

The value of a relatively safe method for predicting difficult laryngoscopy during the COVID-19 epidemic

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Abstract

Background: The current global situation of COVID-19 epidemic is serious. Routine preoperative methods to assess airway such as the interincisor distance, Mallampati classification, and the upper lip bite test have a certain risk of upper respiratory tract exposure and virus spread. The condyle-tragus maximal distance can be used to assess the airway, and the assessment method does not require the patient to expose the upper respiratory tract, but its value in predicting difficult laryngoscopy compared to other indicators (Mallampati classification, interincisor distance, and upper lip bite test) remains unknown. The purpose of this study was to observe the value of condyle-tragus maximal distance to predict difficult laryngoscopy, and provide a new idea for preoperative airway assessment during epidemic.

Methods: We enrolled adult patients who underwent general anesthesia and tracheal intubation. The interincisor distance, Mallampati test result, upper lip bite test result, and the condyle-tragus maximal distance of each patient were evaluated prior to the initiation of anesthesia. The primary outcome was difficult laryngoscopy defined as the Cormack-Lehane Level > grade 2.

Results: A total of 304 patients were successfully included in the study, 39 patients were identified as difficult laryngoscopy. The correlation between the condyle-tragus maximal distance and Cormack-Lehane Level was the highest (Spearman correlation coefficient, -0.317 ; $P=0.001$), and the area under the ROC curve was the highest (AUC 0.699 , $P=0.01$). The condyle-tragus maximal distance <1 finger width was the most consistent with difficult laryngoscopy ($\kappa=0.485$; 99% CI, $0.286-0.612$) and its OR value was 10.09 (95% CI: $4.19-24.28$), sensitivity was 0.469 (95% CI: $0.325-0.617$), specificity was 0.929 (95% CI: $0.877-0.964$), positive predictive value was 0.676 (95% CI: $0.484-0.745$), negative predictive value was 0.847 (95% CI: $0.825-0.865$).

Conclusion: Compared with the interincisor distance, Mallampati classification and the upper lip bite test, the condyle-tragus maximal distance has higher value in predicting difficult laryngoscopy, which can become a safer airway assessment method during the epidemic of COVID-19.

Trial registration: The study was registered on October 21, 2019 in the Chinese Clinical Trial Registry (ChiCTR1900026775).

Background

The coronavirus disease 2019 (COVID-19) pandemic is a serious global health threat whose main transmission route is through respiratory droplets^[1]. To control the pandemic and prevent novel coronavirus pneumonia, admitted patients are required to wear masks for effective prevention. It undoubtedly brings certain difficulties and risks to our anesthesiologists to perform preoperative airway evaluation and predict airway difficulties, because routine physical examination indicators, such as the interincisor distance (IID), Mallampati classification, and the upper lip bite test (ULBT), require the patient to remove their mask and open their mouth while anesthesiologists conduct a close-up observation of the anatomical structure of the pharyngeal cavity and incisors. Doing so will undoubtedly greatly increase the

risk of nosocomial infection. Therefore, it is necessary to explore a preoperative evaluation method that does not require the patient to remove the mask but can relatively safely and effectively predict difficult airways.

Temporomandibular joint (TMJ) mobility plays a significant role in the grading of laryngoscopic exposure and is an important indicator for predicting and evaluating difficult airways^[2]. TMJ mobility is usually indirectly reflected by some routine physical examination indicators such as IID, ULBT, and Mallampati classification. IID, ULBT, Mallampati classification, and other indicators that indirectly reflect the TMJ mobility have certain predictive value for difficult airways, but the accuracy and reliability of this prediction are still relatively limited^[3]. Ultrasound measurement of the maximum movement distance of the condyle is thought to directly reflect the degree of TMJ mobility, and it can be effectively used for preoperative airway assessment^[4]. However, this method is not simple and can not be effectively applied when patients wear protective equipment such as face masks.

The condyle-tragus maximal distance (C-TMD) can be used for preoperative airway assessment. The evaluation method is as follows: The patient sits, and the examiner uses his/her fingers to locate the mandibular condyle of the patient, instructs the patient to open the mouth as wide as possible, and then evaluates whether the distance between the condyle and the tragus can accommodate the width of one finger^[5]. This method of assessing the airway can be completed while the patient wears a mask. It is relatively safe, but its value in predicting difficult laryngoscopy compared to other indicators that indirectly reflect the degree of TMJ mobility (Mallampati classification, IID, and ULBT) remains unknown.

The purpose of this study was to observe the correlation and agreement between C-TMD and other valuable predictive indicators of difficult laryngoscopy in classifying laryngoscopy and predicting difficult laryngoscopy, and to calculate the predictive value of C-TMD. It may provide a new idea for preoperative airway assessment and difficult airway prediction in the general environment of the COVID-19 pandemic.

Methods

This study was approved by the Ethics Committee of Anhui Provincial Hospital, the First Affiliated Hospital of the University of Science and Technology of China, under ethics approval number 2019KY No. 108. It was approved by the China Clinical Trial Registration Center under registration number ChiCTR1900026775. All trial participants were informed about the entire trial process and signed informed consent.

In this trial, we enrolled patients who underwent elective surgeries with endotracheal intubation under general anesthesia and were of ASA status I-III and 18–90 years of age. We excluded patients with no teeth, with maxillofacial injuries, inability to cooperate, a thyromental distance less than three fingers wide, or limited head and neck movement (less than 80 degrees).

For all the patients enrolled in this study, during the preoperative examination one day before the operation or after the patient entered the preparation room on the day of the operation, an

anesthesiologist who was skilled in the operative procedures used in this study examined whether the C-TMD could accommodate one finger width. The specific measurement procedure was as follows: the patient sat upright, and the examiner used the index fingers of both hands to locate the mandibular condyle of the mandible, instructed the patient to open the mouth as wide as possible, and felt that the condyle moved with the mouth opening movement. When the mouth opened as far as possible, the examiner then evaluated whether the distance between the condyle and the tragus could accommodate the width of one finger. The above measurement was repeated three times, and the maximum distance between the condyle and the tragus was taken(See Fig. 1 for details).

Later, another anesthesiologist, who was not aware of the evaluation results of C-TMD, measured other relevant indicators for airway evaluation. These indicators all indirectly reflected the degree of TMJ mobility:

Mallampati classification: The patient sat upright, opened the mouth wide, and extended the tongue to the maximum (no sound is made). The patient was then scored according to the pharyngeal structure that could be observed. Mallampati class > 2 was considered to be a predictive risk factor for difficult airways [6].

Interincisor distance (IID): The patient sat and opened the mouth as wide as possible, and then the doctor estimated IID with fingers. IID less than the width of three fingers was a predictive risk factor for difficult airways [7].

Upper lip bite test (ULBT) classification: The patient sat with the chin extending forward. The patient was asked to try his/her best to bite the upper lip with the lower incisors. According to the ability of the lower incisors to bite the upper lip, the test result was divided into three classes: Class 1: the lower incisors completely bit the upper lip above the vermilion border and completely covered the upper lip membrane; class 2: the lower incisors only bit half of the upper lip membrane and failed to reach the vermilion border; class 3: the lower incisor could not bite the upper lip. Classes 2 and 3 were the predictive risk factors for difficult airways [8].

All patients underwent routine electrocardiographic monitoring and induction of general anesthesia that started after the venous access was opened. The induction protocol utilized the following standardized recipe: midazolam 0.05 mg/kg, sufentanil 0.6 µg/kg, rocuronium 0.6 mg/kg and etomidate 0.3 mg/kg. An anesthesiologist with more than 3 years of experience, who was not aware of any preoperative airway evaluation results, conducted tracheal intubation with laryngoscopic exposure 3 min after bolus injection of rocuronium. According to the specific situation, either No. 3 or No. 4 laryngoscopy blades were used, and all patients took the head-up sniffing position. After intubation, the grading of all patients' laryngoscopic exposure was recorded. The Cormack-Lehane classification was used to grade laryngoscopic exposure, and observations of the structure of the larynx and the glottis were divided into four classes. Class 1: the glottis structure was fully exposed, and the front and back joint structure could be seen; class 2: the glottis was partially revealed, and the rear glottal joint structure could be seen; class

3: only the epiglottis was seen; class 4: neither the glottis nor epiglottis was visible, Classes > 2 were defined as difficult laryngoscopy [9]. If difficult airway appeared in the process, we followed the difficult airway treatment guidelines for the treatment and we also prepared conventional treatment tools such as a fiberoptic bronchoscope, laryngeal mask, and video laryngoscope.

Reliability test

To verify whether C-TMD accommodating the width of one finger can directly reflect the TMJ mobility and whether the method can accurately evaluate the condition when the patient wore protective equipment such as masks, we added two sets of reliability tests. We recruited 20 volunteers. All volunteers wore masks, and an anesthesiologist skilled in the experimental operation method evaluated whether the C-TMD of the volunteers could accommodate the width of a finger (See Fig. 2 for details). After the evaluation was completed, all volunteers took off their masks, and then another anesthesiologist skilled in the operation of this experiment, who was not aware of the previous measurement results, assessed whether the C-TMD of the volunteers could accommodate the width of a finger. The difference between the two evaluation results was compared. In addition, an anesthesiologist used ultrasound to measure the maximum condylar movement distance of all volunteers, that is, the degree of condylar mobility. We then analyzed the correlation between C-TMD and the degree of condyle mobility measured by ultrasound.

Statistical analysis

The SPSS 19.0 and MedCalc 19.2.0 statistical software packages were used. Measurement data were expressed as mean \pm standard deviation ($\bar{x} \pm s$), and ranked or categorical variables were expressed as frequency/ratio (n/%). For univariate comparison between patients with difficult laryngoscopy and those with nondifficult laryngoscopy, the independent-sample t test, rank sum test, and chi-squared test were selected, according to specific circumstances. Spearman correlation analysis was used to analyze the correlation of variables, and the results of each predictor and laryngoscopic exposure were compared with the paired chi-squared test and internal

agreement tests and kappa values were calculated. The receiver operating characteristic curve (ROC curve) was used to analyze the predictive value of each observed parameter to predict difficult laryngoscopy, expressed as the area under the curve (AUC) with its 95% confidence interval (95% CI), and the odds ratio (OR), specificity, and sensitivity of each index for predicting difficult laryngoscopy were calculated. $P < 0.05$ indicated statistical significance.

Results

General information of patients and airway assessment results

373 patients were selected to be intubated under general anesthesia. Laryngeal mask airway management was performed in 58 patients, and surgery was temporarily canceled in 11 patients. Therefore, a total of 304 patients were successfully included in this study, including 137 male patients

and 39 patients with difficult laryngoscopy. After group analysis of all patients according to whether they had difficult laryngoscopy, the differences of Mallampati classification, upper lip bite classification, Interincisor distance, and the condyle-tragus maximal distance between the two groups were statistically significant, while the differences of body mass index were not. Descriptive data of the patients and the airway assessment results are shown in Table 1.

Table 1
Comparison between the difficult and the non-difficult laryngoscopy group

variable	Difficult laryngoscopy	Non-difficult laryngoscopy	<i>P</i> value
	n = 39	n = 265	
Sex (male/female, n)	26/13	111/154	0.003
Age (y)	57 ± 13	49 ± 16	< 0.001
Height (cm)	163 ± 7	165 ± 8	0.32
weight (kg)	62 ± 11	64 ± 12	0.52
Body mass index (kg/m ²)	23.4 ± 3.7	23.4 ± 3.5	0.94
Mallampati classification (Ⅲ/Ⅱgrade, n)	5/34	128/137	< 0.001
ULBT (> 1/1grade, n)	33/6	148/117	< 0.001
IIDⅢ finger width (yes/no,n)	31/8	92/173	< 0.001
C-TMD < 1 finger width (yes/no,n)	35/4	81/184	< 0.001
Data are shown as the means ± standard deviation or numbers. Difficult laryngoscopy was defined as a Cormack and Lehane grade > 2.			
Abbreviations: ULBT, Upper lip bite test; IID, interincisor distance; C-TMD, condyle-tragus maximal distance.			
All patient characteristics were compared using Mann-Whitney U test for continuous variables and χ^2 or Fisher exact test for categorical variables.			

Comparison of preoperative predictors and the Cormack-Lehane Levels

The *r* values of correlation between C-TMD, IID, ULBT, Mallampati classification and Cormack-Lehane Levels was - 0.317,-0.261,0.266 and 0.213 respectively (all *P* values were less than 0.01). The highest

correlation index was the C-TMD. Paired chi-square and agreement test showed that the C-TMD < 1 finger width had the highest *k* value (0.485) (see Table 2 and Table 3 for details).

Table 2
Correlation between each predictor and Cormack-Lehane Levels (n = 304)

variable	rvalue	Pvalue
C-TMD	-0.317	< 0.001
IID	-0.261	< 0.001
ULBT	0.266	< 0.001
Mallampati classification	0.213	0.002
Spearman correlation analysis was used for all correlations.		
Abbreviations:ULBT,Upper lip bite test; IID, interincisor distance; C-TMD, condyle-tragus maximal distance.		

Table 3
Agreement test between each predictor and difficulty laryngoscopy (n = 304)

predictors		Difficult laryngoscopy		κ value	95% CI
		NO	YES		
C-TMD	≤1 finger	184	4	0.485	0.286–0.612
	>1finger	81	35		
IID	≤3finger	173	8	0.382	0.127–0.534
	>3finger	92	31		
ULBT	1 grade	117	6	0.127	0.035–0.216
	>1 grade	148	33		
Mallampati Test	≤3 grade	128	5	0.138	0.17–0.255
	>2 grade	137	34		
Abbreviations: ULBT, Upper lip bite test; IID, interincisor distance; C-TMD, condyle-tragus maximal distance; CI, confidence interval.					

The predictive value of each predictor to predict difficult laryngoscopy

The receiver operating characteristic (ROC) curve analysis showed that the AUC of the C-TMD, IID, Mallampati classification and ULBT classification for predicting difficult laryngoscopy were 0.699, 0.637,

0.613 and 0.648 respectively (all *P* values were less than 0.001). The predictive value of the C-TMD is the highest (See Fig. 3 for details).

The OR value, sensitivity and specificity, positive predictive value and negative predictive value of each predictor were calculated. Among them, the predictive value of the C-TMD was the highest: OR value was 10.09 (95%CI: 4.19–24.28), sensitivity was 0.469 (95%CI:0.325–0.617), specificity was 0.929 (95%CI: 0.877–0.964), positive predictive value was 0.676 (95%CI: 0.484–0.745), negative predictive value was 0.847 (95%CI :0.825–0.865) (see Table 4 for details).

Table 4
Value of each predictor in predicting difficult laryngoscopy (n = 304)

predictors	Odds ratio (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
C-TMD \geq 1 finger	10.09 (4.19–24.28)	0.469 (0.325–0.617)	0.929 (0.877–0.964)	0.676 (0.484–0.745)	0.847 (0.825–0.865)
IID < 3 finger	3.54 (1.55–8.12)	0.429 (0.288–0.578)	0.845 (0.778–0.898)	0.467 (0.418–0.493)	0.824 (0.746–0.887)
ULBT > 1 grade	2.48 (1.02–6.02)	0.796 (0.657–0.898)	0.400 (0.322–0.482)	0.295 (0.174–0.324)	0.861 (0.735–0.923)
Mallampati classification \geq 2 grade	1.77 (0.78–3.91)	0.691 (0.546–0.817)	0.503 (0.422–0.584)	0.306 (0.276–0.371)	0.839 (0.813–0.908)
Abbreviations: CI, confidence interval; ULBT, Upper lip bite test; IID, interincisor distance; C-TMD, condyle-tragus maximal distance; NPV, negative predictive value; PPV, positive predictive value.					

Results of reliability test

Twenty volunteers (14 males and 6 females) were successfully enrolled in the trial. There was no difference between the incidence rates of C-TMD < 1 finger width estimated by the two anesthesiologists (both were 5%). The maximum movement distance of the condyle measured by ultrasound was 12.6 ± 2.3 mm. Analysis of the correlation between whether the C-TMD < 1 finger width and the maximum movement distance of the condyle measured by ultrasound showed $r = 0.91$, and $p < 0.001$ (Spearman correlation analysis).

Discussion

This study confirms that evaluating whether the C-TMD can accommodate the width of one finger can relatively effectively predict difficult laryngoscopy, and it is better than other indicators, as indicated by Spearman's correlation, the agreement test, the AUC value, and OR value.

The differences in the Mallampati classification, ULBT, IID and C-TMD were significant between the difficult laryngoscopy group and the nondifficult laryngoscopy group, which shows that they are all indicators predicting difficult laryngoscopy. The difference in age between the two groups was also significant. The most common age range of patients in the difficult laryngoscopy group was 44–70 years. This result is consistent with the recent study of Schnittker R et al. [10].

The airway is evaluated before anesthesia mainly by two methods: accurate measurement and finger width estimation. Finger-width estimation is more commonly used because of its simplicity and speed, and it is more advantageous in large-scale top-tiered hospitals with a high surgery volume and fast pace. Yao et al. [4] used ultrasound to measure the distance moved by the condyle before and after the opening of the mouth to evaluate the degree of condyle mobility and applied it to the prediction of difficult laryngoscopy. The resulting AUC value of the ROC curve was 0.934, which is higher than those of the accurate measurement methods IID, ULBT grading, and Mallampati classification. The current method used the tragus as a reference line and used the width of the finger to estimate the maximum distance between the condyle and the tragus. This method can avoid the constraints of objective conditions, such as the availability of ultrasound, and is more convenient. Its AUC value was 0.699, which was higher than the AUCs from the finger-width estimation of IID, ULBT grading, and Mallampati classification. These results are basically consistent with those of Yao et al.

C-TMD had the highest correlation and agreement with the laryngoscope classification. This may have been because C-TMD can directly reflect the degree of TMJ movement. Reliability testing results showed that C-TMD was highly correlated with the maximum movement distance of the condyle measured by ultrasound. The maximum movement distance of the condyle measured by ultrasound can directly reflect TMJ mobility, meaning C-TMD can directly reflect the degree of TMJ mobility as well. The process of laryngoscopic exposure is actually the process of mandibular opening and forward movement, in which the condyle is the pivot point of the entire movement [11]. The wider the range of motion of the condyle, the greater the potential for mandibular movement. Sójka A et al. [12] also showed that the degree of TMJ mobility was closely correlated with the range of motion of the condyle at the maximum mouth opening. Taking the tragus as a reference, C-TMD can reflect the maximum mobility of the condyles. Therefore, C-TMD < 1 finger width may be an independent risk factor for difficult laryngoscopy.

The results of this study show that the specificity of this predictive index of C-TMD < 1 finger width was 0.929, and the positive predictive value was 0.676, higher than those of other indices, indicating that the misdiagnosis rate and missed diagnosis rate of this index are lower than those of other related indicators. In predicting difficult airways, the indicator of IID < 3 finger width, which is used most

frequently in our clinical practice, only had a positive predictive value of 0.467, in line with the findings of China AK et al. [13]. These data further support the advantage of C-TMD < 1 finger width in predicting difficult laryngoscopy.

The upper lip bite test has always been considered a useful indicator for predicting difficult laryngoscopy. One advantage is its simple operation, as high ULBT classes can be easily detected by clinicians. However, its misdiagnosis rate is high, and many patients who do not have difficult laryngoscopy are misdiagnosed because of higher ULBT classes [14]. Our results are consistent with this observation and showed that the sensitivity of high ULBT class was 0.796, while its positive predictive value was only 0.295. We believe that the reason why many patients can not bite the upper lip above the vermilion border with the lower incisors could be due to thick lips rather than reduced TMJ mobility. Whether the factor of lip thickness is one of the reasons for the low positive predictive value of ULBT classification needs to be further investigated.

At present, COVID-19 has broken out all over the world, the situation is still very grim, and we can not lower our guard. While adopting protection for ourselves and our patients, we can improve the traditional diagnosis and treatment methods to reduce the cross-infection rate between medical staff and patients [15]. For patients undergoing elective surgery in the new environment, preoperative airway assessment is essential, but it also carries high risk. It is meaningful to find a way to balance the effectiveness and safety of airway assessment. The assessment of C-TMD can be completed even while the patient wears personal protective equipment such as a mask, and it has high predictive value. During this pandemic, it can be used as a safe method to assess airways instead of IID, Mallampati classification, and ULBT classification.

This study still has some limitations. From the perspective of methodology, the method of evaluating the condyle mobility depends on the estimation using finger width. Although it has higher predictive value than other related indicators, whether it will have lower predictive value than accurate measurement still needs to be confirmed. The sample size of this study was small. In clinical practice, limited TMJ mobility in some patients is due to fractures and inflammation. For this type of patient, we cannot tell whether they are unable to open their mouths because of pain. To eliminate such interference, this study excluded this type of patient. In some patients, the condyles can not be accurately identified by touching due to obesity, which may affect the test results.

The width of the index finger of a normal adult is approximately 1.2 cm. Whether this means that C-TMD less than 1.2 cm is a high-risk factor for difficult laryngoscopic exposure still needs to be explored through visualization techniques such as ultrasound. In future studies, we will use ultrasound to locate the condyle to measure C-TMD, in order to calculate the error rate of finger positioning, eliminate the impact of individual finger-width differences on the prediction results, and compare the advantages and disadvantages of ultrasound positioning and finger positioning.

Conclusions

In summary, compared with IID, Mallampati classification, and ULBT grading, C-TMD is better at predicting difficult laryngoscopy, and it can be a safer airway assessment method during the COVID-19 epidemic.

Abbreviations

ASA: American Society of Anesthesiology; BMI: Body mass index; IID: Interincisor distance; ULBT: Upper lip bite test; C-TMD: Condyle-tragus maximal distance.

Declarations

Acknowledgements

Not applicable.

Authors' contributions

WH and ZW helped design the study, conduct the study, collect the data, analyze the data, and prepare the manuscript. HDD helped analyze the data, and prepare the manuscript. CX and ZXB helped conduct the study, collect the data, analyze the data, and prepare the manuscript. XM helped conduct the study and collect the data.

CXQ and WS helped conduct the study and collect the data.

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Availability of data and materials

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

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Anhui Provincial Hospital, the First Affiliated Hospital of the University of Science and Technology of China, under ethics approval number 2019KY No. 108. Written informed consent was obtained from all the patients.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures



Figure 1

When opening the mouth as wide as possible, the condyle will move forward and down, the condyle-tragus maximal distance of this patient could accommodate one finger width without mask on.



Figure 2

The condyle-tragus maximal distance of this patient could accommodate one finger width with mask on.

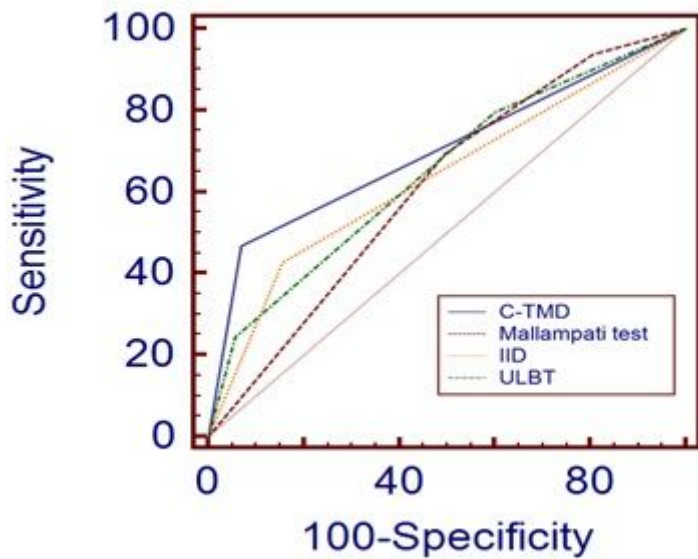


Figure 3

Receiver operating characteristic curve analysis of each predictor for predicting difficult laryngoscopy. IID indicates interincisor distance; ULBT, upper lip bite test; C-TMD, condyle-tragus maximal distance.