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Original Article

Efficacy of Upper Airway Angle and Glottic Height in Unanticipated Difficult Laryngoscopy Prediction

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ABSTRACT

Unanticipated difficult laryngoscopy is a significant problem in airway management and is linked to higher morbidity. **Objectives:** To determine the diagnostic accuracy of upper airway angle and glottic height to predict unanticipated difficult endotracheal intubation, taking Cormack–Lehane classification as the gold standard. **Methods:** This study was a cross-sectional research work conducted at Sindh Institute of Urology and Transplantation, Karachi, during the period of six months from 7 August, 2025 to 31st January, 2026. A sample size of 150 patients aged between 18 and 80 years, subjected to general anesthesia with direct laryngoscopy, was included. The 2 x 2 contingency tables were used to calculate the diagnostic accuracy indices, and the effect modifiers were stratified; an independent t-test was used, where p≤0.05 was regarded as significant. **Results:** UAA showed a sensitivity of 73.7%, a specificity of 85.7%, a PPV of 63.6%, an NPV of 90.6%, and a total accuracy of 82.7%. The sensitivity of GH was 78.9%, specificity was 78.5%, PPV was 55.6%, NPV was 91.7%, and accuracy was 78.7%. **Conclusions:** UAA and GH are non-invasive and easy to use and predict difficult laryngoscopy, especially because they show high negative predictive values. These measurements of the anatomy should be considered in the standard airway evaluation to improve preoperative prediction and patient safety.

INTRODUCTION

Complex tracheal intubation remains a significant issue in an aesthetic practice and is closely linked with perioperative morbidity and mortality [1]. Difficult laryngoscopy continues to be a challenging clinical problem in all parts of the world, and it is estimated to occur in about 5% to 15% of the general surgical population in recent studies [2]. Among elective surgical patients, difficult laryngoscopy rates of about 8-10% have been reported by a 2025 prospective study in China, and other recent airway assessment studies in Asia have reported rates between 7.8% and 17.7%, depending upon the patient population and criteria for difficult laryngoscopy [3]. A recent study in Pakistan has shown a relatively high incidence of difficult laryngoscopy, between 17.3% in the general surgical population and 35% in high-risk groups like those with diabetes mellitus [4]. Conventional bedside predictors like Mallampati classification, thyromental distance, mouth opening, upper lip bite test, sternomental distance, and some multivariate scores have been well assessed [5]. Nevertheless, even though they are widely

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used, those tools always portray a small sensitivity with low positive predictive value when individually used [6]. The upper airway angle and glottic height are among such emerging predictors that have received attention because they can give objective information on the relationship between mandibular, hyoid, and laryngeal structures [7]. Preliminary clinical and radiologic evidence has demonstrated that smaller angles of the upper airway and smaller glottic heights are associated with Cormack-Lehane grade III or IV appearances and more endotracheal intubation [8-10]. According to recent studies, imaging-based airway assessment is gaining relevance because it provides reproducible measurements that are directly related to the anatomy of limitations met during laryngoscopy [11-15].

Although there has been increasing interest in the evaluation of the airway using imaging and/or anatomy, only a limited number of reports exist on the use of upper airway angle (UAA) and the glottic height (GH) to predict unanticipated difficult laryngoscopy. Identifying UAA and GH could be useful for anesthesiologists, perioperative physicians, and surgical staff, and could help identify patients with a high risk of difficult airway management earlier, which would allow for proper preparation, decrease the amount of postoperative airway-related complications, and ultimately increase the safety of the patient. Therefore, this study was conducted to determine the diagnostic accuracy of upper airway angle and glottic height in predicting unanticipated difficult endotracheal intubation, using the Cormack–Lehane classification as the gold standard.

METHODS

This cross-sectional study was conducted in the Department of Anesthesiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, for six months from 7 August, 2025 to 31st January, 2026, following approval from the institutional review board (IRB) of SIUT, approval no: SIUT-ERC-2024/A-499, date: 6 August 2024. The sample size was calculated as 373 participants based on an expected sensitivity of 83.3%, specificity of 91.4%, and a 17.7% prevalence of difficult laryngoscopy, with 95% confidence and 9% precision. Due to time and recruitment constraints during the six-month study period, 150 patients were enrolled. A post-hoc power calculation indicated that this sample provides 80% power to detect a sensitivity of ≥70% (lower 95% CI bound of 58%) and a specificity of ≥75% (lower bound of 66%) at α=0.05. A non-probability consecutive sampling technique was employed. Patients scheduled for surgery under general anesthesia were assessed for eligibility. Patients of either gender aged 18–80 years scheduled for elective surgery under general anesthesia that involved direct laryngoscopy with the Macintosh blade were included. Patients with ASA physical status I–III and Mallampati Class I–IV were included to capture a representative sample of elective surgery patients in real practice. All patients had adequate mouth opening (≥3 finger breadths) [16]. Patients undergoing emergency surgery under rapid sequence induction, or those with pre-existing or apparent difficult airway factors including head and neck tumors, airway trauma, prior head and neck surgery, front-of-neck swellings, a heavy beard, oral submucosal fibrosis and/or systemic musculoskeletal disorders that affect neck movements were excluded. Patients for whom direct laryngoscopy using a Macintosh blade was not possible were also excluded. Demographic data such as name, medical record number, age, height, weight, and BMI were collected after informed consent. The upper lip bite test was performed on a patient in the supine position with a full head extension, and a standardized preoperative photograph was taken. A Nikon D610 camera was used with a Nikon 2470 mm f/2.8 lens at a 90-degree angle, with the camera placed 30 cm from the head of the patient. The angle of the upper airway at rest, the height of the glottis, and the length of the mandible were calculated using these photographs. The data collector approached the anesthetist who was conducting the intubation during laryngoscopy, with both having at least five years of experience working with a Macintosh blade. All airway measurements (upper airway angle, glottic height, and mandibular length) were obtained from standardized preoperative photographs taken at a fixed distance (30 cm) and angle (90°) using a Nikon D610 camera under uniform patient positioning (supine with full head extension). Measurements were then performed using Fiji software with predefined anatomical landmarks, and each measurement was repeated independently by two observers to ensure consistency. All measurements were made twice by a primary and secondary analyst to check accuracy. UUA (Upper Airway Angle): angle between Line 1 and Line 2 from the intersection point (X). GH (Glottic Height): vertical distance from the horizontal reference line to the peak of Line 2.

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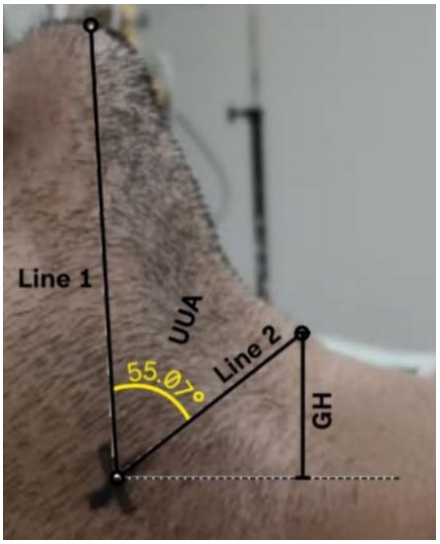


Figure 1: Measurement of Submental Ultrasound Parameters

All measurements were made from the preoperative photograph with the use of Fiji, and an angle of 60 degrees or higher was deemed to represent easy laryngoscopy, and an angle of less than 60 degrees was regarded as expected to be difficult.[9] Glottic height was measured as the linear distance in centimeters from the mandibular angle to the glottic prominence. This measurement was also taken from the standardized photograph using Fiji software. A glottic height of 3.5 cm or less was categorized as easy, while a measurement greater than 3.5 cm was considered difficult [9]. All measurements of upper airway angle and glottic height were independently performed by two observers (primary and secondary analysts). Inter-observer reliability was assessed to ensure consistency of measurements. *Difficult laryngoscopy was defined as a Cormack-Lehane grade III or IV (CL III-IV),* in accordance with the standard definition used in most airway research. The view obtained during laryngoscopy was graded according to the Cormack–Lehane classification [17]. The Modified Mallampati Test was performed to assess the relative size of the tongue in relation to the oropharyngeal opening while the patient was instructed to open the mouth fully without phonation [18].

The analysis of the data was conducted with the help of SPSS version 26.0. Normality of continuous variables was assessed using the Shapiro–Wilk test before applying parametric tests. Age, weight, height, and BMI were summarized as mean and standard deviation in case of normal distribution, and between the median and interquartile range where there is no normal distribution. Qualitative variables including gender, ASA class, Mallampati class, Cormack-Lehane grade, difficult laryngoscopy based on the angle of the upper airways, and the height of the glottis were given as frequencies and percentages. Sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy are diagnostic measures that were computed using 2x2 contingency tables. The effect modifiers, including age, gender, BMI, ASA class, and Mallampati class, were then adjusted by employing stratification, after which the parameters of diagnostic accuracy were recalculated at every stratum.

RESULTS

The number of participants enrolled in the study was 150. The participants had a mean age of 41.8± 11.6 years. Most of them were male (58.7%), and 41.3% of the sample consisted of females. The average weight and height measured 70.6± 10.8 kg and 165.4 ± 8.7 cm, respectively, giving a mean BMI of 25.3 ± 3.6 kg/m2. In terms of physical status, 36% of the respondents were ASA I, 52% were ASA II, and 12% were ASA III. Airway evaluation showed that the percentage of those who were identified as having Class I was 22.7%, Class II was 40%, Class III was 26.7%, and Class IV was 10.6% using the Modified Mallampati classification. Assessment of the angle of the upper airway revealed that 74.7% of the participants had an easy airway (≥60deg), and 25.3% of them had a difficult airway (<60deg). Glottic height: 69.3% of the participants were found to have an easy airway (≥3.5 cm), and 30.7% had a difficult airway (>3.5 cm)(Table 1).

Table 1: Demographic Characteristics of Participants and Airway Assessment and Laryngoscopy Findings(n=150)

Variables	Mean ± SD / n (%)
Age (years)	41.8 ± 11.6
Gender	
Male	88 (58.7%)
Female	62 (41.3%)
Others	
Weight (kg)	70.6 ± 10.8
Height (cm)	165.4 ± 8.7
BMI (kg/m^2)	25.3 ± 3.6
ASA Class	
ASA I	54 (36%)
ASA II	78 (52%)
ASA III	18 (12%)
Modified Mallampati Class	
Class I	34 (22.7%)
Class II	60 (40%)
Class III	40 (26.7%)
Class IV	16 (10.6%)
Upper Airway Angle (UAA)	
Easy (≥60°)	112 (74.7%)
Difficult (<60°)	38 (25.3%)
Glottic Height (GH)	
Easy (≤3.5 cm)	104 (69.3%)
Difficult (>3.5 cm)	46 (30.7%)

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Cormack–Lehane Grade	
Grade I	52 (34.7%)
Grade II	60 (40%)
Grade III	26 (17.3%)
Grade IV	12 (8%)
Difficult Laryngoscopy (CL III–IV)	38 (25.3%)

Among the 150 participants, 28 patients with difficult laryngoscopy were correctly identified as having a difficult UAA (true positive), while 16 patients with easy laryngoscopy were incorrectly classified as difficult (false positive). Ten patients with difficult laryngoscopy were misclassified as easy (false negative), and 96 patients with easy laryngoscopy were correctly identified as easy (true negative)(Table 2).

Table 2: Diagnostic Performance of Upper Airway Angle (UAA) in Predicting Difficult Laryngoscopy Using Cormack–Lehane Classification as Gold Standard

UAA Prediction	Difficult Laryngoscopy (CL III–IV)	Easy Laryngoscopy (CL I–II)	Total
Difficult (< 60°)	TP = 28	FP = 16	44
Easy (≥ 60°)	FN = 10	TN = 96	106
Total	38	112	150

Sensitivity (%)73.7% (57.8% - 86.0%), Specificity (%)85.7% (78.0% - 91.4%), Positive Predictive Value (%) 63.6% (47.8% - 77.6%), Negative Predictive Value (%) 90.6% (83.2% - 95.3%), and Overall Accuracy (%)82.7% (75.7% - 88.4%)

Out of 150 participants, 30 patients with difficult laryngoscopy were correctly identified as having a difficult GH (true positive), while 24 patients with easy laryngoscopy were incorrectly classified as difficult (false positive). Eight patients with difficult laryngoscopy were misclassified as easy (false negative), and 88 patients with easy laryngoscopy were correctly identified as easy (true negative)(Table 3).

Table 3: Diagnostic Performance of Glottic Height (GH) in Predicting Difficult Laryngoscopy Using Cormack–Lehane Classification as Gold Standard

GH Prediction	Difficult Laryngoscopy (CL III–IV)	Easy Laryngoscopy (CL I–II)	Total
Difficult (> 3.5 cm)	TP = 30	FP = 24	54
Easy (≤ 3.5 cm)	FN = 8	TN = 88	96
Total	38	112	150

Sensitivity (%) 78.9% (62.7% - 90.4%), Specificity (%) 78.5% (69.8% - 85.7%), Positive Predictive Value (%) 55.6% (42.4% - 68.3%), Negative Predictive Value (%)91.7% (84.2% - 96.0%)

Comparison of airway parameters between easy and difficult laryngoscopy revealed significant differences. Participants with easy laryngoscopy (n = 112) had a higher mean upper airway angle (66.8 ± 5.9°) compared to those with difficult laryngoscopy (p<0.001). Similarly, the mean glottic height was significantly lower in the easy laryngoscopy group (3.2 ± 0.4 cm) than in the difficult group (p<0.001). Mandibular length was also greater in the easy laryngoscopy group (9.8 ± 0.9 cm) compared to the difficult group (p=0.002)(Table 4).

Table 4: Comparison of UAA, GH, and Mandibular Length between Easy and Difficult Laryngoscopy

Variables	Easy Laryngoscopy (n = 112), Mean ± SD	Difficult Laryngoscopy (n=38), Mean ± SD	p-value
Upper Airway Angle (degrees)	66.8 ± 5.9	54.2 ± 4.8	<0.001
Glottic Height (cm)	3.2 ± 0.4	4.1 ± 0.5	<0.001
Mandibular Length (cm)	9.8 ± 0.9	9.1 ± 0.7	0.002

Independent Samples t-test and p≤ 0.05 is considered significant

Sensitivity of UAA ranged from 68% to 80%, while GH ranged from 72% to 84%. Specificity of UAA varied between 82% and 90%, whereas GH specificity ranged from 74% to 84% (Table 5).

Table 5: Stratified Diagnostic Accuracy of Upper Airway Angle (UAA) and Glottic Height (GH) According to Age, Gender, BMI, and Mallampati Class

Stratum	Sensitivity (UAA/GH)	Specificity (UAA/GH)
Age		
< 40 years	72% / 77%	87% / 80%
≥ 40 years	75% / 80%	84% / 78%
Gender		
Male	74% / 78%	86% / 79%
Female	73% / 79%	85% / 77%
BMI		
< 25 kg/m^2	71% / 75%	88% / 82%
≥ 25 kg/m^2	76% / 81%	84% / 76%
Mallampati		
I–II	68% / 72%	90% / 84%
III–IV	80% / 84%	82% / 74%

DISCUSSION

In this study of 150 patients, both upper airway angle (UAA) and glottic height (GH) demonstrated good diagnostic performance in predicting unanticipated difficult laryngoscopy (Cormack–Lehane grade III–IV). The sensitivity (73.7%) and specificity (85.7%) of UAA, and the sensitivity (78.9%) and specificity (78.5%) of GH, suggest that these anatomical-angle measures are promising adjuncts to conventional airway evaluation. When compared to ultrasound-based airway assessments, our results are also comparable. A study on sonographic parameters such as hyomental distance ratio (HMDR), skin-to-epiglottis distance, tongue thickness, and derived a composite "Difficult Laryngoscopy Prediction (DLP)" score [19]. The current anatomical measures (UAA, GH) are conceptually complementary to their approach, offering a geometric (angle/height) perspective that may enhance prediction when combined with sonographic parameters.

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Further supporting the value of ultrasound, a prospective observational study found that the sonographic distance from the anterior neck surface to the epiglottis (ANS–E) predicted difficult laryngoscopy with a sensitivity of 64.7% and specificity of 78.5% in 150 adult patients [20]. One meta-analysis of point-of-care ultrasound measures (including skin-to-epiglottis distance, hyomental distance ratio, and pre-epiglottic/E-VC ratio) reported sensitivities around 75–82% and specificities 83–88%, similar to the current findings [21]. Another review covering 26 sonographic parameters found that hyomental distance in the neutral position and preepiglottic space (relative to vocal cord distance) were among the most reliable predictors of difficult laryngoscopy [22]. Recent work has also confirmed the utility of pre-epiglottic space measurement. In a 174-patient cohort, researchers used ultrasound to measure the pre-epiglottic gap (pre-E), the ratio of pre-epiglottic to epiglottic–vocal cord midpoint distance (Pre-E/E-VC), and the hyomental distance ratio (HMDR) [23]. They reported that a Pre-E/E-VC cutoff >1.90 had a sensitivity of 92% and a specificity of 85% for predicting CL grade III–IV.

This study has several limitations, including the use of a photographic method that may be influenced by head position, camera angle, and soft-tissue distortion, as well as a smaller-than-calculated sample size, which may have reduced statistical power and generalizability. Although upper airway angle and glottic height showed good negative predictive value, their positive predictive value was modest, and the absence of ROC/AUC analysis together with potential observer bias may have limited the assessment of overall diagnostic performance. The identical prevalence of UAA-predicted difficulty and actual CL III–IV (25.3%) is coincidental and reflects the sample composition. However, we acknowledge that this perfect match could raise concerns; we therefore emphasise that the laryngoscopist was blinded to the preoperative measurements (as stated in Methods) to avoid circularity Future multicenter studies with larger and more diverse populations should validate these findings, assess interobserver reliability, and compare these measures with established clinical and ultrasound-based airway assessment tools.

CONCLUSIONS

Upper airway angle and glottic height had moderate to good diagnostic utility to predict difficult laryngoscopy compared to the Cormack-Lehane classification, and also relatively high negative predictive values, suggesting possible diagnostic value for excluding difficult intubation. The results indicate that anatomical measurements using simple photographs could prove helpful in routine preoperative airway assessment.

Authors' Contribution

Conceptualization: TB
Methodology: TB, MQA, VK, MC
Formal analysis: SMA
Writing and Drafting: TB, MQA, SMA, VK, MC, MS
Review and Editing: TB, MQA, SMA, VK, MC, MS

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflict of Interest

All the authors declare no conflict of interest.

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