BMC Anesthesiology

RESEARCH

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Radiological indicators and a novel combined predictive model for anticipating difficult laryngoscopy in cervical spondylosis patients: a prospective cohort study

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Abstract

Backgrounds Anticipating difficult laryngoscopy is crucial for preoperative assessment, especially for patients with cervical spondylosis. Radiological assessment has become essential for improving airway management safety. This research introduces novel radiological indicators from lateral cervical X-ray in the extended head position proposed to enhance the accuracy of predicting difficult laryngoscopy.

Methods A prospective cohort study included 422 patients scheduled for elective cervical spine surgery. The Cormack-Lehane grades I and II were categorized as "easy laryngoscopy group", while grades III and IV were labeled "difficult laryngoscopy group". Demographic data, conventional bedside indicators including inter-incisor gap (IIG), neck circumference (NC), thyromental distance, the upper lip bite test (ULBT), and 4 radiological indicators including Mandibular Length, Laryngeal Height, the Larynx-Mandibular Angle Test (LMAT) and Larynx-Mandibular Height Test (LMHT) were analyzed comparatively. A binary logistic regression model was developed to identify independent predictive factors. The predictive value of the indicators was evaluated with the area under the curve (AUC).

Results A total of 402 patients were analyzed in the present study. A binary logistic regression model identified IIG, NC, ULBT, and LMAT as the independent indicators associated with difficult laryngoscopy. A novel combined predictive model equation was derived: $l = -0.969 - 1.33 \times IIG + 0.408 \times ULBT + 0.201 \times NC - 0.042 \times LMAT$. The AUC for this composite model was 0.776, exceeding the individual AUC of 0.677 for LMHT.

Conclusion LMHT and the novel combined predictive model incorporating LMAT are potentially valuable predictors for difficult laryngoscopy in patients with cervical spondylosis.

Trial registration The study was registered at the Chinese Clinical Trial Registry (ChiCTR2200058361) on April 7, 2022.

Keywords Difficult laryngoscopy, Radiological indicator, Predictive model, Cervical spondylosis, Airway assessment, Predictive tests, Diagnostic imaging, X-ray

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Introduction

The identification of a potentially difficult airway is crucial for anaesthesiologists, especially during cervical spine surgery. The incidence of challenging endotracheal intubation in patients with cervical spondylosis is alarmingly high, ranging from 20.0 to 30.2%, which is considerably higher than the 5.8% observed in the general population [1–3]. A previous study indicated that the rate of difficult laryngoscopy in elective cervical surgeries was as high as 17.1% [4]. An unexpected difficult airway can precipitate endotracheal intubation failure, potentially leading to irrevocable catastrophic sequelae such as airway trauma, cerebral hypoxia, or even fatal outcomes [5].

Cass et al. identified six common anatomical causes of difficult laryngoscopy, with subsequent additions including skeletal deformities, tumors, trauma, soft tissue scar contracture and trismus [6]. Kharrat et al. emphasized the impact of maxillary overgrowth, upper teeth protrusion and limited cervical spine extension as the major risk factors for difficult laryngeal exposure [7]. Banister and Macbeth highlighted the critical role of head and neck positioning in achieving proper alignment of the oral, pharynx and laryngeal axes during laryngoscopy [8]. However, patients with cervical spondylosis often have a reduced range of motion, and endotracheal intubation is frequently performed in a neutral position to prevent spinal cord compression, which is less favorable for the convergence of the three axes. These factors inevitably increase the complexity of laryngoscopic exposure and intubation [9].

Conventional bedside airway evaluation indicators, such as cervical spine mobility, inter-incisor gap (IIG), neck circumference (NC), thyromental distance (TMD), and the upper lip bite test (ULBT), have been introduced to predict an unanticipated difficult airway [10]. However, these indicators may be not totally reliable for patients with cervical spondylosis. Utilizing advanced imaging techniques like ultrasound, X-ray, and computerized tomography can offer more effective methods to assess anatomical features such as antero-posterior thickness of tongue, anterior cervical soft tissue thickness, atlantodental interval, depth of spine C2, and the mandibular space, along with other radiological indicators [4, 11–14]. Radiological data, readily accessible from the extended head position in preoperative X-rays for patients scheduled for elective cervical spine surgery, underscore the significance and practicality of thorough preoperative airway assessment in individuals with cervical spondylosis.

According the anatomical causes of difficult laryngoscopy, we focused on the significant area between the mandible and the thyroid cartilage in the extended head position on lateral cervical X-rays. A line connecting the mentum to the mandibular angle (Line AB) could represent the oral axis, while a line connecting the mandibular angle to the anterior border of the thyroid cartilage (Line BC) could represent the pharyngeal axis. We termed the angle between Line AB and Line BC as the Larynx-Mandibular Angle Test (LMAT). Subsequently, we constructed a vertical line (Line CD) from the thyroid prominence to Line AB, intersecting at Point D (Fig. 1).

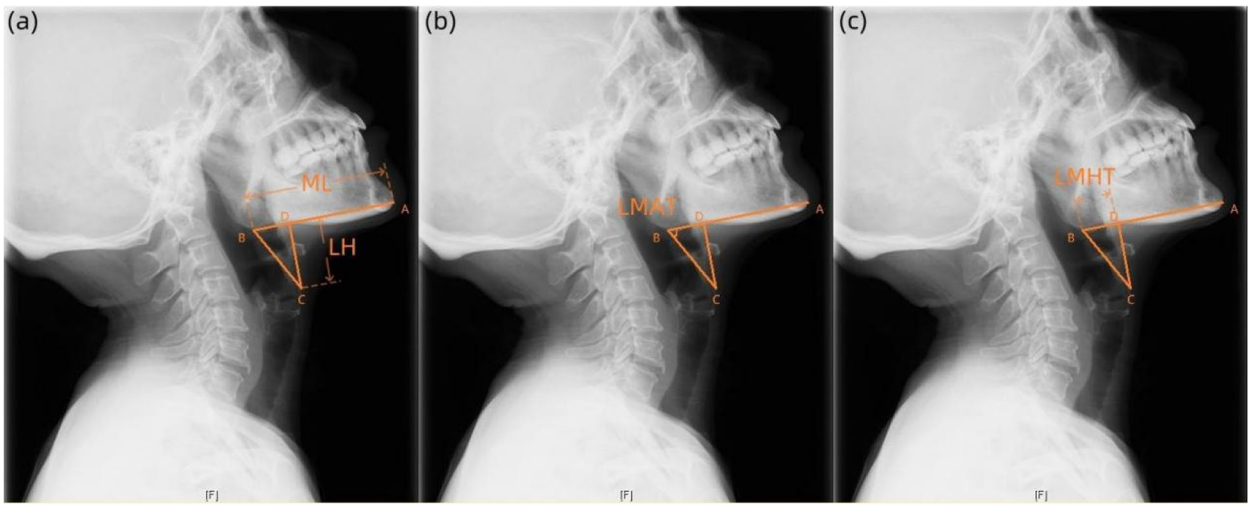

Fig. 1 Radiologic indicators on extension lateral X-ray films. A, mentum; B, mandibular angle; C, the anterior border of the thyroid cartilage; D, foot of perpendicular from the thyroid prominence to Line AB. **a** Mandibular Length (ML): The length between the mentum and the mandibular angle; Laryngeal Height (LH): The distance from the anterior border of the thyroid cartilage to the mandible. **b** Larynx-Mandibular Angle Test (LMAT): The angle formed by Line AB and Line BC. **c** Larynx-Mandibular Height Test (LMHT): The vector from the mandibular angle to the intersected point D

The vector from the mandibular angle to the intersection point D was termed as the Larynx-Mandibula Height Test (LMHT), with the direction towards the mentum considered positive and oppositive direction considered negative. These radiological parameters above could provide a comprehensive assessment of the submandibular space, cervical spine mobility and the alignment between the oral and pharyngeal axes, We hypothesized that these radiological parameters might become an important factor in predicting difficult laryngoscopy and serve as surrogates for conventional bedside physical examinations.

Methods

Ethics statement

The present study protocol was reviewed and approved by the Peking University Third Hospital Medical Science Research Ethics Committee (IRB00006761-M2022105) on March 7, 2022. Additionally, the study was registered with the Chinese Clinical Trial Registry (ChiCTR2200058361) on April 7, 2022. Informed consent was submitted by all subjects when they were enrolled.

Study design

This prospective cohort study enrolled individuals who were scheduled to undergo elective cervical spine surgery with general anaesthesia. The recruitment period spanned from May 2023 to May 2024. Inclusion criteria were as follows: [1] mentally competent adults; [2] aged 18 years or older; [3] American Society of Anesthesiologists Physical Status Classification (ASA-PS) score of I-III; and [4] elective cervical spine surgery for cervical spondylosis. Patients were excluded if they were pregnant, had an oropharyngeal mass, or underwent awake laryngoscopy (Fig. 2).

Group and treatment

After establishing standard monitoring and venous access in the operating room and preparing the required equipment for difficult intubation management, induction of anaesthesia was performed in the supine position with sufentanil (0.3 μg/kg) and propofol (2 mg/kg) intravenously. The rocuronium 0.6 mg/kg was administered intravenously to facilitate laryngoscopic exposure and intubation. The exposure of laryngoscope was carefully evaluated by an anaesthesiologist with more than 5 years of anaesthesia experience. It is important to note that this anaesthesiologist did not participate in preoperative radiographic assessments. The evaluation was performed using the Macintosh laryngoscope according to the Modified Cormack-Lehane (C-L) grading system [15]. Patients were categorized into easy or difficult laryngoscopy groups based on the C-L scale classification. In instances when the Macintosh laryngoscope failed to provide a clear view, the patient was arranged to receive further airway management according to the Difficult Airway Society's 2022 guidelines [16].

Measurements

The day prior to surgery, a meticulous documentation was conducted by an anaesthesiologist not affiliated with the anaesthesia induction capturing traditional preoperative airway assessment indicators along with demographic data, such as gender, age, height, weight, and body mass index (BMI). These bedside clinical indicators included the IIG, TMD, NC, ULBT, which were popular

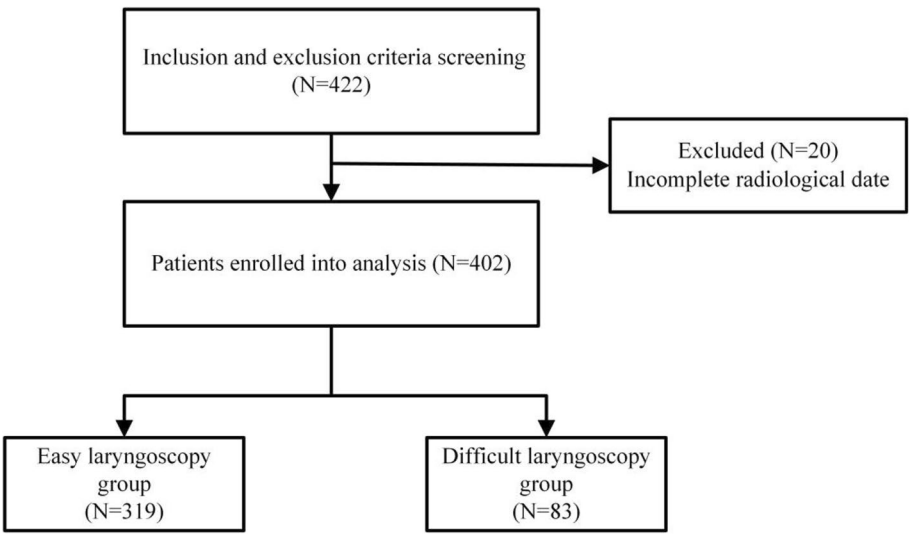

Fig. 2 Diagram with the flow of participants through the study

and instrumental in foreseeing potential difficult laryngoscopic exposure [17, 18].

A routine neck lateral view was taken with the patients in an upright, standing position and patient's shoulder on the level with radiology film. The patient's neck was located at approximately 10 cm distance from the film and patient's midsagittal plane being parallel to the surface of the film. In order to maintain uniformity, all the patients were asked to look at an object located in their eye axis in the neutral position, and tilt the head backward as much as possible in the extension position. The radiological data were extracted from the Picture Archiving and Communication Systems (PACS) by an experienced radiologist, who was not involved in the preoperative evaluation or anaesthesia induction process. The following radiological indicators on the cervical X-rays were measured from the extension position.

Mandibular Length (ML): The length between the mentum and the mandibular angle, measured on extension lateral X-ray films (Line AB).

Laryngeal Height (LH): The distance from the anterior border of the thyroid cartilage to the mandible, measured on extension lateral X-ray films (Line CD).

Larynx-Mandibular Angle Test (LMAT): The angle is formed by Line AB and Line BC on extension lateral X-ray films.

Larynx-Mandibular Height Test (LMHT): A vertical line is drawn from the thyroid prominence to Line AB, intersecting at Point D. The LMHT is the vector from the mandibular angle to the intersected point D on extension lateral X-rays, with the direction towards the mentum considered positive and oppositive direction considered negative.

The primary end point was calculation of the validity indexes (area under the curve, sensitivity, specificity, positive predictive value, negative predictive value) for the radiological and traditional indicators. And the secondary end point was to calculate their predictive index (cutoff value).

Statistics

In the present study, a total of 8 independent variables were observed, including 4 conventional indicators and 4 radiological indicators. According to the Events Per Variable (EPV) principle, the number of events per variable should be at least 10 with difficult laryngoscopy as the outcome event. Therefore, the minimum sample size for the difficult laryngoscopy group was estimated to be 80 (8 multiplied by 10 equals 80) cases. According to the previous study, the incidence of difficult direct laryngoscopy in patients with cervical spine disease was about 20% [1], and the sample size was calculated to be 400 (80 divided by 20% equals 400).

Continuous variables were summarized using the mean ± standard deviation (mean ± SD) for data exhibiting normal distribution, and the median with interquartile range for data that deviated from normality. To discern differences in continuous variables between the two groups, an independent samples t-test was applied to normally distributed data, while the Mann-Whitney U test was utilized for data that was not normally distributed. Categorical variables were subjected to Chi-square analysis. A binary logistic regression model was adeptly employed to identify independent predictors, with the odds ratio (OR) and 95% confidence interval (95% CI) being used to denote the magnitude of association. The model's ability to accurately distinguish between easy and difficult laryngoscopy was evaluated with the analysis of the receiver operating characteristic (ROC) curve. The AUC was adopted as a quantitative indicator of the model's diagnostic performance. The Youden's index, calculated as (sensitivity + specificity − 1), was used to identify the optimal predictive cut-off value, with the highest index score indicating the most accurate threshold. Data were analyzed using SPSS version 22 statistical software (SPSS, Inc., Chicago, IL). A P-value of <0.05 was considered statistically significant.

Results

A total of 422 participants were initially enrolled in the study, with 402 included in the final analysis. Twenty patients were excluded due to incomplete radiological data. The study population comprised 257 men (63.9%) and 145 women (36.1%). The overall incidence of difficult laryngoscopy was 20.6% (83 out of 402). Demographic variables and conventional bedside indicators for the study population were detailed in Table 1. The statistical analysis revealed a multitude of risk factors significantly linked to difficult laryngoscopy, including gender, age, height, weight, BMI, NC, IIG, TMD, ULBT, American Society of Anesthesiologists Physical Status (ASA-PS) and surgical approach. The radiologic indicators, measured from lateral cervical X-ray in the extended head position, were detailed in Table 2. A comparative analysis between the easy and difficult laryngoscopy groups highlighted three radiological indicators that were markedly different: LH, LMAT and LMHT.

In our comparative analysis, seven conventional bedside and radiological indicators —namely, IIG, TMD, NC, ULBT, LH, LMAT, and LMHT showed significant differences. Through binary logistic regression analysis using the backward-Wald method, four independent risk factors were identified with the strongest association to difficult laryngoscopy: IIG (OR, 0.264; 95% CI, 0.151–0.462; $P<0.001$), ULBT (OR, 1.504; 95% CI, 1.046–2.162; $P=0.028$), NC (OR, 1.223; 95% CI, 1.129–1.325;

Table 1 Demographics and bedside indicators of the easy and difficult laryngoscopy groups

Characteristic	Easy laryngoscopy group	Difficult laryngoscopy group	Statistical Test	*P* value
	n = 319	*n* = 83	χ^2/t/Z	
Gender			7.877	0.005
Male	193 (60.5%)	64 (77.1%)		
Female	126 (39.5%)	19 (22.9%)		
Age(y)	55 (45–62)	58 (50–65)	−2.07	0.038
Height(cm)	168 (160–173)	170 (164–175)	−3.185	0.001
Weight (kg)	70 (61–77)	76 (67.5–85)	−4.178	< 0.001
BMI (kg/m2)	24.9 (23–27)	26.1 (24–28.7)	−2.967	0.003
IIG (cm)	4.5 (4.2–5)	4.5 (4–4.8)	−4.078	< 0.001
TMD (cm)	9 (8–9.5)	8.5 (7.5–9)	−3.022	0.003
NC (cm)	39 (36–41.4)	41.4 (38–44)	−4.464	< 0.001
ULBT (Class)			20.722	< 0.001
I	220 (69.0%)	35 (42.2%)		
II	68 (21.3%)	31 (37.3%)		
III	31 (9.7%)	17 (20.5%)		
ASA-PS (Class)			0.031	0.985
I	78 (24.5%)	20 (24.1%)		
II	201 (63%)	52 (62.7%)		
III	40 (12.5%)	11 (13.3%)		
Surgical approach			3.701	0.157
AO	168 (52.7%)	34 (41%)		
PO	140 (43.9%)	46 (55.4%)		
AP	11 (3.4%)	3 (3.6%)		

Data are presented as median (interquartile range) or number (%)

Abbreviations: BMI body mass index, *IIG* inter-incisor gap, *TMD* thyromental distence, *SMD* sternomental distance, *NC* neck circumference, *ULBT* upper lip bite test, *ASA-PS* American Society of Anesthesiologists Physical Status Classification, *AO* anterior-only, *PO* posterior-only, *AP* combined anterior and posterior

Table 2 Radiologic indicators on extension lateral X-ray films

Indicators	Easy laryngoscopy group	Difficult laryngoscopy group	Statistical Test	*P* value
	n = 319	*n* = 83	t/Z	
ML (mm)	80.7(76.3–86.5)	81.2(76.4–85.5)	−0.077	0.939
LH (mm)	68.1 ± 12.7	71.5 ± 12.7	−2.183	0.03
LMHT (mm)	17.6 ± 13.8	27.2 ± 14.9	−5.559	< 0.001
LMAT (°)	75.6 ± 11.1	69.2 ± 11.2	4.678	< 0.001

Data are presented as mean ± standard deviation or median (interquartile range)

Abbreviations: ML mandibular length, *LH* laryngeal Height, *LMHT* larynx-mandibula height test, *LMAT* larynx-mandible angle test

$P < 0.001$), and LMAT (OR, 0.959; 95% CI, 0.934–0.984; $P < 0.001$) (Table 3). The predictive model equation, combining these factors, was formulated as follows:

$l = -0.969 - 1.33 \times IIG + 0.408 \times ULBT + 0.201 \times NC - 0.042 \times LMAT$. The efficacy of the model in discriminating difficult laryngoscopy was assessed with ROC analysis. The AUC for the combined model was 0.776 (95% CI: 0.724–0.827), as depicted in Fig. 3. Notably, the AUC values for LMAT and LMHT as simple predictors were slightly higher than those of other conventional bedside indicators, such as IIG and ULBT, with AUCs of 0.651 (95% CI: 0.586–0.716) and 0.677 (95% CI:0.613–0.742), respectively, as detailed in Table 4. These findings underscore the predictive utility of the combined model and the radiological indicators in particular for anticipating difficult laryngoscopy.

The clinical tests' performance was evaluated through the calculation of positive predictive value (PPV), negative predictive value (NPV), sensitivity, and specificity, with the results presented in Table 5.

Table 3 Predictors for difficult laryngoscopy identified by binary logistic regression (backward-Wald) model

Variable	B	SE	*P* value	OR	95%CI
IIG	−1.33	0.285	< 0.001	0.264	0.151–0.462
ULBT	0.408	0.185	0.028	1.504	1.046–2.162
NC	0.201	0.041	< 0.001	1.223	1.129–1.325
LMAT	−0.042	0.013	0.001	0.959	0.934–0.984
Constant	−0.969	1.938	0.617	0.38	

Abbreviations: SE standard error, *OR* Odds radio, *CI* confidence interval, *IIG* inter-incisor gap, *ULBT* upper lip bite test, *NC* neck circumference, *LMAT* larynx-mandible angle test

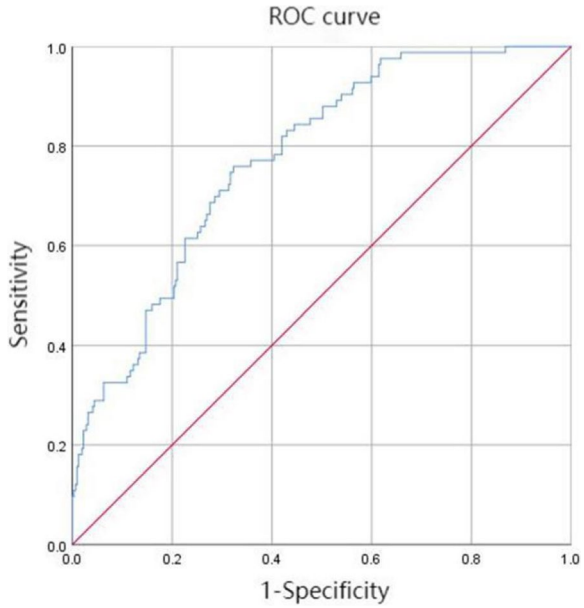

Fig. 3 The area under the curve of combined model for anticipating difficult laryngoscopy was 0.776

Table 4 Predictive values of tests for predicting difficult laryngoscopy

Indicators	AUC	SE	95%CI	*P* value
Combined model	0.776	0.026	0.724–0.827	< 0.001
LMHT	0.677	0.033	0.613–0.742	< 0.001
NC	0.659	0.034	0.593–0.725	< 0.001
LMAT	0.651	0.033	0.586–0.716	< 0.001
IIG	0.642	0.034	0.576–0.708	< 0.001
ULBT	0.638	0.035	0.569–0.706	< 0.001

Abbreviations: AUC area under the curve, *SE* standard error, *OR* odds radio, *CI* confidence interval, *LMHT* larynx-mandibula height test, *NC* neck circumference, *LMAT* larynx-mandible angle test, *IIG* inter-incisor gap, *ULBT* upper lip bite test, *LH* laryngeal Height

Utilizing the highest Youden's index in conjunction with clinical practice, the optimal cut-off value for LMAT was 75 degrees (AUC = 0.651, sensitivity = 69.9%, specificity = 54.2%) and LMHT was 20 millimeters (AUC = 0.677, sensitivity = 69.9%, specificity = 57.7%). The combined predictive model demonstrated greater sensitivity and specificity than single predictors (AUC = 0.776, sensitivity = 75.9%, specificity = 67.7%). Furthermore, this study made a noteworthy observation: when the LMAT measurement exceeded 90 degrees, there were no instances of difficult laryngoscopy reported. This finding suggests that the LMAT angle could be a critical threshold in the clinical assessment of difficult laryngoscopy, potentially serving as a valuable addition to existing predictive tools in airway management.

Discussion

In the present study, we demonstrated that the incidence of difficult laryngoscopy in cervical spine surgery is 20.6%. We found that the two radiological indicators obtained from extension lateral X-rays are useful in assessing difficult laryngoscopic exposure for patients with cervical spondylosis. The predictive accuracy of the single LMHT is higher than that of several traditional tests such as IIG, ULBT and NC. Furthermore, the new predictive model incorporating LMAT provides a better predictive value, achieving an AUC of 0.776.

Airway management is a critical technique in clinical anaesthesia, with the potential for serious complications such as hypoxemia, neurological damage, and in extreme cases, death if not performed effectively [19]. Patients with degenerative cervical spine disease, instability, or spondylosis, who are prepared for elective cervical spine surgery, face a heighted vulnerability to encountering difficult laryngoscopy [20, 21]. Therefore, comprehensive preoperative evaluation and reliable predictive methods are essential for facilitating airway management in elective cervical surgeries. A review of the literature reveals a paucity of research dedicated to employing preoperative radiological measurements as predictors of difficult laryngoscopy [22, 23]. This study could provide valuable insights for clinical anaesthesia practice. Utilizing the C-L classification as the criterion for defining difficult laryngoscopy - a method widely regarded as the gold standard for such assessments [24] - the incidence of difficult laryngoscopy was 20.6% in our study. While this rate was somewhat lower than the ranges reported in previous studies, which varied from 20 to 30.2%, it was substantially higher than the incidence observed in the general population, underscoring the need for specialized airway management strategies in cervical spondylosis patients [3].

Table 5 Evaluation of predictive tests for difficult laryngoscopy

Indicators	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Combined model (≥ 0.2)	75.9	67.7	38	91.5
LMHT (≥ 20 mm)	69.9	57.7	30.1	88
LMAT (< 75°)	69.9	54.2	28.4	87.4
ULBT (≥ 2)	57.8	69	32.7	86.3
NC (≥ 41 cm)	56.6	68.7	32	85.9
IIG (< 4 cm)	13.3	94	36.7	80.6

Abbreviations: LMHT larynx-mandibula height test, *LMAT* larynx-mandible angle test, *ULBT* upper lip bite test, *NC* neck circumference, *IIG* inter-incisor gap

In our study, we examined a range of preoperative conventional bedside indicators and identified IIG, ULBT and NC as effective predictors through binary logistic regression analysis. However, these indicators demonstrated relatively low sensitivity and specificity as simple clinical predictors. A systematic review, including 133 studies with a total of 844,206 participants revealed that all external assessment indicators exhibit relatively low sensitivity and considerable variability, which may be attributed to the study's focus on a specific patient population [25].

The IIG is directly related to laryngoscope placement, which is crucial for endotracheal intubation. Studies have shown that IIG correlates with atlantooccipital movement, achieving nearly its maximum gap with approximately 26 degrees of craniocervical extension from the neutral position [26]. In patients with cervical spondylosis, the IIG might be restricted. In our study, the AUC for IIG in predicting difficult laryngoscopy was only 0.642, which was not sufficiently high. Additionally, the sensitivity of an IIG (the cutsoff value ≤ 4 cm) or less was 13.3%, suggesting that it was not a reliable single predictor for cervical spondylosis.

Regarding the ULBT, it is a comprehensive indicator that reflects both mandibular protrusion and the presence of buck teeth. In a recent meta-analysis led by Roth, the ULBT was revealed to get the diagnostic test accuracy properties among common bedside screening tests, with a sensitivity of 0.67 [27]. However, our findings showed that the ULBT had a sensitivity of 57.8% and specificity of 69%, which were lower than those in the original study by Khan et al. (sensitivity = 76%, specificity = 88%) [18]. The observed difference might be attributed to the diverse study populations. Khan's study focused on general population, excluding individuals with no teeth and limited cervical mobility, whereas our study involved those patients with a higher proportion.

Considering NC, Riad et al. found that an NC greater than 42 cm was an independent predictor of difficult intubation [28]. Similarly, Ezri and colleagues identified that an excess of pre-tracheal soft tissue at the level of the vocal cord was a reliable predictor for distinguishing between easy and difficult laryngoscopy, particularly in obese patients [29]. However, relying solely on NC as an indicator might not provide a clear picture of the soft tissue distribution throughout the neck's diverse anatomical regions, suggesting it is not a perfect indicator, with a sensitivity of 56.6% and an AUC of 0.659.

The effectiveness of the TMD were often compromised in patients with cervical spondylosis due to impaired cervical range of motion [30]. These factors emerged as confounding variables in our study and were duly considered and adjusted for within the framework of the binary logistic regression analysis.

With advancements in medical imaging, an increasing body of research points to a correlation between radiological indicators and the presence of the difficult airway laryngoscopy [31–34]. Given the routine collection of radiological data in patients undergoing elective cervical surgery, there is a need to place greater emphasis on radiological assessment in the pre-anesthetic phase. Our study identified X-ray indicators, the LMAT and LMHT as effective predictors of difficult laryngoscopy, offering a non-invasive and patient-friendly approach even suitable for those with severe cervical spinal cord lesions. LMAT provides a comprehensive assessment of the submandibular space and cervical spine mobility, both of which are anatomical factors that can contribute to difficult laryngoscopy. To some extent, it also reflects the alignment between the oral and pharyngeal axes. Similarity, LMHT reflects both the height of the glottis relative to the mandible and the degree of head reclining backward. These indicators have shown potential predictive value with AUCs of 0.651 and 0.677, respectively. A more anterior larynx position and significantly limited cervical movement, associated with difficult laryngoscopy, may correlate with a smaller LMAT and a larger LMHT. For instance, an LMAT of less than 75 degrees might indicate

the necessity for advanced airway management tools on the initial attempt. Notably, no case of difficult laryngoscopy was observed when the LMAT exceeded 90 degrees.

Other studies have also employed various methods to focus on these important regions. De Carvalho et al. introduced two new indicators for laryngeal exposure: the upper airway angle, which was the angle between mandible and thyroid cartilage notch, and the glottic height, referring to the vertical distance from the thyroid cartilage notch to mandibular angle. These predictors were derived from a lateral cervical and facial photograph taken with the patient in a supine position, the head fully extended without occipital support, while performing ULBT [35]. Compared to our study, obtaining these measurements was more intricate and laborious, susceptible to errors from the photographic angles, and the study was limited by a small sample size, including only 12 patients in the difficult laryngoscopy group.

Etezadi et al. Identified the thyromental height, measured between the anterior border of the thyroid cartilage and the anterior border of the mentum in supine position, as a more precise predictor of difficult laryngoscopy [36]. However, differences in study populations, variation in positioning, and a small sample size have prompted further investigation in our study. The X-ray indicators in our research were easily obtained from the patient's self-positioned extended lateral radiograph, aligning with the maximal head extension tilt during intubation, without imposing any additional examination burden.

Our study's approach offers a streamlined and patient-friendly method for assessing difficult laryngoscopy, which is particularly advantageous in the context of preoperative evaluations for patients undergoing elective cervical spine surgery. By leveraging these X-ray indicators, we aim to enhance the predictive accuracy of difficult laryngoscopy and contribute to a more informed and safer anesthetic practice.

Given that no simple indicators can attain 100% predictive accuracy, it is recommended to use a combination of screening tests to improve the predictive ability for laryngoscopic exposure in patients with cervical spondylosis [37]. Although various clinical models had been devised for the prediction of difficult laryngoscopy, they tended to get low sensitivities. Naguib et al. integrated radiological indicators into a predictive model of difficult airway and achieved high sensitivity and specificity, surpassing the recognized Wilson risk-sum score and Arnè model [38]. Our novel combined predictive model for difficult laryngoscopy selected three popular clinical independent variables and one easily obtainable radiological indicator, which did not require patients to extend their necks during preoperative assessment, potentially reducing the risk of spinal cord injury. The new combined model was easy to implement with an AUC of 0.776 for airway assessment. These findings also suggested that radiological indicators, used as part of a screening protocol, played a significant role in the prediction of difficult laryngoscopy within the population with cervical disease.

This study has several limitations. Firstly, no prospective validation of the proposed combination of predictive tests was conducted. Secondly, a multicenter study, including a larger number of participants, could enhance the study's power and provide validation for our model. Third, determination of the best cutoff point for LMAT and combined model is more applicable to cervical spondylosis patients and extending their application to other populations would require further validation.

Conclusion

Radiological indicators could improve the predictive accuracy. LMHT and the novel combined predictive model incorporating LMAT appear be valuable predictors for identifying difficult laryngoscopy in patients with cervical spondylosis.

Abbreviations

ASA-PS	American Society of Anesthesiologists Physical Status Classification
AUC	Area under the curve
BMI	Body mass index
CI	Confidence interval
C-L	Cormack-Lehane
IIG	Inter-incisor gap
LH	Laryngeal Height
LMAT	Larynx-Mandibula Angle Test
LMHT	Larynx-Mandibula Height Test
ML	Mandibular length
NC	Neck circumference
NPV	Negative predictive value
OR	Odds ratio
PACS	Picture archiving and communication systems
PPV	Positive predictive value
ROC	Receiver operating characteristic
TMD	Thyromental distance
ULBT	The upper lip bite test

Acknowledgements

None.

Authors' contributions

JL, YT and MW: Designed the work and drafted the work; JF and HZ: Analyzed and interpretation of data, YF: Prepared figures 1-3 ML MX, JW, ML and XG: Reviewing the manuscript. YH: Revised the manuscript and approving the final version of the manuscript. All authors reviewed the manuscript.

Funding

This study was funded by grants from Capital's Funds for Health Improvement and Research (2024-2-40912), Innovation and Transformation Project, Peking University Third Hospital (BYSYZHKC2022103), Wu Jieping Medical Foundation (320.6750.2023-08-5).

Data availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request

Declarations

Ethics approval and consent to participate

All the procedures were followed in accordance with the relevant guidelines (Ethics approval from Peking University Third Hospital), specifically, ethics permission for this research was obtained from the Medical Science Research Ethics Committee of Peking University Third Hospital (IRB00006761-M2022105) on March 7, 2022. All participants provide informed consent to participate in the study. Patients were enrolled in this research at the Chinese Clinical Trial Registry (http://www.chictr.org.cn; identifier: ChiCTR2200058361) on April 7, 2022.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 21 September 2024 Accepted: 21 November 2024
Published online: 02 December 2024

References

1. Calder I, Calder J, Crockard HA. Difficult direct laryngoscopy in patients with cervical spine disease. Anaesthesia. 1995;50(9):756–63.
2. Xu M, Li X, Wang J, Guo X. Application of a new combined model including radiological indicators to predict difficult airway in patients undergoing surgery for cervical spondylosis. Chin Med J. 2014;127(23):4043–8.
3. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology. 2005;103(2):429–37.
4. Han YZ, Tian Y, Zhang H, Zhao YQ, Xu M, Guo XY. Radiologic indicators for prediction of difficult laryngoscopy in patients with cervical spondylosis. Acta Anaesthesiol Scand. 2018;62(4):474–82.
5. Xia M, Ma W, Zuo M, Deng X, Xue F, Battaglini D, et al. Expert consensus on difficult airway assessment. Hepatobiliary Surg Nutr. 2023;12(4):545–66.
6. Cass NM, James NR, Lines V. Difficult direct laryngoscopy complicating intubation for anaesthesia. Br Med J. 1956;1(4965):488–9.
7. Kharrat I, Achour I, Trabelsi JJ, Trigui M, Thabet W, Mnejja M, et al. Prediction of difficulty in direct laryngoscopy. Sci Rep. 2022;12(1):10722.
8. Bannister F, Macbeth R. Direct, laryngoscopy and tracheal intubation. Lancet. 1944;244(6325):651–4.
9. Gadomski BC, Hindman BJ, Poland MJ, Page MI, Dexter F, Puttlitz CM. Intubation biomechanics: computational modeling to identify methods to minimize cervical spine motion and spinal cord strain during laryngoscopy and tracheal intubation in an intact cervical spine. J Clin Anesth. 2022;81: 110909.
10. Vannucci A, Cavallone LF. Bedside predictors of difficult intubation: a systematic review. Minerva Anestesiol. 2016;82(1):69–83.
11. Aceto P, Modesti C, Perilli V, Sacco T, De Cicco R, Calabrese C, et al. A new score which includes ultrasound-assessed tongue thickness to predict difficult intubation in morbidly obese patients: a prospective observational cohort study. Eur J Anaesthesiol. 2022;39(4):388–90.
12. Wu J, Dong J, Ding Y, Zheng J. Role of anterior neck soft tissue quantifications by ultrasound in predicting difficult laryngoscopy. Med Sci Monit. 2014;20:2343–50.
13. Izeki M, Neo M, Ito H, Nagai K, Ishizaki T, Okamoto T, et al. Reduction of atlantoaxial subluxation causes airway stenosis. Spine (Phila Pa 1976). 2013;38(9):E513-520.
14. Zhou Y, Han Y, Li Z, Zhao Y, Yang N, Liu T, et al. Preoperative X-ray C(2)C(6) AR is applicable for prediction of difficult laryngoscopy in patients with cervical spondylosis. BMC Anesthesiol. 2021;21(1):111.
15. Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. Anaesthesia. 1984;39(11):1105–11.
16. Apfelbaum JL, Hagberg CA, Connis RT, Abdelmalak BB, Agarkar M, Dutton RP, et al. 2022 American Society of Anesthesiologists Practice Guidelines for Management of the difficult Airway. Anesthesiology. 2022;136(1):31–81.
17. Min JJ, Kim G, Kim E, Lee JH. The diagnostic validity of clinical airway assessments for predicting difficult laryngoscopy using a grey zone approach. J Int Med Res. 2016;44(4):893–904.
18. Khan ZH, Kashfi A, Ebrahimkhani E. A comparison of the upper lip bite test (a simple new technique) with modified Mallampati classification in predicting difficulty in endotracheal intubation: a prospective blinded study. Anesth Analg. 2003;96(2):595–9 table of contents.
19. Domino KB. Death and brain damage from difficult airway management: a never event. Can J Anaesth. 2021;68(2):169–74.
20. Redhu S, Radhakrishnan M, Rao GS. An audit of the current practices, of airway management in patients undergoing surgery for atlanto-axial dislocation in a single institution. Middle East J Anaesthesiol. 2015;23(2):163–70.
21. Epstein N. Ossification of the cervical posterior longitudinal ligament: a review. Neurosurg Focus. 2002;13(2):Ecp1.
22. Rana V, Mehrotra S, Asthana V, Raghuvanshi S. Radiological versus traditional parameters for Airway Assessment: a comparison. Anesth Essays Res. 2022;16(1):109–14.
23. Ji C, Ni Q, Chen W. Diagnostic accuracy of radiology (CT, X-ray, US) for predicting difficult intubation in adults: a meta-analysis. J Clin Anesth. 2018;45:79–87.
24. Krage R, van Rijn C, van Groeningen D, Loer SA, Schwarte LA, Schober P. Cormack-Lehane classification revisited. Br J Anaesth. 2010;105(2):220–7.
25. Mashour GA, Stallmer ML, Kheterpal S, Shanks A. Predictors of difficult intubation in patients with cervical spine limitations. J Neurosurg Anesthesiol. 2008;20(2):110–5.
26. Calder I, Picard J, Chapman M, O'Sullivan C, Crockard HA. Mouth opening: a new angle. Anesthesiology. 2003;99(4):799–801.
27. Roth D, Pace NL, Lee A, Hovhannisyan K, Warenits AM, Arrich J, et al. Bedside tests for predicting difficult airways: an abridged Cochrane diagnostic test accuracy systematic review. Anaesthesia. 2019;74(7):915–28.
28. Riad W, Vaez MN, Raveendran R, Tam AD, Quereshy FA, Chung F, et al. Neck circumference as a predictor of difficult intubation and difficult mask ventilation in morbidly obese patients: a prospective observational study. Eur J Anaesthesiol. 2016;33(4):244–9.
29. Ezri T, Gewürtz G, Sessler DI, Medalion B, Szmuk P, Hagberg C, et al. Prediction of difficult laryngoscopy in obese patients by ultrasound quantification of anterior neck soft tissue. Anaesthesia. 2003;58(11):1111–4.
30. Ashebir Z, Fentie F, Mohammed Z. Assessment of predictive value of thyromental height in predicting difficult laryngoscopy compared with Mallampati, and thyromental distance among surgical patient who will take general anesthesia at selected governmental hospital cross-sectional study: Ethiopia, 2022. Ann Med Surg (Lond). 2024;86(9):5112–9.
31. Lee HC, Kim MK, Kim YH, Park HP. Radiographic predictors of difficult Laryngoscopy in Acromegaly patients. J Neurosurg Anesthesiol. 2019;31(1):50–6.
32. Gupta K, Gupta PK. Assessment of difficult laryngoscopy by electronically measured maxillo-pharyngeal angle on lateral cervical radiograph: a prospective study. Saudi J Anaesth. 2010;4(3):158–62.
33. Jain K, Gupta N, Yadav M, Thulkar S, Bhatnagar S. Radiological evaluation of airway - what an anaesthesiologist needs to know! Indian J Anaesth. 2019;63(4):257–64.
34. Lee J, Kim JS, Kang S, Shin YS, Doo AR. Prediction of difficult airway management in traumatic cervical spine injury: influence of retropharyngeal space extension. Ther Clin Risk Manag. 2019;15:669–75.
35. de Carvalho CC, da Silva DM, Leite MS, de Andrade LB. Upper airway angle and glottic height: a prospective cohort to evaluate two new features for airway prediction. Braz J Anesthesiol. 2023;73(5):570–7.
36. Etezadi F, Ahangari A, Shokri H, Najafi A, Khajavi MR, Daghigh M, et al. Thyromental height: a new clinical test for prediction of difficult laryngoscopy. Anesth Analg. 2013;117(6):1347–51.

37. Liaskou C, Vouzounerakis E, Trikoupi A, Staikou C. [Evaluation of bedside tests and proposal of a model for predicting difficult laryngoscopy: an observational prospective study]. Braz J Anesthesiol. 2020;70(2):125–33.
38. Naguib M, Malabarey T, AlSatli RA, Al Damegh S, Samarkandi AH. Predictive models for difficult laryngoscopy and intubation. A clinical, radiologic and three-dimensional computer imaging study. Can J Anaesth. 1999;46(8):748–59.

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