs to be assessed (7-9).

The present study was therefore conducted to assess the role of preoperative radiological airway measurements in predicting difficult airway management during general anesthesia. The study specifically evaluated the relationship of skin-to-epiglottis distance, tongue thickness, pre-epiglottic space, hyomental distance, hyomental distance ratio, and mandibular length with subsequent difficulty during laryngoscopy and endotracheal intubation. It also aimed to determine the diagnostic performance of these parameters and identify the radiological measurements that independently predict difficult airway management.

METHODOLOGY

This prospective observational study was conducted at Islamabad Diagnostic Centre**,** Islamabad, from January 2025 to June 2025. A total of 85 adult patients scheduled to undergo elective surgical procedures under general anesthesia with endotracheal intubation were included. Patients were enrolled using a consecutive non-probability sampling technique after fulfillment of the predefined eligibility criteria. Written informed consent was taken from all participants. Patients aged 18 years or above who required general anesthesia with planned tracheal intubation were eligible. Patients requiring emergency surgery, those with facial or upper-airway trauma, previously diagnosed upper-airway tumors, severe maxillofacial deformity, tracheostomy, cervical spine instability, or inability to undergo the planned radiological examination were excluded.

Demographic and clinical data was taken on a structured proforma before surgery, such as age, sex, weight, height, BMI, ASA physical status, presence of known difficult intubation history and the presence of relevant comorbidities. A standard bedside airway examination was then conducted by an anaesthesiologist who was not part of the radiological measurements interpretation. The clinical examination involved modified Mallampati classification, thyromental distance, sternomental distance, inter-incisor distance, neck circumference and observation of cervical neck extension. The Mallampati class was evaluated when the patient was seated and had his or her mouth opened wide with the tongue fully extended and not phonating. The inter-incisor distance was measured when the mouth was maximally open, thyromental distance and sternomental distance were measured with the head fully extended. These findings were documented pre-anaesthetic, and then correlated with the radiological and intraoperative findings of airways.

Radiological assessment of airways was done before surgery in a standard manner using the imaging facilities available at Islamabad Diagnostic Centre. Measurements were taken with the patient in the same position to minimise variation between examinations. They examined the following parameters: skin-to-epiglottis distance, tongue thickness, pre-epiglottis soft-tissue space, hyomental distance, hyomental distance ratio, and mandibular length. When applicable measurements were taken in the mid-sagittal plane and recorded in millimetres or centimetres. Hyomental distance ratio was calculated as a ratio of distances between the hyoma and mental tuberosity in different head positions following the departmental imaging protocol. All measurements were pre-surgery and the radiological assessor was blinded to the laryngoscopic grade and the difficulty of intubation following surgery to minimize observer bias. If more than one measurement was taken, an average was used for purposes of analysis.

Prior to induction of anesthesia on the day of surgery, standard monitoring was used, such as non-invasive blood pressure, electrocardiography, and pulse oximetry. General anesthesia was administered using the standard method of induction used in the institution, and then a suitable neuromuscular blocking agent was administered. Once the muscles were relaxed, direct laryngoscopy was carried out by an anesthesiologist who had the necessary experience in airway management. The laryngoscopic view was recorded using the Cormack-Lehane classification where grades I and II were regarded as relatively good views and grades III and IV as difficult laryngoscopy. Airway-management variables were: First pass success, number of intubation attempts, total intubation time, external laryngeal manipulation, bougie/stylet use, video laryngoscopy and use of any other airway device. An "airway" was considered "difficult" if the laryngoscopic picture was difficult and/or more than one attempt or other airway maneuvers were required to successfully intubate the trachea.

The data were analysed in IBM SPSS Statistics version 26. Data was presented as mean ± standard deviation if the variables were approximately normally distributed, and frequencies and percentages if the variables were categorical. The independent-samples t test was used to compare radiological measurements between the easy-airway and difficult-airway groups; the chi-squared test or Fisher's exact test was used, when suitable. Receiver operating characteristic (ROC) curve analysis was carried out to identify the predictive value of the radiological factors for difficult airway management. The area under the curve (AUC), optimal cut-off value, sensitivity, specificity, positive predictive value, negative predictive value and 95% confidence interval were computed. Multivariably binary logistic regression was used to determine the independent predictors of DAM when variables with clinically relevant or statistically significant associations were entered into the model and results presented as adjusted odds ratios with 95% confidence intervals. A p-value <0.05 was considered statistically significant.

RESULTS

There were 85 patients in general anesthesia who were endotracheally intubated that were included in the analysis. The average age of the participants was 42.6 ± 13.1 years, and the average BMI was 26.8 ± 3.9 kg/m². There were 47 (55.3%) males and 38 (44.7%) females. The majority of the patients had ASA physical status I and II. Difficult airway management was seen in 19 (22.4%) patients while an uncomplicated airway was seen in 66 (77.6%) patients.

Table 1. Baseline Demographic and Clinical Characteristics of the Study Participants (N = 85)

Variable	Result
Age, years, mean ± SD	42.6 ± 13.1
Male, n (%)	47 (55.3)
Female, n (%)	38 (44.7)
BMI, kg/m², mean ± SD	26.8 ± 3.9
ASA I, n (%)	31 (36.5)
ASA II, n (%)	42 (49.4)
ASA III, n (%)	12 (14.1)

History of previous difficult intubation, n (%)	6 (7.1)
Difficult airway, n (%)	19 (22.4)
Easy airway, n (%)	66 (77.6)

On clinical evaluation of the airway prior to the surgery, 21 (24.7%) had Mallampati class III or IV. Those patients who went on to have a difficult airway were more likely to have a higher Mallampati grade, shorter thyromental distance, larger neck circumference and less mouth opening.

Table 2. Preoperative Clinical Airway Assessment

Variable	**Overall (n = 85)**
Mallampati I, n (%)	24 (28.2)
Mallampati II, n (%)	40 (47.1)
Mallampati III, n (%)	16 (18.8)
Mallampati IV, n (%)	5 (5.9)
Thyromental distance, cm, mean ± SD	6.7 ± 0.8
Sternomental distance, cm, mean ± SD	13.4 ± 1.5
Inter-incisor distance, cm, mean ± SD	4.3 ± 0.7
Neck circumference, cm, mean ± SD	38.7 ± 4.2
Restricted neck extension, n (%)	13 (15.3)

Patients with easy versus difficult airways were shown to be measurable differences with radiological assessment. The difficult airway group had a mean skin to epiglottis distance of 25.8 ± 3.6 mm and the easy airway group 20.4 ± 3.2 mm. Similarly, tongue thickness and pre-epiglottic soft-tissue thickness were greater among patients with difficult airway management. The hyomental distance and the hyomental distance ratio were, however, smaller in the difficult-airway group.

Table 3. Comparison of Preoperative Radiological Airway Measurements between Easy and Difficult Airway Groups

Radiological parameter	**Easy airway (n = 66)**	**Difficult airway (n = 19)**	**p-value**
Skin-to-epiglottis distance, mm	20.4 ± 3.2	25.8 ± 3.6	<0.001
Tongue thickness, mm	52.1 ± 5.7	59.3 ± 6.1	<0.001
Pre-epiglottic space, mm	11.7 ± 2.4	14.6 ± 2.8	<0.001
Hyomental distance, cm	5.7 ± 0.6	4.9 ± 0.7	<0.001
Hyomental distance ratio	1.23 ± 0.12	1.08 ± 0.11	<0.001
Mandibular length, cm	10.2 ± 0.9	9.6 ± 0.8	0.011

During direct laryngoscopy, 58 (68.2%) patients had Cormack–Lehane grade I, 18 (21.2%) had grade II, 7 (8.2%) had grade III and 2 (2.4%) had grade IV. Intubation was successful in the first attempt in 70 (82.4%) patients. Two or more attempts were necessary in 15 (15.5%) patients and external laryngeal manipulation was needed in 13 (15.3%). Eleven (12.9%) patients required the use of a bougie or stylet and 7 (8.2%) patients had to have video laryngoscopy performed.

Table 4. Intraoperative Airway-Management Outcomes

Airway outcome	**n (%)**
Cormack–Lehane grade I	58 (68.2)
Cormack–Lehane grade II	18 (21.2)
Cormack–Lehane grade III	7 (8.2)
Cormack–Lehane grade IV	2 (2.4)
First-pass intubation success	70 (82.4)
≥2 intubation attempts	15 (17.6)
External laryngeal manipulation required	13 (15.3)
Bougie/stylet required	11 (12.9)

Video laryngoscope required	7 (8.2)
Difficult airway management	19 (22.4)

Intubation time significantly exceeded the mean intubation time of patients with an easy airway (24.9 ± 8.2 seconds) in patients with difficult airways (48.7 ± 13.5 seconds; p < 0.001). The difficult-airway group also had significantly poorer first-pass success, and significantly higher need for adjunct airway devices.

Table 5. Airway-Management Characteristics According To Airway Difficulty

Variable	Easy airway (n = 66)	Difficult airway (n = 19)	p-value
Intubation time, seconds	24.9 ± 8.2	48.7 ± 13.5	<0.001
First-pass success, n (%)	62 (93.9)	8 (42.1)	<0.001
≥2 attempts, n (%)	4 (6.1)	11 (57.9)	<0.001
External laryngeal manipulation, n (%)	4 (6.1)	9 (47.4)	<0.001
Bougie/stylet use, n (%)	3 (4.5)	8 (42.1)	<0.001
Video laryngoscope use, n (%)	1 (1.5)	6 (31.6)	<0.001

The skin-to-epiglottis distance demonstrated the best discriminatory ability to predict difficult airway management using the receiver operating characteristic analysis (ROC) with an AUC of 0.86. The sensitivity and specificity of 23.5 mm was 84.2% and 80.3%, respectively. The hyomental distance ratio also had good diagnostic performance with an AUC of 0.80, and the thickness of the tongue was also good with an AUC of 0.82.

Table 6. Diagnostic Performance of Radiological Parameters for Prediction of Difficult Airway

Predictor	Cut-off value	Sensitivity (%)	Specificity (%)	AUC	95% CI	p-value
Skin-to-epiglottis distance	>23.5 mm	84.2	80.3	0.86	0.77–0.94	<0.001
Tongue thickness	>56.5 mm	78.9	75.8	0.82	0.72–0.91	<0.001
Pre-epiglottic space	>13.0 mm	73.7	72.7	0.77	0.65–0.88	<0.001
Hyomental distance	<5.2 cm	73.7	77.3	0.79	0.68–0.89	<0.001
Hyomental distance ratio	<1.14	78.9	74.2	0.80	0.70–0.90	<0.001

Increased skin-to-epiglottis distance was still an independent predictor of difficult airway management after adjusting for selected clinical variables in multivariable logistic regression analysis. For every mm increase in skin to epiglottis distance, there was a 4.7-fold increase in the odds of a difficult airway. Mallampati class III-IV and presence of a thick tongue were also found to be independent risk factors for difficult airway management.

Table 7. Multivariable Logistic Regression Analysis for Predictors of Difficult Airway Management

Predictor	Adjusted OR	95% CI	p-value
Skin-to-epiglottis distance >23.5 mm	4.71	1.61–13.78	0.005
Tongue thickness >56.5 mm	3.28	1.12–9.63	0.031
Mallampati class III–IV	3.76	1.21–11.68	0.022
Neck circumference >40 cm	2.41	0.82–7.08	0.109
Hyomental distance ratio <1.14	2.89	1.01–8.31	0.048

Overall, the findings demonstrated a significant relationship between selected preoperative radiological airway measurements and subsequent difficulty during airway management. Among the evaluated parameters, skin-to-epiglottis distance showed the strongest predictive ability, followed by tongue thickness and hyomental distance ratio. These findings indicate that incorporating radiological airway assessment alongside conventional bedside examination may improve the preoperative identification of patients at increased risk of difficult laryngoscopy and tracheal intubation.

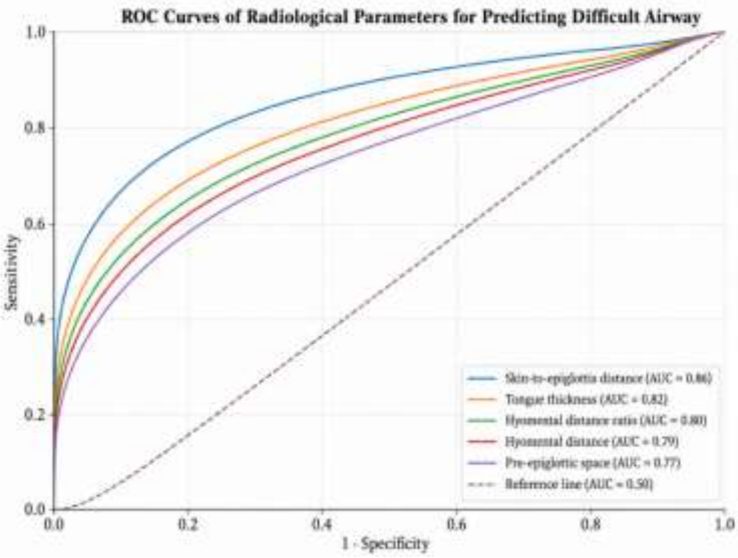

Figure 1. Receiver Operating Characteristic (ROC) Curves of Preoperative Radiological Parameters for Predicting Difficult Airway Management during General Anesthesia.

Skin-to-epiglottis distance demonstrated the highest discriminative performance (AUC = 0.86), followed by tongue thickness (AUC = 0.82), hyomental distance ratio (AUC = 0.80), hyomental distance (AUC = 0.79), and pre-epiglottic space (AUC = 0.77).

DISCUSSION

The present study evaluated the usefulness of preoperative radiological airway assessment for predicting difficult airway management in patients undergoing general anesthesia. Difficult airway management was observed in 19 of 85 patients (22.4%), while the majority had uncomplicated tracheal intubation. The findings showed that patients with difficult airways had significantly greater skin-to-epiglottis distance, tongue thickness, and pre-epiglottic soft-tissue thickness, whereas hyomental distance and hyomental distance ratio were lower than in patients with easy airways. These results support the concept that radiological assessment can provide objective anatomical information that complements conventional bedside airway examination (10-12).

The skin to epiglottis distance had the highest AUC value of 0.86, and yielded the highest sensitivity and specificity of 84.2% and 80.3% respectively at the chosen cut-off. This implies that a thicker anterior part of the soft-tissues in the neck is a significant anatomical factor associated with poor visualization of the glottis on laryngoscopy. A wider soft-tissue gap between skin and epiglottis could also restrict tongue and soft-tissue movement during direct laryngoscopy, thus risking a diminished laryngeal view. This strong association seen in the present study suggests that this measurement could be a useful radiological parameter for use in patients with a suspected difficult airway (13-15).

The thickness of the tongue also showed high predictive capability (AUC 0.82) and the hyomental distance ratio showed high predictive capability (AUC 0.80). Thick tongue can decrease the oral, pharyngeal and laryngeal axes alignment during intubation, and can also decrease the available oropharyngeal space. A short hyomental distance or hyomental ratio is a different story, and may indicate inadequate space in the mandible and minimum ability to move the tongue forward during the laryngoscopy. The results of this study have clinical significance as these traditional bedside measurements (Mallampati class, mouth opening and thyromental distance) may not adequately reflect the internal airway's anatomy. Radiological measurements are therefore more objective in evaluating structures that directly affect laryngoscopic exposure (16, 17).

The intraoperative findings confirmed the predictive value of the radiological assessment made preoperatively. Patients with challenging airways had a significantly longer mean intubation time, lower first pass success, higher number of intubation attempts, more external laryngeal manipulation, bougie/stylet assistance, and more intubation assistance with video laryngoscopy. Multivariate analysis revealed that a skin-to-epiglottis distance of more than 23.5 mm, thicker tongue and Mallampati class III-IV were independently associated with difficult airway management. The main idea from these observations is that the best way to approach the patient before surgery may be to use a combined model using both clinical bedside tests and measurements of the airways on the X-rays, rather than limiting it to one predictor (18-20).

Several limitations should be considered when interpreting these findings. This study was carried out in one diagnostic centre and the number of patients was a relatively small group of 85 patients, which may restrict the generalizability of the study findings. There may also be operator related variation in both the radiological measurement and laryngoscopic assessment. Furthermore, not every advanced radiological parameters and dynamic airway measurements were assessed. The identified cut-off values should now be validated in future multicentre studies with larger numbers of patients and combined predictive scoring systems should be developed which combine radiological, ultrasonographic and conventional clinical airway variables. These models can help with better risk stratification of patients preoperatively and can enable advanced airway preparation prior to induction for high-risk patients.

CONCLUSION

Preoperative radiological airway assessment was significantly associated with difficult airway management during general anesthesia. Skin-to-epiglottis distance was the strongest radiological predictor, followed by tongue thickness and hyomental distance ratio. Patients with unfavorable radiological measurements were more likely to require multiple intubation attempts, additional airway maneuvers, and alternative airway devices. Incorporating objective radiological airway measurements with standard bedside examination may improve the early identification of patients at risk of difficult laryngoscopy and tracheal intubation and may contribute to safer perioperative airway planning.

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