# Preoperative X-ray C2C6AR 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 clinical 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 and are more prone to appear unexpected difficult airway, so it is important to figure out the most valuable predictor 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 risk factors from the cervical mobility indicators that correlated best as a predictor of difficult laryngoscopy: modified Mallampati test (MMT) and $C_2C_6AR$ (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 over 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. $C_2C_6AR$ exhibited the largest area under the curve (0.714; 95% CI 0.633–0.794).

**Conclusions:** $C_2C_6AR$ 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-16008598) on June 6, 2016.

# Background

Airway management is one of the most important techniques in clinical anesthesia practice. Airway management failure is the primary cause of anesthesia-related deaths. The number of deaths due to failure of airway management accounts for 40% of the total number of anesthesia-related deaths[1]. Inappropriate airway management may lead to airway injury, brain hypoxia, and even death. 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]. Considering that cervical spondylosis patients are more prone to appear unexpected difficult airway and even emergency airway, such as can’t intubation can’t ventilation situation, it is fundmentlly important to figure out the most valuable predictor of difficult laryngoscopy in patients with cervical spondylosis.

The most popular conventional predictors of difficult laryngoscopy are Mallampati Ⅲ and Ⅳ grade[5, 6]. Although it is a quick and convenient assessment test, the prognostic value has been proved 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. In order to screen out potential difficult airway patients with cervical spondylosis and avoid the unanticipated difficult airway, we had better make full use of radiological image 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 cervical spondylosis patients (spinal cord and nerve root type) with preoperative X-ray in both neutral and extension positions, and the aim of this study was to recognize the most precise predictor associate with cervical mobility for difficult laryngoscopy 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 who needed to have elective cervical spine surgery under general anesthesia with oro-tracheal intubation were included. Patients who were pregnant or had cervical spinal instability or an oropharyngeal mass were excluded. It was also registered at the Chinese Clinical Trial Registry (http://www.chictr.org.cn; identifier: ChiCTR-ROC-16008598) on June 6, 2016.

MMT was assessed preoperatively. The patients were asked to sit, open their mouths as much as they can, and protrude the tongue without phonation[2]. Radiological data were obtained by cervical X-ray examination, which was performed in both neutral and extension positions. All radiological indicators were measured on the lateral films in the neutral and extension position (Figures 1 and 2), using the radiography information system (Centricity RIS-IC CE V3.0; GE Healthcare, Little Chalfont, UK) of Peking University Third Hospital, by an attending radiologist who was blind to the intubation.

No premedication was administrated. All patients were given the same anesthesia protocol, induced with sufentanil (0.3 μg/kg), propofol (2 mg/kg) and rocuronium (0.6 mg/kg). The laryngoscopy view was assessed by the same senior anesthesiologist not involved in the preoperative radiological data with Macintosh laryngoscope. The result was determined by the Cormack–Lehane (C–L) grade[9]. Patients with Cormack-Lehane grade > 2 were assigned to the difficult laryngoscopy group, and patients with Cormack-Lehane grade I or II 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%[10]. A power calculation showed that 245 patients would be required to detect a difference in predictors between the difficult and easy laryngoscopy groups (α=0.05 and β=0.1). In consideration of 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 ± 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) were 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), $C_2C_6$An (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 position, P=0.013) and $C_2C_6$AR (the ratio by 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).

Binary multivariate logistic regression (backward-Wald) analyses identified two independent risk factors from the cervical mobility indicators that correlated best as predictors of difficult laryngoscopy: MMT and $C_2C_6$AR. The odds ratio (OR) and 95% CI were2.292 (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. $C_2C_6$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 C2C6AR was set to 1.48, with the sensitivity and specificity were 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 C2C6AR was set to 1.36, with the sensitivity of 0.71 and the specificity of 0.60.

# Discussion

It has been reported that patients with cervical spondylosis have a high incidence of difficult laryngoscopy. Therefore, we studied the predictors of cervical mobility indicators which can reflect the difficult laryngoscopy in patients with cervical spondylosis. We compared cervical mobility indicators and found that $C_2C_6AR$ was the best indicator associated with difficult laryngoscopy.

A significantly greater proportion of difficult laryngoscopy and tracheal intubation had been found in obese patients[11, 12]. 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 was in accordance with the study reported by Prakash et al[13]. MMT is the most popular test for preoperative airway evaluation which could reflect oropharyngeal cavity volume, but its disadvantage is that it could not 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 prefer predictor for patients with cervical spondylosis.

HMD, the abbreviation of hyomental distances, is the distance between the hyoid bone and the tip of the chin which could reflect the submandibular and sublingual spaces, the floor of the mouth and the root of the tongue. The stylohyoid ligament fixes the hyoid bone to the occiput, which makes the hyoid with a stationary position in relation to the base of the skull[14]. With the head maximally extended, the mandible is moved away from the hyoid. Thus, HMD measurements in different positions might reflect the cervical mobility. Suyama et al[15] 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 difficult airway. Based on HMD, hyomental distance ratio (HMDR), the ratio between the HMD in the extension position (HMDe) and the one in the neutral position (HMDn), 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[16]. HMD and HMDR can be measured with the help of ultrasonography by placing a curvilinear probe in the midsagittal position in the submental area. The investigator can easily identify the bright hyperechoic structures: the mandible and the hyoid bone. HMD is measured between the anterior border of the chin and the anterior border of the hyoid[17]. In the study by Petrisor et al[18], 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 HMDn, HMDe and HMDR were not significantly different between the easy and difficult laryngoscopy groups, respectively: HMDn (5.4±0.8 cm vs 5.3±0.9 cm; p=0.438), HMDe (6.6±1.0 cm vs 6.5±0.8 cm; p=0.285), HMDR [1.21 (0.19) vs 1.22 (0.13); p=0.703]. 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 and usually there was no significant difference in the upper cervical spines. 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[18]. 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.

$C_0C_1D$, the distance between the occipital bone and first cervical vertebra in the neutral position, is also called atlantooccipital. Patients with atlantooccipital distance impairment had a higher prevalence of difficulty laryngoscopy[19]. Basaranoglu et al[20] 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.

$C_1C_2D$, the distance between the first cervical vertebra and the second cervical vertebra, is also known as atlantoaxial distance. Xu et al[21] created a new combined model including radiological indicators to predict difficult airway. In their study, atlantoaxial distance had no significant difference between the easy and difficult laryngoscopy groups (4.6±1.0 vs 4.7±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.

$C_2C_6A$, the angle between a line passing through the bottom of second cervical vertebra and a line passing through the bottom of sixth cervical vertebra, can reflect the lower cervical spine mobility. 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 $C_2C_6Ae$ ($C_2C_6A$ in the extension position) was not a valuable indicator for predicting difficult laryngoscopy in patients with cervical spondylosis. However, $C_2C_6An$ ($C_2C_6A$ in the neutral position) and $C_2C_6AR$ (the ratio between $C_2C_6Ae$ and $C_2C_6An$) were both effective indicators. $C_2C_6AR$ was a new predictor and the only independent risk factor from the cervical mobility indicators for difficult laryngoscopy in cervical spondylosis patients with AUC of 0.714. More researches 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 were applicable to patients with cervical spondylosis and the extention of the present results wanrants further investigation.

# Conclusion

$C_2C_6AR$ based on preoperative X-ray images may be the most accurate predictor of cervical mobility indicators for difficult laryngoscopy in patients with cervical spondylosis.

# 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 is no conflicts of interest regarding the publication of this paper.

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### Authors' contributions

Yang Zhou, Yongzheng Han and Mao Xu designed and coordinated the study. Yang Zhou, Yongzheng Han, Ning Yang, Taotao Liu, Min Li and Jun Wang recruited the patients and collected data. Yang Zhou, Yongzheng Han, Zhengqian Li and Xiangyang Guo drafted the manuscript. Yang Zhou and Mao Xu analyzed the data and performed statistical analysis. Yuqing Zhao participated in measuring radiologic indicators. All authors discussed the results, read and approved the final manuscript.

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# Tables

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

| Items | Easy laryngoscopy group<br><br>(n=230) | Difficult laryngoscopy group<br><br>(*n*=40) | Statistical Test | *P*-values |
|---|---|---|---|---|
| BMI | 25.1±3.3 | 25.7±2.5 | t=-1.127 | 0.261 |
| MMT (class I-II/class III-IV) | 149(64.8)/81(35.2) | 19(47.5)/21(52.5) | $\chi^2$ =4.33 | 0.037 |
| 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 |
| $C_0C_1$Dn (mm) | 6.7±2.6 | 6.4±3.1 | t=0.665 | 0.507 |
| $C_0C_1$De (mm) | 0.6±0.3 | 0.5±0.3 | t=1.249 | 0.213 |
| $C_0C_1$DR | 12.14 (10.29) | 13.70 (10.10) | z=0.490 | 0.624 |
| $C_1C_2$Dn (mm) | 4.6 (2.5) | 5.0 (4.3) | z=1.113 | 0.266 |
| $C_1C_2$De (mm) | 0.5 (0.3) | 0.6 (0.3) | z=1.087 | 0.277 |
| $C_1C_2$DR | 8.88 (5.36) | 8.96 (6.51) | z=0.259 | 0.796 |
| $C_2C_6$An (°) | 9.0 (12.0) | 13.5 (10.9) | z=2.484 | 0.013 |
| $C_2C_6$Ae (°) | 16.7 (13.6) | 17.6 (16.1) | z=-0.572 | 0.568 |
| $C_2C_6$AR | 1.80 (2.25) | 1.26 (0.56) | z=-4.127 | <0.001 |

BMI,Body Mass Index; MMT, modified Mallampati test; HMDn, the distance between the hyoid bone and the tip of the chin in the neutral position; HMDe, the distance between the hyoid bone and the tip of the chin in the extension position; HMDR, the ratio between HMDe and HMDn; $C_0C_1$Dn, the distance between the occipital bone and the first cervical vertebra in the neutral position; $C_0C_1$De, the distance between the occipital bone and the first cervical vertebra in the extension position; $C_0C_1$DR, the ratio between $C_0C_1$Dn and $C_0C_1$De; $C_1C_2$Dn, the distance between first cervical vertebra and the second cervical vertebra in the neutral position; $C_1C_2$De, the distance between the first cervical vertebra and the second cervical vertebra in the extension position; $C_1C_2$DR, the ratio between $C_1C_2$Dn and $C_1C_2$De; $C_2C_6$An, 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 position; $C_2C_6$Ae, 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; $C_2C_6$AR, the ratio between $C_2C_6$Ae and $C_2C_6$An.

**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 |
| $C_2C_6AR$ | -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; MMT, modified Mallampati test; $C_2C_6AR$, the ratio between $C_2C_6Ae$ (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 $C_2C_6An$ (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 position)

**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 |
| $C_0C_1Dn$ (mm) | 0.541 | 0.436-0.647 | 0.054 | 0.404 |
| $C_0C_1De$ (mm) | 0.571 | 0.482-0.660 | 0.045 | 0.152 |
| $C_0C_1DR$ | 0.524 | 0.433-0.616 | 0.047 | 0.624 |
| $C_1C_2Dn$ (mm) | 0.555 | 0.451-0.659 | 0.053 | 0.266 |
| $C_1C_2De$ (mm) | 0.554 | 0.459-0.649 | 0.049 | 0.277 |
| $C_1C_2DR$ | 0.513 | 0.415-0.610 | 0.050 | 0.796 |
| $C_2C_6An$ (°) | 0.629 | 0.533-0.724 | 0.049 | 0.013 |
| $C_2C_6Ae$ (°) | 0.530 | 0.421-0.638 | 0.055 | 0.568 |
| $C_2C_6AR$ | 0.714 | 0.633-0.794 | 0.041 | <0.001 |

AUC, area under the curve; 95%CI, 95% confidence interval; SE, standard error; BMI, Body Mass Index; HMDn, the distance between the hyoid bone and the tip of the chin in the neutral position; HMDe, the distance between the hyoid bone and the tip of the chin in the extension position; HMDR, the ratio between HMDe and HMDn; $C_0C_1Dn$, the distance between the occipital bone and the first cervical vertebra in the neutral position; $C_0C_1De$, the distance between the occipital bone and the first cervical vertebra in the extension position; $C_0C_1DR$, the ratio between $C_0C_1Dn$ and $C_0C_1De$; $C_1C_2Dn$, the distance between the first cervical vertebra and the second cervical vertebra in the neutral position; $C_1C_2De$, the distance between the first cervical vertebra and the second cervical vertebra in the extension position; $C_1C_2DR$, the ratio between $C_1C_2Dn$ and $C_1C_2De$; $C_2C_6An$, 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 position; $C_2C_6Ae$, 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; $C_2C_6AR$, the ratio of $C_2C_6Ae$ over $C_2C_6An$.

**Table 4.** Calculated cut-off values that show the best range of sensitivity and specificity for the $C_2C_6AR$.

| 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 |

$C_2C_6AR$, the ratio between $C_2C_6Ae$ (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 $C_2C_6An$ (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 position); Youden index = sensitivity+specificity-1.

## Figures

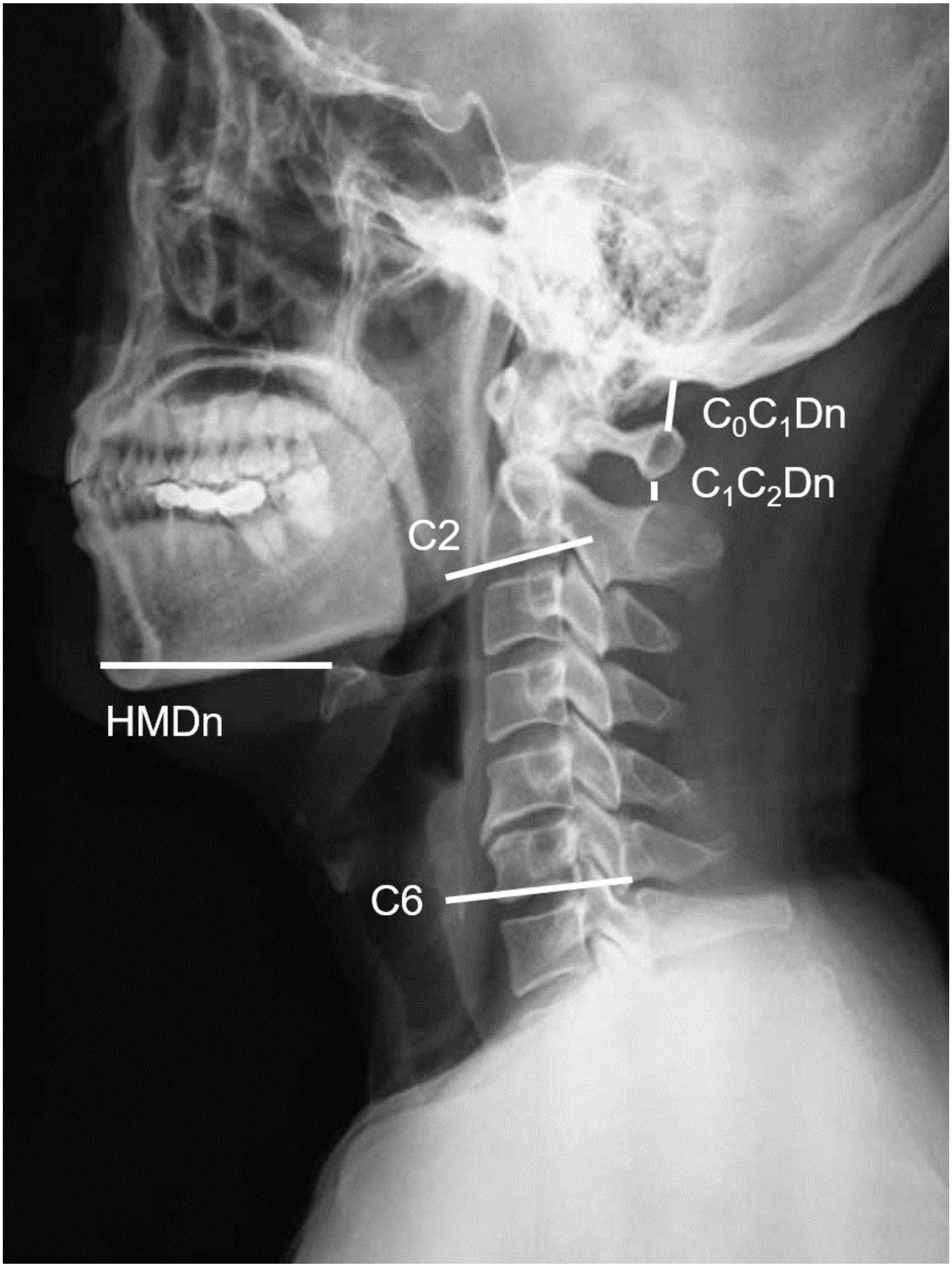


Figure 1

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; C0C1Dn, the distance between the occipital bone and first cervical vertebra in the neutral position; C1C2Dn, the distance between the first cervical vertebra and the second cervical vertebra in the neutral position.


**Figure 2**

Lateral cervical X-ray film in the neutral positions. HMDe, the distance between the hyoid bone and the tip of the chin in the extension position; C0C1De, the distance between the occipital bone and first cervical vertebra in the extension position; C1C2De, the distance between the first cervical vertebra and the second cervical vertebra in the extension position.