Original Article
Lateral neck radiography in prediction of difficult laryngoscopy in Chinese patients

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Abstract: Several tests of radiology have been designed to predict difficult laryngoscopy, but there were few relative studies of Chinese patients. Our study is to investigate the accuracy of lateral neck radiography in predicting difficult laryngoscopy in Chinese patients. The operative database of Xuanwu Hospital, Capital Medical University, was reviewed and all the patients who had performed lateral neck radiography before thyroid surgery from February 2014 to February 2015 were recruited. The results of Modified Mallampati test (MMT) and Thyromental distance (TMD) of the patients were obtained from the Database. Two trained reviewers independently measured α' (the angle between hyoid cartilage, root of epiglottis and arytenoid cartilage) and several other angles and parameters on the X-ray. Receiver operating characteristic curves (ROC) were drawn and the areas under curves (AUC) were calculated to analyze the accuracy of each indicator. The cut off points were determined by maximizing the Youden index. In the study, 114 patients were included. The most accurate indicator of lateral neck radiography was α', of which AUC was 0.896 (95% confidence interval [0.813, 0.979]). The cut off point of α' was set as 85.52. The clinical test MMT (47% and 75%) has lower sensitivity and specificity than α' (87% and 86%) and other indicators have lateral neck radiography. The diagnostic accuracy of lateral neck radiography in prediction of difficult laryngoscopy in Chinese patients may be superior to MMT and TMD. However, the method of lateral neck radiography is not perfectly precise.

Keywords: Intubation, difficult laryngoscopy, prediction, radiography, sensitivity and specificity

Introduction

The management of difficult airway is one of the most challenging tasks for anesthesiologists. The incidence rate of difficult intubation in surgical patients under going general anesthesia is estimated to 1.5%-13%, approximately [1-4]. An unanticipated difficult endotracheal intubation or failed endotracheal intubation is frequently cited as a cause of anesthesia-related morbidity in otherwise healthy patients [5]. So it is crucial to predict difficult intubation before the induction of anesthesia and intubation.

Current bedside tests have limited and inconsistent capacity to discriminate between patients with difficult and easy intubation [6]. It is generally accepted that the clinical tests such as Modified Mallampati test [7, 8] and thyro-mental distance [9] have considerable false-positive and false-negative rates in prediction of difficult laryngoscopy [10-12].

The role of radiography in prediction of difficult intubation had been analyzed in some studies [5, 13, 14]. Interestingly, the study of Kamalipour [13] showed that several angles in lateral neck radiography can be used in the prediction of difficult tracheal intubation of Iranian patients, and the accuracy of his method was 100%.

On one hand, the weight [15] and Body Mass Index [16] of patients, which may effect the incidence of difficult laryngoscopy, varies between Chinese and Iranian patients [17]. Without relative study or data of Chinese patients, the application of lateral neck radiography in prediction of difficult laryngoscopy in Chinese patients was limited. On another hand, it was suspected
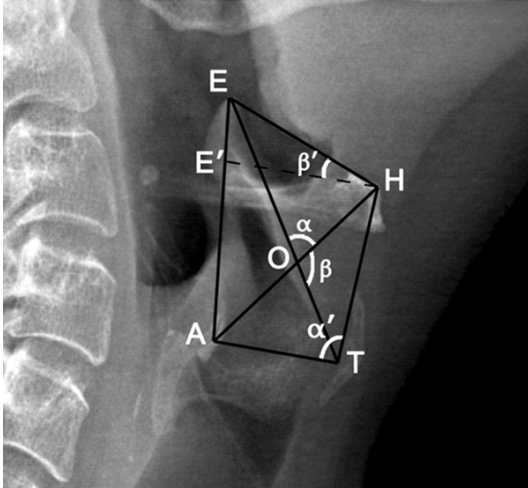
Figure 1. Lateral X-ray of the neck in a patient. E: tip of epiglottis; E': base of epiglottis; A: arytenoid; T: thyroid cartilage; H: hyoid bone; O: the intersection of HA and ET.

that lateral neck radiography could predict difficult tracheal intubation so perfectly. Therefore, this study was designed and conducted.

Material and methods

Study ethics

This study was approved by the ethics committee of Xuanwu Hospital Capital Medical University (XWHCMU), and the written informed consent was waived by the ethics committee.

Data collection

The operative database of XWHCMU was reviewed, and all the patients who had performed lateral neck radiography before thyroid surgery between February 2014 and February 2015 were recruited.

Sample size was calculated using the method of Arkin and Wathtel [18]. The confidence level α was set as 0.05, and power was set as 0.80. Sensitivity was estimated approximately as 0.8. The result of sample size of difficult laryngoscopy was calculated as 15.

Inclusion criteria are listed as following: Patients were more than 18 years old. They have had elective thyoid surgery with endotracheal intubation in XWHCMU. Their lateral neck radiological images were performed within one month before the operation. Their intubations were performed by anesthesiologists with more than three years experience.

Exclude criteria are listed as following: 1) Patients had congenital cranial and maxillofacial deformities; 2) Patients had large tumor in the upper airway or adjacent areas: oral tumor, laryngeal cancer; 3) Thyroid neoplasms of patients were more than 4 cm in length under ultrasound examination, or compressing the airway or inducing airway displacement; 4) Patients had oral and maxillofacial deformities which were generated by Trauma, infection or tumors; 5) Patients had small mouth deformities or sternomental adhesions which were generated by burn scar adhesions; 6) Patients were with abnormalities anatomical structures near the airway which were generated by the surgery or radiotherapy; 7) Patients were with mandibular joint ankylosis; 8) Patients were with cervical spondylosis; 9) Patients were edentulous or anisodont; 10) Patients were not intubated with Macintosh laryngoscopy; 11) Radiographs of patients could not be interpreted (e.g. because of thyroid calcification or technical problems or vague).

During the period from February 2014 to February 2015, all eligible patients were included consecutively in the study.

The following data were collected from the database. Demographic variables included age, sex, height, weight, Body Mass Index (BMI), and ASA physical status. Modified Mallampati test (MMT): Samsoon and Young's modification of the Mallampati test [8] recorded oropharyngeal structures visible upon maximal mouth opening. While seated, each patient was asked to open his or her mouth maximally and to protrude the tongue without phonation. The view was classified as I: good visualization of the soft palate, fauces, uvula and tonsillar pillars; II: pillars obscured by the base of the tongue but the soft palate, fauces and uvula visible; III: soft palate and base of the uvula visible; and VI: soft palate not visible. Thyromental distance (TMD): TMD was measured from the bony point of the mentum while the head was fully extended and the mouth closed. Difficult laryngoscopy was defined as laryngoscopy Grades III and IV according to Cormark and Lehane's [19] grading.

Radiological measurements

Two anesthesiologists were trained by a radiologist before measurements. The two reviewers were blinded to other information of patients

Figure 2. Flowgram of the study. Difficult laryngoscopy defined as laryngoscopy Grades III and IV according to Cormark and Lehane's grading. Easy laryngoscopy defined as laryngoscopy Grades I and II according to Cormark and Lehane's grading.
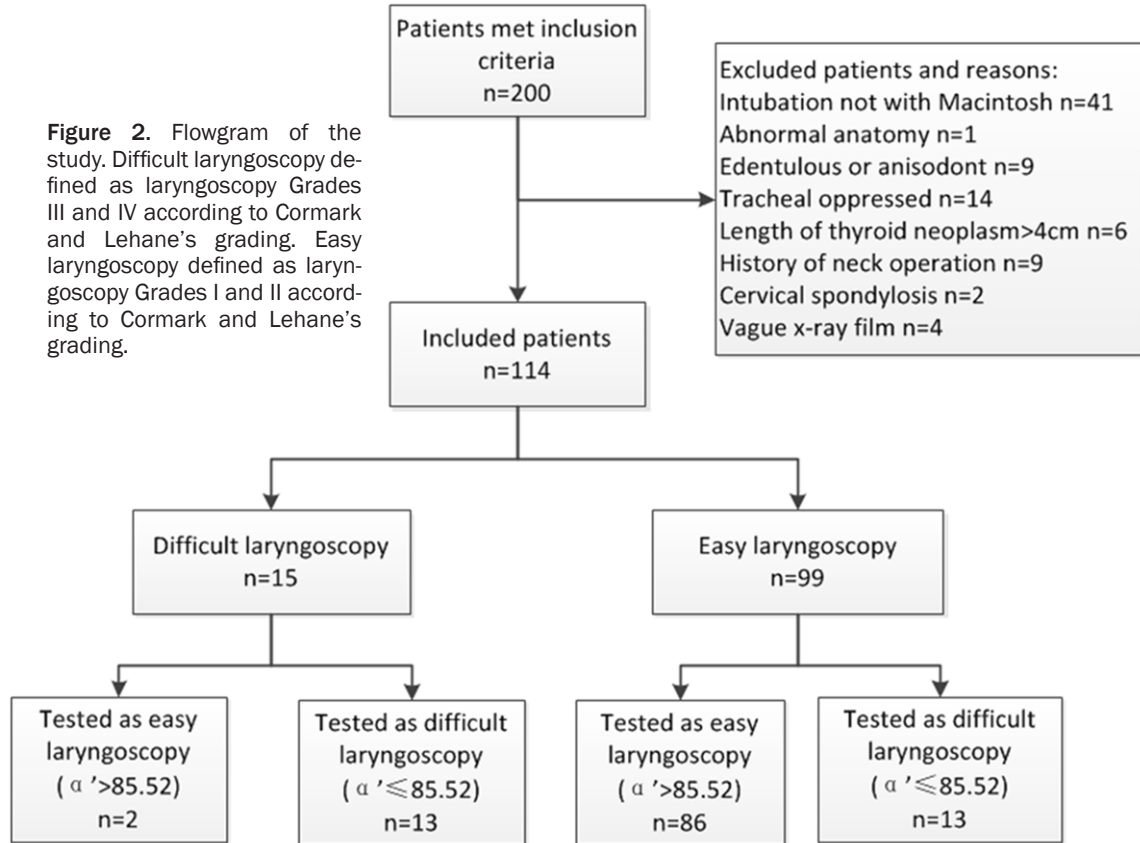
Table 1. Demographic data of the patients

	Easy laryngoscopy	Difficult laryngoscopy
Gender (male/female)	15/84	11/4
Age	48±11	48±10
Height (cm)	162±7	172±7
Weight (Kg)	66±11	80±12
Body mass Index (BMI, Kg/m^2)	25±4	26±3
ASA status (I/II/III)	13/83/3	3/12/0

Difficult laryngoscopy defined as laryngoscopy Grades III and IV according to Cormark and Lehane's grading. Easy laryngoscopy defined as laryngoscopy Grades I and II according to Cormark and Lehane's grading.

and measured independently. The X-ray was analyzed with the following measurements according to the study of Kamalipour [13] in the Picture Archiving and Communication Systems of XWHCMU (**Figure 1**):

1. The distance between the middle of the hyoid bone (H) and the junction of the true vocal cords at the posterior surface of the thyroid bone (T) and this was referred to as distance HT. 2. The distance between the highest point of the epiglottis (E) and the midline of the hyoid bone (H), which was referred to as HE. 3. The distance between the highest point of the epiglottis (E) and the connection point of the true vocal cords at the posterior surface of the arytenoid bone (A), which was referred to as AE. 4. The true vocal cords, which was referred to as TA. 5. Two angles, HOE (α) and HOT (β) which are formed by the connection of the two diameters in the square. We only measured the angle β. 6. The angle HTA (α'). 7. A line from point H and parallel to TA was drawn (HE') and the angle formed between HE and HE' was called β' (EHE'). 8. Difference between lines HT and AE, which was referred to as HT-AE. 9. Difference between lines HE and TA, which was referred to as HE-TA.

Statistical methods

Statistical analysis was performed by SPSS software (Version 17.0, SPSS Inc., Chicago, IL, USA). It was considered statistically significant (all 2-tailed) if *P*-value is less than 0.05. Averages of each X-ray indicators by the two reviewers were calculated to be statistically ana-

Table 2. Angles or parameters in X-ray of each group

	β (°)	α' (°)	β' (°)	HT-AE (cm)	HE-TA (cm)
Easy laryngoscopy (n = 99)	116.4±8.6	93.5±8.8	12.1±7.9	-0.5±0.3	0.4±0.4
Difficult laryngoscopy (n = 24)	117.7±7.1	78.1±8.8	2.2±6.8	-0.0±0.3	0.1±0.4
P-value	0.552	< 0.001	< 0.001	< 0.001	0.006

Data are expressed as mean ± standard deviation (SD). α': the angle HTA in the lateral neck X-ray; β': the angle EHE'; HT-AE: Difference between lines HT and AE; HE-TA: Difference between lines HE and TA.

Table 3. Comparisons between MMT, TMD and lateral neck X-ray indicators

Tests	Sensitivity	Specificity	PPV	NPV	LR+	LR-
MMT	47%	75%	22%	90%	1.85	0.71
TMD	37%	91%	43%	88%	4.05	0.69
α' angle	87%	86%	50%	98%	6.6	0.15
β' angle	80%	84%	43%	96%	4.95	0.24
HT-AE	87%	71%	32%	97%	3.06	0.19
α' angle OR β' angle	93%	75%	36%	99%	3.69	0.09
α' angle AND β' angle	73%	95%	69%	96%	14.52	0.28

PPV: Positive prediction value, NPV: negative prediction value, LR+: positive likelihood ratio, LR-: negative likelihood ratio. α' angle OR β' angle: it is positive if α' ≤ 85.52 or/and β' ≤ 5.12, and it is negative if α' > 85.52 and β' > 5.12. α' angle AND β' angle: it is positive if α' ≤ 85.52 and β' ≤ 5.12, and it is negative if α' > 85.52 or/and β' > 5.12.

Table 4. Comparision of the area under curves (AUC) of α', β', HT-AE

	z-value	*P*-value	95% CI of the Difference
α' vs β'	0.119	0.905	(-0.076, 0.086)
α' vs HT-AE	1.390	0.164	(-0.033, 0.194)
β' vs HT-AE	1.899	0.058	(-0.002, 0.158)

The comparisons of the AUCs among the indicators were performed with area z-score test.

lyzed. Two independent sample t-test was used to compare the indicators of two groups. The receiver operating characteristic curves (ROC) of β, α', β', HT-AE, HE-TA were drawn and area under the curves (AUC) were calculated. To quantify uncertainty, 95% confidence intervals of AUC were calculated. Furthermore, if the AUCs of any angles or parameters are more than 0.7, Youden indexes were calculated for determinating the cut off points and the AUCs were compared using ROCKIT software (Version 0.9.1 BETA, The University of Chicago, USA) with univariate z-score test [20]. Two of the most accuracy indicators were combined using the OR rule and the AND rule [21]. Agreement between the Two reviewers was estimated using Bland-Altman plots using MedCalc for

Windows, version 11.4.2.0 (MedCalc Software, Ostend, Belgium).

Results

From February 2014 to February 2015, 200 patients met the inclusion criteria. Eighty-six patients were exluded and the reasons are listed in the flowgram (**Figure 2**). A total of 114 participants were included in the study. Fifteen patients were identified as difficult laryngoscopy (Cormack and Lehnane Grades III and IV). Demographic data of the patients were summarised in **Table 1**.The angles or parameters in X-ray of patients were compared in **Table 2**.

The AUCs of β, α', β', HT-AE, HE-TA were 0.543 (*P* = 0.589), 0.896 (*P* < 0.001), 0.833 (*P* < 0.001), 0.845 (*P* < 0.001), 0.725 (*P* = 0.005), and the 95% confidence intevals (95% CI) of them are [0.388, 0.699], [0.813, 0.979], [0.740, 0.926], [0.761, 0.928], [0.590, 0.860], respectively. The ROC of α' was shown in **Figure 3**.

To obtain a maximal Youden index, the numberic value of α', β', HT-AE were 85.52, 5.12, -0.35. Setting the above numbers as thresholds, we got the sensitivity and specificity of the factors (**Table 3**). MMT 3 or 4, TMD < 6 cm were tranditional indicators of difficult intubation. The comparisons of MMT, TMD and lateral neck X-ray indicators were compared in **Table 3**. Two most accuracy indicators α' and β' were combined according to the OR rule, in which the diagnosis is positive if one or both of the two indicators is positive and the diagnosis is negative if both of the two indicators are negative, and the AND rule, in which the diagosis is positive if the two indicators are both positive and the diagnosis is nagative if they are not all posi-

Table 5. Comparison of the AUCs of different indicators between females and males

Indicator	AUC		z-value	P-value
	female	male		
α' angle	0.908	0.718	1.571	0.116
β' angle	0.792	0.855	-0.213	0.280
HT-AE	0.784	0.839	-1.229	0.845

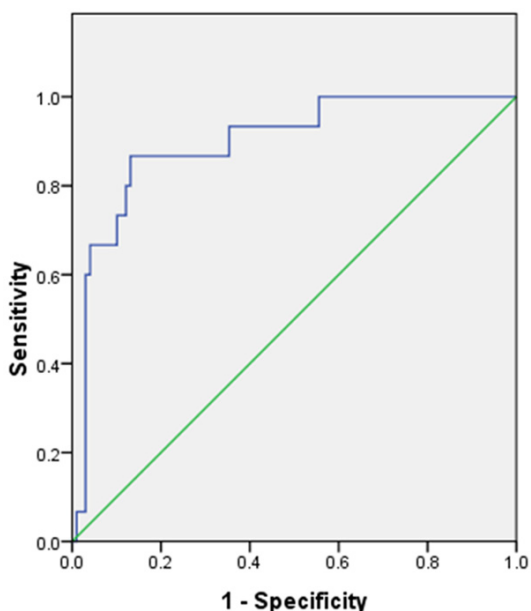95% CI: 95% confidence intevals. The area test was performed with univariate z-score test.

Figure 3. The Receiver operating characteristic curve (ROC) of α' (the angle HTA). The area under curves (AUC) is 0.896 (*P* < 0.001) and the 95% confidence intevals is [0.813, 0.979].

tive. The results were also summarized in **Table 3**. The AUCs of α', β', HT-AE were compared with univariate z-score test [20] (**Table 4**).

Subgroup analysis

The AUCs were compared between males and females (**Table 5**), which was performed with univariate z-score test.

Reproductivity analysis

Figure 4 displayed the Bland-Altman plots for difference and 95% limits of agreement between the two reviewers. A high degree of reliabilities of α' (mean: -1.6, 95% limits of agreement: [-9.4, 6.1]), β' (mean: -2.4, 95% limits of agreement: [-12.4, 7.6]), HT-AE (mean: -0.03, 95% limits of agreement: [-0.38, 0.44]) were observed.

Discussion

This study was designed as a retrospective one. The most crucial reason of performing this study is that there is few similar study in Chinese patients. Retrospective study can minimize extra radiation exposure, when the accuracy of radiography was uncertain in Chinese patients. Another reason is that, it is recommended to determine whether the test has any diagnostic value in distinguishing specific patients in as short a period of time as possible [22].

In our study, 15 of 114 patients were identified as difficult laryngoscopy. There were several factors impacting on the incidence of difficult larygoscopy. Not all the thyroid patients were performed with lateral neck radiography. Furthermore, 86 of 200 patients were excluded for various reasons (**Figure 2**). The skill of the anesthesiologists, which might influence the assessment of the laryngoscopy grade, was slightly different. On the other hand, in this study, difficult laryngoscopy was focused on and it was defined as laryngoscopy Grades III or IV similar to most of the larger studies. Although it is well known that difficult tracheal intubation is different from difficult laryngoscopy, difficult laryngoscopy is still an essential factor that leads to difficult tracheal intubation.

In our study, theory of Kamalipour was used to predict difficult laryngoscopy in Chinese patients. Our data showed that α', β' and HT-AE were more accurate than the traditional predictors such as MMT and TMD. The AUC of β and HE-TA are less than 0.8, therefore they are not a useful test for difficult laryngoscopy. The angle α' is the most valuable indicator, with the best sensitivity, specificity, positive predict value, negative predictive value, positive likelihood ratio and negative likelihood ratio. At present, it has been widely suggested that combinations of factors could improve predictability of difficult intubation. Combinations of two indicators of radiography may be used to elevate the sensitivity or the specificity. With the OR rule, the sensitivity of the combined results is higher than either test individually, but the specificity is lower than either test individually. With the AND rule, the result is opposite. In reproductivity analysis, it is showed that the measurements of two reviewers have great agreement. In subgroup analysis, there is no so significant difference of accurate that lateral

C. Showed the differences in HT-AE (HT-AE: difference between lines HT and AE in the lateral neck X-ray) between the two reviewers.
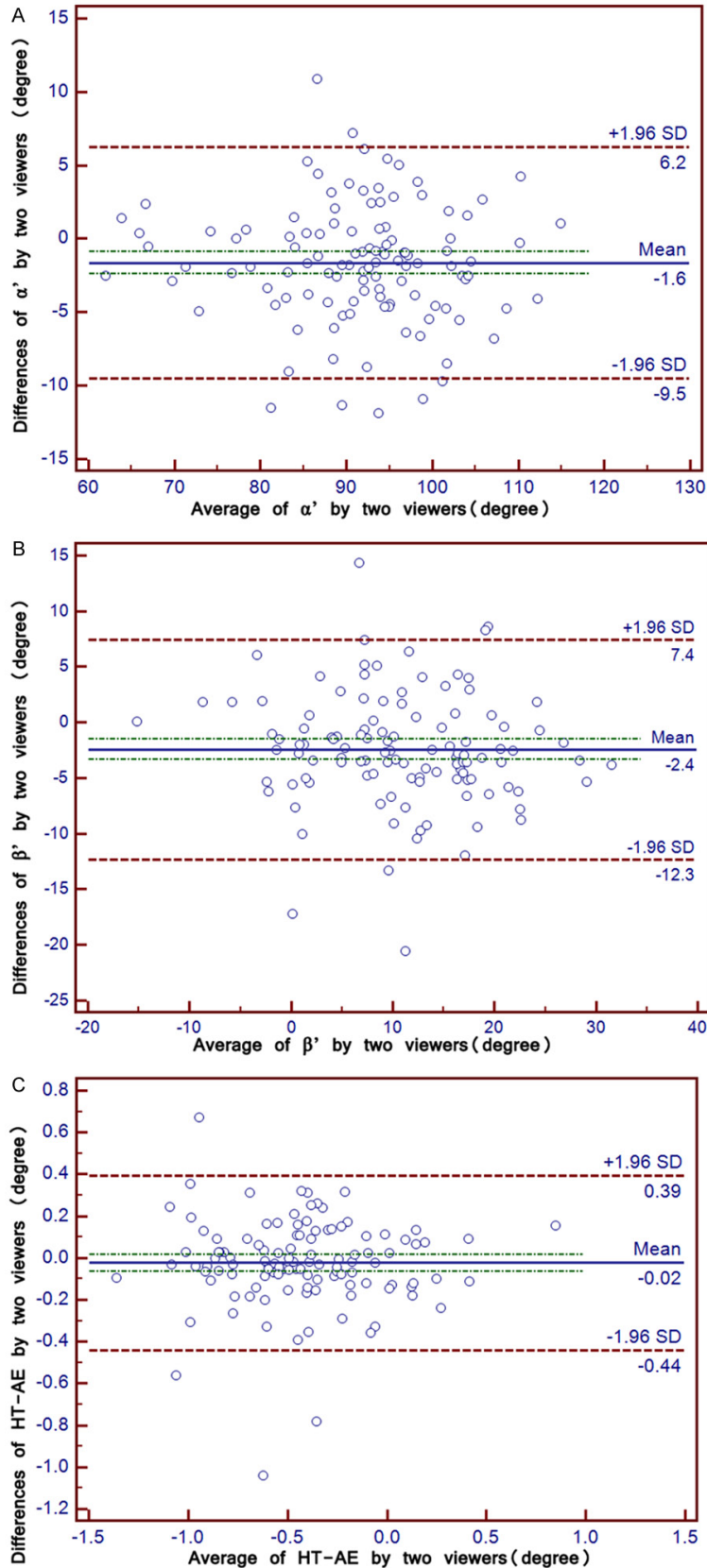
Figure 4. Bland-Altman plots. A. Showed the differences in α' between the two reviewers. B. Showed the differences in β' between the two reviewers.

neck radiography in prediction of difficult laryngoscopy in between females and males.

In Wilson's editorial [23], he concluded that no single test would be likely to be a perfect predictor of difficult intubation. Anesthesiologists are confronted daily with the task of determining whether endotracheal intubation will be of increased difficulty in a patient. Several clinical tests were designed to predict difficult intubation, such as Modified Mallampati test (MMT), thyromental distance (TMD) and Wilson scores etc. But none of the tests has provided satisfactory results in terms of sensitivity and specificity [11, 12, 24, 25]. It would be useful to predict difficult tracheal intubation before it occurs, but no preoperative test has adequate sensitivity to identify most cases without substantial false-positive results. A reasonable explanation is that the clinical tests are all physical examination according to the surface markers, so the effects of soft tissue may not be included. Several tests of ultrasound or radiology were designed to prediction difficult laryngoscopy. The Kamalipour test [13] is a test closest to (but is not) the golden standard.

Lateral neck radiography may be regarded as an additional method in prediction of difficult laryngoscopy. In clinic, lateral neck radiography was used for determining diagnosis and choosing surgical options in selected patients with cervical spine disorders or thyroid

tumor. It is very simple to use this method to evaluate airway of the patients who had been performed with lateral neck radiography. Even if computer measurement is not available, indicators can be measured by visual observation. For example, if angle α' is close to or greater than 90 degrees with eyeballing, patients may be little possible of difficult tracheal intubation; on the contrary, it suggests that the possibility of difficult endotracheal intubation must not be ignored.

This study also give us some new ideas. The relationship of structures of larynx (hyoid, glottis epiglottis, etc) is the main factor producing difficulty intubation. An increased angle α' means that the vocal cords will achieve a more diagonal position and subsequently be viewed much better. Although it is still controversial that anterior larynx is a predictor of difficult laryngoscopy [26], this study showed that the more the thyroid cartilage was anterior compared with hyoid bone, the more likely the difficult laryngoscopy happened. Ultrasound is recently used for airway management and prediction of difficult intubation [27, 28]. Hyoid bone, thyroid cartilage and arythenoid cartilages can be visualized with ultrasound machine. Combination ultrasonography and the methods of Kamalipour may be a new research field in prediction of difficult intubation.

Compared with Kamalipour's study [13], the novelty of our study included the following points. Firstly, this study has proved that lateral neck radiography is useful but NOT perfect in prediction of difficult intubation in Chinese patients. Secondly, with data we collected and analyzed, the cut-off points were determined. Thirdly, the weight [15] and Body Mass Index [16] of patients, which may effect the incidence of difficult laryngoscopy, varies between Chinese and Iranian patients [17], therefore this study and the data were very helpful to apply lateral neck radiography to predict difficult laryngoscopy in Chinese patients. At last, it has shown that the reliability of measurement by two trained viewers of radiography was greater, compared to clinical tests [10].

Limitation

In this study findings should be interpreted with caution due to that the data was all obtained from the database. There is a possibility that unrecognised clinical, environmental, operational or educational factors might have influenced the results. Secondly, details on the number of attempts at intubation, time taken for intubation to be achieved and physiological derangements were not recorded in this study. The intubation data has to be interpreted with caution in the absence of this information. Thirdly, Optimal decision on cut off points of the indicators should be determined taking into account the finicial and health costs (especially the costs when difficult intubation happens), which are difficult to get. Lastly, although patients with large thyroid were excluded, thyroid could potentially affect patient's airway structure.

Conclusions

The diagnostic accuracy of lateral neck radiography in prediction of difficult laryngoscopy in Chinese patients may be superior to Modified Mallampati test and Thyromental distance. However, the method of lateral neck radiography is not perfectly precise.

Acknowledgements

Disclosure of conflict of interest

None.

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