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# Preoperative X-ray C<sub>2</sub>C<sub>6</sub>AR is applicable for prediction of difficult laryngoscopy in patients with cervical spondylosis

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## Abstract

**Background:** Airway management is one of the most important techniques in anesthesia practice and inappropriate airway management is related with airway injury, brain hypoxia, and even death. The patients with cervical spondylosis are often confronted with difficult laryngoscopy who are more prone to appear difficult airway, so it is important to figure out valuable predictors of difficult laryngoscopy in these patients.

**Methods:** We randomly enrolled 270 patients undergoing elective cervical spine surgery and analyzed the cervical mobility data in predicting difficult laryngoscopy. The preoperative X-ray radiological indicators were measured by an attending radiologist. Cormack-Lehane scales were assessed during intubation, and patients with a class III or IV view were assigned to the difficult laryngoscopy group.

**Results:** Univariate analysis showed that the hyomental distance (HMD, the distance between the hyoid bone and the tip of the chin) and the hyomental distance ratio (HMDR, the ratio between HMD in the extension position and the one in the neutral position) might not be suitable indicators in patients with cervical spondylosis. Binary multivariate logistic regression (backward-Wald) analyses identified two independent correlative factors from the cervical mobility indicators that correlated best as a predictor of difficult laryngoscopy: modified Mallampati test (MMT) and C<sub>2</sub>C<sub>6</sub>AR (the ratio of the angle between a line passing through the bottom of the second cervical vertebra and a line passing through the bottom of the sixth cervical vertebra in the extension position and the one in the neutral position). The odds ratio (OR) and 95 % CI were 2.292(1.093–4.803) and 0.493 (0.306–0.793), respectively. C<sub>2</sub>C<sub>6</sub>AR exhibited the largest area under the curve (0.714; 95 % CI 0.633–0.794).

**Conclusions:** C<sub>2</sub>C<sub>6</sub>AR based on preoperative X-ray images may be the most accurate predictor of cervical mobility indicators for difficult laryngoscopy in patients with cervical spondylosis.

**Trial registration:** The study was registered at the Chinese Clinical Trial Registry (<http://www.chictr.org.cn>; identifier: ChiCTR-ROC-16,008,598) on June 6, 2016.

**Keywords:** X-ray, Difficult laryngoscopy, Cervical spondylosis, Radiologic indicators, Cervical mobility

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## Background

Airway management is one of the most important techniques in clinical anesthesia practice. Inappropriate airway management may lead to airway injury, brain hypoxia and airway management failure is the primary cause of anesthesia-related deaths. According to the recent ASA Closed Claims, the number of claims related to difficult tracheal intubation is comparable with the previous phase, however, outcomes remained poor and differed with a higher proportion of death (73 % in 2000 to 2012 vs. 42 % in 1993 to 1999) [1]. At present, the incidence rate of cervical spondylosis is increasing year by year, and these patients are often confronted with difficult laryngoscopy [2], with the incidence of difficult laryngoscopy to be 17.1 % [3], far more than the incidence of 5.8 % in the general population [4]. Although cervical spondylosis could be an alert signal for a predictable difficult airway, the difficulty of tracheal intubation is variable in different types of cervical spondylosis. Some of the patients are more prone to appear difficult laryngoscopy during tracheal intubation, which could even develop into the emergency airway, such as can't intubation and can't ventilation situation. There is still a lack of effective and specific evaluation methods for these patients, and it is fundamentally important to figure out the most valuable predictor of difficult laryngoscopy in patients with cervical spondylosis.

Mallampati III and IV are the most popular conventional predictors for difficult ventilation [5, 6], but their prognostic value for difficult laryngoscopy was poor. After a meta-analysis involving 177 088 patients, Lundstrøm et al [7] found that the modified Mallampati test (MMT) is inadequate as a stand-alone test of a difficult laryngoscopy with the predictive sensitivity of 0.35. To screen out the potential difficult airway patients with cervical spondylosis and avoid the unanticipated difficult airway, we had better make full use of the radiological images as indicators preoperatively. Difficult Airway Society 2015 guideline had pointed out that radiological examination which could provide more precise information regarding anatomical structures proved to be a suitable method for predicting a difficult airway [8]. In this study, we recruited patients diagnosed with cervical spondylosis or myelopathy, aimed to explore a valuable radiologic indicator to predict difficult laryngoscopy compared to physical examinations in patients with cervical spondylosis.

## Methods

The protocol was approved by the Medical Ethics Committee of the authors' hospital (IRB00006761-2015021), and the informed consent forms were obtained from the patients. Patients with cervical spondylosis or myelopathy who needed to undergo elective cervical

spine surgery under general anesthesia with oral endotracheal intubation were included. Exclusion criteria included pregnancy, cervical spondylolisthesis, cervical segmental instability, anatomical abnormality like oropharyngeal mass or micrognathia, medical history of failed or difficult intubation. This study was approved by the ethics committee of the hospital and registered at the Chinese Clinical Trial Registry (<http://www.chictr.org.cn>; identifier: ChiCTR-ROC-16,008,598) on June 6, 2016.

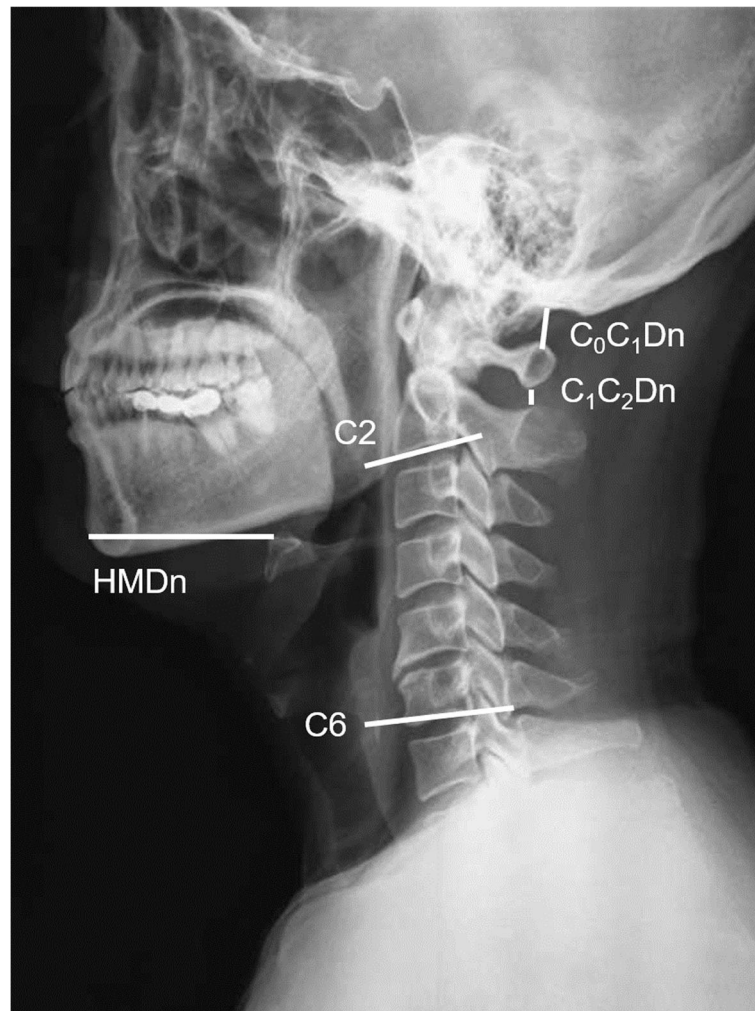
MMT was assessed preoperatively. The patients sit upright with the head in a neutral position. The oropharyngeal structures were observed when the mouth was maximally opened and the tongue protruded by the anesthesiologist who sits opposite at eye level with a pen torch. The airway was classified according to the structures seen: class I, soft palate, fauces, uvula, pillars; class II, soft palate, fauces, uvula; class III, soft palate, base of the uvula; class IV, soft palate not visible at all [9].

The patients were routinely examined with cervical spine plain X-ray at lateral view both in neutral and extension positions. They were instructed to stand in a designated location and were requested to keep the upper cervical spines with retroversion as much as possible when extension applied and ordered not to move the lower cervical spines and shoulder muscles. All radiological indicators were measured using the radiography information system (Centricity RIS-IC CE V3.0; GE Healthcare, Little Chalfont, UK), by the same experienced radiologist who was blind to the anesthesia operation (Figs. 1 and 2).

All patients received standardised general anaesthesia with sufentanil (0.3 mcg/kg), propofol (2 mg/kg) and rocuronium (0.6 mg/kg). After muscle relaxation was achieved, the laryngoscopy view was assessed by a single experienced anesthesiologist who was blind to the preoperative radiological data using the Macintosh laryngoscope. The result was determined by the Cormack-Lehane (C-L) grade [10]. Patients with Cormack-Lehane grade 3 or 4 were assigned to the difficult laryngoscopy group, and patients with Cormack-Lehane grade 1 or 2 were assigned to the easy laryngoscopy group. Then, tracheal intubation was performed with a Macintosh laryngoscope or alternative device by the same anesthesiologist. In patients with a difficult airway, intubation was performed according to the Difficult Airway Society 2015 guidelines [8].

## Statistical analysis

The previous study had reported that the incidence of difficult laryngoscopy could be as high as 20 % [11]. A power calculation showed that 245 patients would be

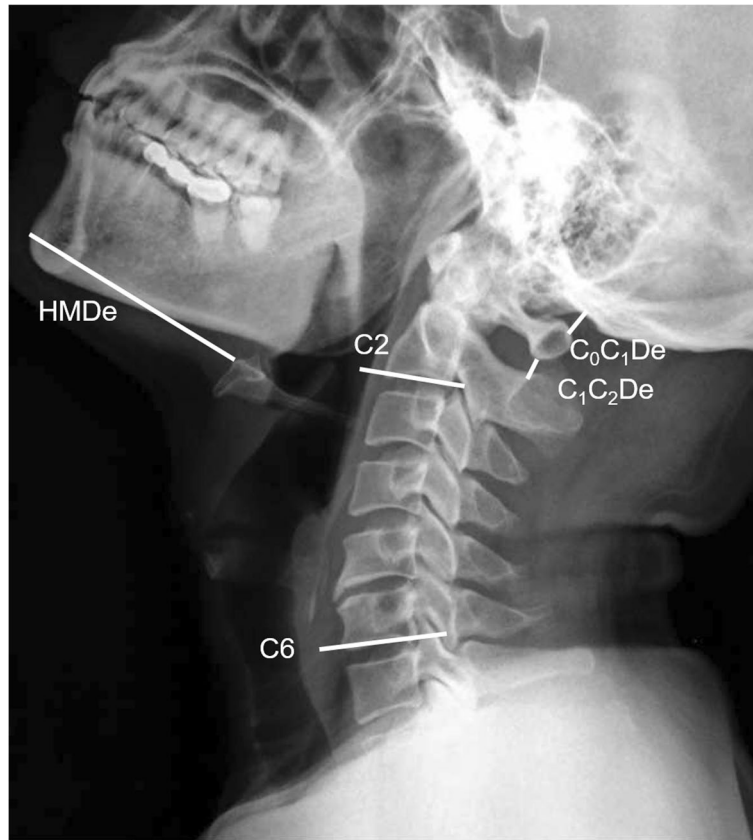


**Fig. 1** Lateral cervical X-ray film in the neutral positions. HMDn, the distance between the hyoid bone and the tip of the chin in the neutral position; C<sub>0</sub>C<sub>1</sub>Dn, the distance between the occipital bone and first cervical vertebra in the neutral position; C<sub>1</sub>C<sub>2</sub>Dn, the distance between the first cervical vertebra and the second cervical vertebra in the neutral position

required to detect a difference in predictors between the difficult and easy laryngoscopy groups ( $\alpha = 0.05$  and  $\beta = 0.1$ ). In consideration of a potential dropout, 270 patients were recruited for the study. Data were analyzed by SPSS software (Version 21.0; IBM Corp., USA). The data are expressed as the mean  $\pm$  standard deviation (SD), the median and interquartile range (IQR), or the number (%). The Kolmogorov–Smirnov method was used to test the normality of all of the variables. Categorical variables were analyzed using a  $\chi^2$  test, while continuous variables were analyzed using an independent-samples t-test. The Mann–Whitney U-test was used to analyze non-normal variables. Binary multivariate logistic regression analyses were performed. A receiver operating characteristic (ROC) curve and the area under the curve (AUC) was used to describe the discrimination abilities of the predictive indicators. Statistical significance was set at  $P < 0.05$ .

## Results

270 patients meeting the inclusion criteria were recruited from June 2016 to December 2016. The cervical mobility indicators assessed in this study are listed in Table 1. Three indicators were significantly different between the easy and difficult laryngoscopy groups: the MMT grade ( $P = 0.037$ ), C<sub>2</sub>C<sub>6</sub>An (the angle between a line passing through the bottom of the second cervical vertebra and a line passing through the bottom of the sixth cervical vertebra in the neutral position,  $P = 0.013$ ) and C<sub>2</sub>C<sub>6</sub>AR (the ratio of the angle between a line passing through the bottom of second cervical vertebra and a line passing through the bottom of sixth cervical vertebra in the extension position and the one in the neutral position,  $P < 0.001$ ). There was a higher MMT grade (class III–IV) ratio, less C<sub>2</sub>C<sub>6</sub>An, and less C<sub>2</sub>C<sub>6</sub>AR in difficult laryngoscopy group patients versus the easy laryngoscopy group.



**Fig. 2** Lateral cervical X-ray film in the extension positions. HMDe, the distance between the hyoid bone and the tip of the chin in the extension position; C<sub>0</sub>C<sub>1</sub>De, the distance between the occipital bone and first cervical vertebra in the extension position; C<sub>1</sub>C<sub>2</sub>De, the distance between the first cervical vertebra and the second cervical vertebra in the extension position

**Table 1** Cervical mobility indicators to predict difficult laryngoscopy between the two groups of patients undergoing cervical spine surgery

Items	Easy laryngoscopy group (n = 230)	Difficult laryngoscopy group (n = 40)	Statistical Test	P-values
BMI	25.1 ± 3.3	25.7 ± 2.5	t=-1.127	0.261
<b>MMT (class I-II/class III-IV)</b>	<b>149(64.8)/81(35.2)</b>	<b>19(47.5)/21(52.5)</b>	<b>χ<sup>2</sup> = 4.33</b>	<b>0.037</b>
HMDn (cm)	5.4 ± 0.8	5.3 ± 0.9	t = 0.777	0.438
HMDe (cm)	6.6 ± 1.0	6.5 ± 0.8	t = 1.073	0.285
HMDR	1.21 (0.19)	1.22 (0.13)	z=-0.382	0.703
C <sub>0</sub> C <sub>1</sub> Dn (mm)	6.7 ± 2.6	6.4 ± 3.1	t = 0.665	0.507
C <sub>0</sub> C <sub>1</sub> De (mm)	0.6 ± 0.3	0.5 ± 0.3	t = 1.249	0.213
C <sub>0</sub> C <sub>1</sub> DR	12.14 (10.29)	13.70 (10.10)	z = 0.490	0.624
C <sub>1</sub> C <sub>2</sub> Dn (mm)	4.6 (2.5)	5.0 (4.3)	z = 1.113	0.266
C <sub>1</sub> C <sub>2</sub> De (mm)	0.5 (0.3)	0.6 (0.3)	z = 1.087	0.277
C <sub>1</sub> C <sub>2</sub> DR	8.88 (5.36)	8.96 (6.51)	z = 0.259	0.796
<b>C<sub>2</sub>C<sub>6</sub>An (°)</b>	<b>9.0 (12.0)</b>	<b>13.5 (10.9)</b>	<b>z = 2.484</b>	<b>0.013</b>
C <sub>2</sub> C <sub>6</sub> Ae (°)	16.7 (13.6)	17.6 (16.1)	z=-0.572	0.568
<b>C<sub>2</sub>C<sub>6</sub>AR</b>	<b>1.80 (2.25)</b>	<b>1.26 (0.56)</b>	<b>z=-4.127</b>	<b>&lt; 0.001</b>

BMI Body Mass Index; MMT modified Mallampati test; HMDn/e the distance between the hyoid bone and the tip of the chin in the neutral/ extension position; HMDR the ratio between HMDe and HMDn; C<sub>0</sub>C<sub>1</sub>Dn/e the distance between the occipital bone and the first cervical vertebra in the neutral/ extension position; C<sub>0</sub>C<sub>1</sub>DR the ratio between C<sub>0</sub>C<sub>1</sub>Dn and C<sub>0</sub>C<sub>1</sub>De; C<sub>1</sub>C<sub>2</sub>Dn/e the distance between first cervical vertebra and the second cervical vertebra in the neutral/ extension position; C<sub>1</sub>C<sub>2</sub>DR the ratio between C<sub>1</sub>C<sub>2</sub>Dn and C<sub>1</sub>C<sub>2</sub>De; C<sub>2</sub>C<sub>6</sub>An/e the angle between a line passing through the bottom of second cervical vertebra and a line passing through the bottom of sixth cervical vertebra in the neutral/ extension position; C<sub>2</sub>C<sub>6</sub>AR the ratio between C<sub>2</sub>C<sub>6</sub>Ae and C<sub>2</sub>C<sub>6</sub>An

Binary multivariate logistic regression (backward-Wald) analyses identified two independent correlative factors from the cervical mobility indicators that correlated best as predictors of difficult laryngoscopy: MMT and C<sub>2</sub>C<sub>6</sub>AR. The odds ratio (OR) and 95% CI were 2.292 (1.093–4.803) and 0.493 (0.306–0.793), respectively (Table 2).

The AUC and standard error calculated for those clinical tests are shown in Table 3. We used the ROC curve and AUC to identify the predictive abilities of these predictors. C<sub>2</sub>C<sub>6</sub>AR exhibited the largest area under the curve (0.714; 95% CI 0.633–0.794).

A prefer cut-off value should take both sensitivity and specificity into account, therefore, we used the Youden index (sensitivity + specificity-1) to screen out the best cut-off value. When the Youden index took the maximum value of 0.39, the cut-off value of C<sub>2</sub>C<sub>6</sub>AR was set to 1.48, with the sensitivity and specificity was 0.64 and 0.76 respectively. We got rid of the sensitivity values less than 0.60 and specificity values less than 0.3 (Table 4). In clinical application, we pay more attention to screen out the most potential difficult laryngoscopy patients with prefer sensitivity value, the cut-off value of C<sub>2</sub>C<sub>6</sub>AR was set to 1.36, with the sensitivity of 0.71 and the specificity of 0.60.

**Discussion**

Most anesthesiologists have experienced difficult airway management, which handled improperly could cause anesthesia-related deaths. There are many physical examinations used to identify people at high risk of difficult airway or difficult intubation, and the upper lip bite test was considered as the most valuable bedside screening test for predicting difficult intubation in general populations [12, 13]. But none of the common bedside tests is well suited for detecting difficult airways for patients with cervical spondylosis, who were reported having a high incidence of difficult laryngoscopy. Although the video laryngoscope provides indirect visualization of the glottis and might be easier to operate, it did not yield a higher first-attempt tracheal intubation success rate than direct laryngoscopy [14, 15]. Therefore, we studied the predictors of cervical mobility indicators which can reflect the difficult laryngoscopy in patients with cervical

**Table 2** Cervical mobility predictors for difficult laryngoscopy identified by binary multivariate logistic regression (backward-Wald) model

Variable	B	SE	P-value	OR	95% CI
MMT	0.829	0.378	0.028	2.292	1.093–4.803
C <sub>2</sub> C <sub>6</sub> AR	-0.708	0.243	0.004	0.493	0.306–0.793
Constant	-1.566	0.661	0.018	0.209	

SE standard error; OR Odds ratio; 95%CI 95% confidence interval

**Table 3** Predictive values of cervical mobility indicators for predicting difficult laryngoscopy

Indicators	AUC	95% CI	SE	P-value
BMI	0.574	0.487–0.661	0.044	0.136
MMT (class I-II/class III-IV)	0.586	0.489–0.684	0.050	0.081
HMDn (cm)	0.569	0.466–0.671	0.052	0.183
HMDe (cm)	0.586	0.492–0.679	0.048	0.102
HMDR	0.520	0.423–0.617	0.049	0.703
C <sub>0</sub> C <sub>1</sub> Dn (mm)	0.541	0.436–0.647	0.054	0.404
C <sub>0</sub> C <sub>1</sub> De (mm)	0.571	0.482–0.660	0.045	0.152
C <sub>0</sub> C <sub>1</sub> DR	0.524	0.433–0.616	0.047	0.624
C <sub>1</sub> C <sub>2</sub> Dn (mm)	0.555	0.451–0.659	0.053	0.266
C <sub>1</sub> C <sub>2</sub> De (mm)	0.554	0.459–0.649	0.049	0.277
C <sub>1</sub> C <sub>2</sub> DR	0.513	0.415–0.610	0.050	0.796
<b>C<sub>2</sub>C<sub>6</sub>An (°)</b>	<b>0.629</b>	<b>0.533–0.724</b>	<b>0.049</b>	<b>0.013</b>
C <sub>2</sub> C <sub>6</sub> Ae (°)	0.530	0.421–0.638	0.055	0.568
<b>C<sub>2</sub>C<sub>6</sub>AR</b>	<b>0.714</b>	<b>0.633–0.794</b>	<b>0.041</b>	<b>&lt; 0.001</b>

AUC area under the curve

spondylosis using direct Macintosh laryngoscopy. We compared several cervical mobility indicators including the Body Mass Index (BMI), MMT, the hyomental distance (HMD), and found that C<sub>2</sub>C<sub>6</sub>AR was the best indicator associated with difficult laryngoscopy in patients with cervical spondylosis.

A significantly greater proportion of difficult laryngoscopy and tracheal intubation had been found in obese patients [16, 17]. However, in our study, we found there was no significant difference between the easy and difficult groups (25.1 ± 3.3 vs. 25.7 ± 2.5, P = 0.261) which were in accordance with the study reported by Prakash et al [18]. MMT is the most popular test for preoperative airway evaluation which could reflect oropharyngeal cavity volume, but its disadvantage is that it could not

**Table 4** Calculated cut-off values that show the best range of sensitivity and specificity for the C<sub>2</sub>C<sub>6</sub>AR

Cut-off point	Sensitivity	Specificity	Youden index
1.48	0.64	0.76	0.40
1.45	0.67	0.70	0.37
1.42	0.68	0.65	0.33
1.36	0.71	0.60	0.31
1.27	0.75	0.54	0.29
1.26	0.76	0.51	0.27
1.21	0.78	0.43	0.21
1.16	0.81	0.41	0.22
1.14	0.82	0.38	0.20
1.04	0.87	0.35	0.22
1.00	0.88	0.30	1.18

Youden index = sensitivity + specificity-1



adequately reflect laryngeal condition and cervical mobility. In our study, we found MMT had low AUC (0.586) which indicated that MMT might not be a preferred predictor for patients with cervical spondylosis.

HMD measurements in different positions might reflect cervical mobility. Suyama et al [19] presented earlier the test for predicting the difficult intubation airway in 476 patients excluding those with neck disease and anatomical abnormalities and they found that HMD less than 3.0 cm could predict a difficult airway. Based on HMD, HMDR was developed for reflecting neck extension. Takenaka et al. firstly introduced HMDR measured by goniometer in patients with rheumatoid arthritis for evaluation of reduced occipitoatlantoaxial extension capacity [20]. HMD and HMDR can also be measured with the help of ultrasonography. HMD is measured between the anterior border of the chin and the anterior border of the hyoid [21]. In the study by Petrisor et al [22], HMDR seemed to have superior diagnostic accuracy with a cut-off value of 1.23 provides 100 % (39.8–100.0) sensitivity and 90.5 % (69.6–98.8) specificity for the prediction of difficult airway in the obese population.

In our study, we measured HMDn, HMDe, and HMDR by preoperative X-ray, which might be more accurate than ultrasound in the evaluation of skeleton structure. However, we found that they were not significantly different between the easy and difficult laryngoscopy groups, respectively. The median of HMDR in the easy laryngoscopy group was 1.21 which was smaller than the median of HMDR (1.34) in the study by Petrisor et al. However, the median of HMDR in the difficult laryngoscopy group was 1.22 which was in accordance with the median of HMDR (1.21) in the study by Petrisor et al [22]. Our results were different from those of previous studies, which might be related to the following two reasons. Firstly, in our study, all participants were cervical spondylosis patients with abnormal lower cervical spines below hyoid level. Secondly, the HMDR measured by ultrasound in other studies could not eliminate the influence of soft tissue on the indicator measurement. When the boundary of soft tissue and skeleton structure is not clear, the measurement results will have errors.

Patients with atlantooccipital distance impairment had a higher prevalence of difficulty laryngoscopy [23]. Basaranoglu et al [24] conducted a study for 239 patients with an emergency cesarean section, and they found that atlantooccipital extension could not predict difficult tracheal intubation. In our study, there was no significant difference between the easy and difficult laryngoscopy groups in  $C_0C_1Dn$ ,  $C_0C_1De$ , and  $C_0C_1DR$  which were consistent with theirs.  $C_0C_1D$  and  $C_0C_1DR$  might not be suitable indicators for patients with cervical spondylosis.

Xu et al [25] created a new combined model including radiological indicators to predict the difficult airway. In

their study, atlantoaxial distance had no significant difference between the easy and difficult laryngoscopy groups ( $4.6 \pm 1.0$  vs.  $4.7 \pm 1.1$ ,  $P = 0.542$ ). In our study, the result was in line with Xu et al. and we found that  $C_1C_2Dn$ ,  $C_1C_2De$  and  $C_1C_2DR$  were not significantly different between the easy and difficult laryngoscopy groups, respectively:  $C_1C_2Dn$  [4.6(2.5)mm vs. 5.0(4.3)mm;  $P = 0.266$ ],  $C_1C_2De$  [0.5(0.3)mm vs. 0.6(0.3)mm;  $P = 0.277$ ],  $C_1C_2DR$  [8.88(5.36) vs. 8.96(6.51);  $P = 0.796$ ]. It needs further researches to find out suitable distance index reflecting the activity of cervical spine mobility for predicting difficult laryngoscopy.

The angle from C2-C6 seen in our study implied the limited flexion of lower cervical spines, which might result in difficult laryngoscopy. Under such circumstances, indicators reflecting lower cervical spine mobility may have a better prediction. In our study, we found that  $C_2C_6Ae$  was not a valuable indicator for predicting difficult laryngoscopy in patients with cervical spondylosis. However,  $C_2C_6An$  and  $C_2C_6AR$  were both effective indicators.  $C_2C_6AR$  was a new predictor and the only independent correlative factor from the cervical mobility indicators for difficult laryngoscopy in cervical spondylosis patients with an AUC of 0.714. More studies are needed to explore and evaluate the application of  $C_2C_6AR$  as a difficult laryngoscopy predictor to other types of patients.

### Limitations

Our study had some limitations. The best cut-off-point of  $C_2C_6AR$ , as a predictor of difficult laryngoscopy, was determined and analyzed both in the same population. We didn't recruit another group of patients for external validation. Besides, the results of our study applied to patients just with cervical spondylosis, and the extension of the present results warrants further investigation.

### Conclusions

$C_2C_6AR$  based on preoperative X-ray images could be a valuable radiologic predictor of cervical mobility indicators for difficult laryngoscopy in patients with cervical spondylosis.

### Abbreviations

MMT: Modified Mallampati test; BMI: Body Mass Index; HMD: The hyomental distance; HMDn/e: The distance between the hyoid bone and the tip of the chin in the neutral/extension position; HMDR: The ratio between HMDe and HMDn;  $C_0C_1Dn/e$ : The distance between the occipital bone and the first cervical vertebra in the neutral/extension position;  $C_0C_1DR$ : The ratio between  $C_0C_1Dn$  and  $C_0C_1De$ ;  $C_1C_2Dn/e$ : The distance between the first cervical vertebra and the second cervical vertebra in the neutral/extension position;  $C_1C_2DR$ : The ratio between  $C_1C_2Dn$  and  $C_1C_2De$ ;  $C_2C_6An/e$ : The angle between a line passing through the bottom of second cervical vertebra and a line passing through the bottom of sixth cervical vertebra in the neutral/extension position;  $C_2C_6AR$ : The ratio between  $C_2C_6Ae$  and  $C_2C_6An$ ; SD: Standard deviation; SE: Standard error; IQR: The median and

interquartile range; OR: Odds ratio; CI: Confidence interval; ROC: Receiver operating characteristic; AUC: Area under the curve

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### Authors' contributions

YZ, YZH and MX designed and coordinated the study. YZ, YZH, NY, TTL, ML and JW recruited the patients and collected data. YZ, YZH, ZQL and XYG drafted the manuscript. YZ and MX analyzed the data and performed the statistical analysis. YQZ participated in measuring radiologic indicators. All authors have read and approved the manuscript.

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### Availability of data and materials

The data used to support the findings of this study are available upon reasonable request via e-mail with the corresponding authors.

### Declarations

#### Ethics approval and consent to participate

The study was approved by the ethics committee of Peking University Third Hospital, and the reference number was IRB00006761-2015021, and we have obtained the informed consent which was written of all participants in the study.

#### Consent for publication

Not Applicable.

#### Competing interests

The authors declare there are no conflicts of interest regarding the publication of this paper.

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### References

- Joffe AM, Aziz MF, Posner KL, Duggan LV, Mincer SL, Domino KB. Management of Difficult Tracheal Intubation: A Closed Claims Analysis. *Anesthesiology*. 2019;131(4):818–29.
- Han YZ, Tian Y, Xu M, Ni C, Li M, Wang J, Guo XY. Neck circumference to inter-incisor gap ratio: a new predictor of difficult laryngoscopy in cervical spondylosis patients. *BMC Anesthesiol*. 2017;17(1):55.
- 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.
- 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.
- Toure T, Williams SR, Kerouch M, Ruel M. Patient factors associated with difficult flexible bronchoscopic intubation under general anesthesia: a prospective observational study. *Can J Anaesth*. 2020;67(6):706–14.
- Chhina AK, Jain R, Gautam PL, Garg J, Singh N, Grewal A. Formulation of a multivariate predictive model for difficult intubation: A double blinded prospective study. *J Anaesthesiol Clin Pharmacol*. 2018;34(1):62–7.
- Lundstrom LH, Vester-Andersen M, Moller AM, Charuluxananan S, L'Hermite J, Wetterslev J, Danish Anaesthesia D. Poor prognostic value of the modified Mallampati score: a meta-analysis involving 177 088 patients. *Br J Anaesth*. 2011;107(5):659–67.
- Frerik C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM, Ahmad I. Difficult Airway Society intubation guidelines working group: Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth*. 2015;115(6):827–48.
- Samsoon GL, Young JR. Difficult tracheal intubation: a retrospective study. *Anaesthesia*. 1987;42(5):487–90.
- Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. *Anaesthesia*. 1984;39(11):1105–11.
- Etezadi F, Ahangari A, Shokri H, Najafi A, Khajavi MR, Daghigh M, Moharari RS. Thyromental height: a new clinical test for prediction of difficult laryngoscopy. *Anesth Analg*. 2013;117(6):1347–51.
- Roth D, Pace NL, Lee A, Hovhannisyan K, Warenits AM, Arrich J, Herkner H. Bedside tests for predicting difficult airways: an abridged Cochrane diagnostic test accuracy systematic review. *Anaesthesia*. 2019;74(7):915–28.
- Detsky ME, Jivraj N, Adhikari NK, Friedrich JO, Pinto R, Simel DL, Wijeyesundera DN, Scales DC. Will This Patient Be Difficult to Intubate?: The Rational Clinical Examination Systematic Review. *JAMA*. 2019;321(5):493–503.
- Lascarrou JB, Boissrame-Helms J, Bailly A, Le Thuaut A, Kamel T, Mercier E, Ricard JD, Lemiale V, Colin G, Mira JP, et al. Video Laryngoscopy vs Direct Laryngoscopy on Successful First-Pass Orotracheal Intubation Among ICU Patients: A Randomized Clinical Trial. *JAMA*. 2017;317(5):483–93.
- Janz DR, Semler MW, Lentz RJ, Matthews DT, Assad TR, Norman BC, Keriwala RD, Ferrell BA, Noto MJ, Shaver CM, et al. Randomized Trial of Video Laryngoscopy for Endotracheal Intubation of Critically Ill Adults. *Crit Care Med*. 2016;44(11):1980–7.
- Wang T, Sun S, Huang S: The association of body mass index with difficult tracheal intubation management by direct laryngoscopy: a meta-analysis. *BMC Anesthesiol* 2018, 18(1):79.
- Saasouh W, Laffey K, Turan A, Avitsian R, Zura A, You J, Zimmerman NM, Szarpak L, Sessler DI, Ruetzler K. Degree of obesity is not associated with more than one intubation attempt: a large centre experience. *Br J Anaesth*. 2018;120(5):1110–6.
- Prakash S, Kumar A, Bhandari S, Mullick P, Singh R, Gogia AR. Difficult laryngoscopy and intubation in the Indian population: An assessment of anatomical and clinical risk factors. *Indian J Anaesth*. 2013;57(6):569–75.
- Suyama H, Tsuno S, Takeyoshi S. [The clinical usefulness of predicting difficult endotracheal intubation]. *Masui*. 1999;48(1):37–41.
- Takenaka I, Iwagaki T, Aoyama K, Ishimura H, Kadoya T. Preoperative evaluation of extension capacity of the occipitoatlantoaxial complex in patients with rheumatoid arthritis: comparison between the Bellhouse test and a new method, hyomental distance ratio. *Anesthesiology*. 2006;104(4):680–5.
- Petrisor C, Dirzu D, Tranca S, Hagau N, Bodolea C. Preoperative difficult airway prediction using suprahyoid and infrahyoid ultrasonography derived measurements in anesthesiology. *Med Ultrason*. 2019;21(1):83–8.
- Petrisor C, Szabo R, Constantinescu C, Prie A, Hagau N. Ultrasound-based assessment of hyomental distances in neutral, ramped, and maximum hyperextended positions, and derived ratios, for the prediction of difficult airway in the obese population: a pilot diagnostic accuracy study. *Anaesthesiol Intensive Ther*. 2018;50(2):110–6.
- Calder I, Calder J, Crockard HA. Difficult direct laryngoscopy in patients with cervical spine disease. *Anaesthesia*. 1995;50(9):756–63.
- Basaranoglu G, Columb M, Lyons G. Failure to predict difficult tracheal intubation for emergency caesarean section. *Eur J Anaesthesiol*. 2010;27(11):947–9.
- 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 (Engl)*. 2014;127(23):4043–8.

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