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Anterior neck soft tissue thickness for airway evaluation measured by magnetic resonance imaging in cervical spondylosis patients: an prospective cohort study

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ABSTRACT

Objectives Anterior neck soft tissue thickness, usually measured by ultrasound, is increasingly being investigated to predict difficult laryngoscopy, but results have not been validated. Considering the conflicting measurement data, different measuring body positions, and lack of a standard ultrasound procedure, we used magnetic resonance imaging (MRI) to verify the efficacy of these popular ultrasonographic parameters.

Design Prospective cohort study.

Setting A tertiary hospital in Beijing, China.

Methods We enrolled 315 adult patients who underwent cervical spinal surgery in Peking University Third Hospital from April 2016 to October 2016. We analyzed physical and MRI data to predict difficult laryngoscopy. 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 male sex ($p<0.01$), older age ($p=0.03$), and body weight ($p=0.02$) were associated with difficult laryngoscopy. MRI data consisted of five common ultrasonographic variables used to predict difficult laryngoscopy, but none was a valuable predictor: skin to hyoid ($p=0.18$), skin to midpoint of epiglottis ($p=0.72$), skin to thyroid cartilage at the level of the vocal cords ($p=0.10$), skin to vocal cords ($p=0.44$), or skin to anterior to the trachea at the level of suprasternal notch ($p=0.92$). Adjusted by sex, age, and body weight, none of the five MRI indicators had predictive value ($p>0.05$).

Conclusion The five most-commonly-studied ultrasonographic indicators of anterior soft tissue thickness appeared unreliable to predict difficult laryngoscopy in patients with cervical spondylosis. Further study is needed to validate the most valuable indicator to predict difficult laryngoscopy.

Trial registration number ChiCTRROC-16008598.

Keywords difficult laryngoscopy, cervical spondylosis, ultrasound, magnetic resonance imaging

Strengths and limitations of this study

- Preoperative airway assessment is essential for difficult laryngoscopy in patients with cervical spondylosis.
- Indicators for predicting difficult laryngoscopy measured by ultrasound were increasingly studied.
- The results of anterior neck soft tissue thickness for airway evaluation are inconsistent.
- We found that five common ultrasonographic indicators (skin to hyoid, skin to midpoint of epiglottis, skin to thyroid cartilage at the level of the vocal cords, skin to vocal cords, and skin to anterior to the trachea at the level of suprasternal notch) measured by magnetic resonance imaging (MRI) could not predict difficult laryngoscopy in patients with cervical spondylosis.
- The MRI technical limitation is that it is not a dynamic measurement method and all measurements were taken with patients in the neutral position instead of the intubation position.

INTRODUCTION

The rate of difficult laryngoscopy and intubation ranges widely from 0.5% to 10% of patients undergoing general anesthesia.[1-3] Patients with cervical spondylosis have a higher incidence of difficult laryngoscopy compared with patients without cervical spondylosis [4,5] and in patients with cervical spondylosis, anesthesiologists may encounter a large percentage of unexpected difficult airways, which are associated with increased morbidity and mortality.

Airway examination is an essential component of the preoperative assessment. Preoperative assessment of a patient's airway enables the anesthesiologist to predict the ease of visualizing the glottis and performing intubation. Predictors have variable sensitivities and specificities for identifying a difficult airway.[6] Common bedside physical airway assessment tests include interincisor gap (IIG), thyromental distance, and Mallampati test.[7] However, these measurements have high interobserver variability, and predictive accuracy is too low to identify patients with the most difficult laryngoscopy.[8-11] To increase the accuracy of preoperative evaluation, recent studies have measured anterior neck soft tissue thickness using ultrasound. Ultrasonographic measurements are rapid and convenient to perform, but ultrasonographic findings in studies of preoperative difficult airway assessment are inconsistent. Therefore, whether these measurements are appropriate as difficult laryngoscopy predictors requires further evaluation. These ultrasonographic measurements are related to the operator's skill in ultrasonographic scanning, target image recognition and measurement, patient positioning during ultrasonographic scanning, and patients' ethnic differences and operation type. To verify the accuracy of ultrasonographic measurements as predictors of difficult airway, we used magnetic resonance imaging (MRI) to quantify anterior neck soft tissue thickness, which is more accurate than ultrasonography for evaluating soft tissues.

MATERIALS AND METHODS

Study participants

315 patients aged 20–70 years, mentally competent, American Society of Anesthesiologists' physical status I or II, who were scheduled for elective cervical spinal surgery under general anesthesia from April 2016 to October 2016 were recruited in this prospective cohort study. Written informed consent was obtained from all patients. We excluded patients who were pregnant, experienced cervical spinal instability, or who had an oropharyngeal mass.

Equipment and researchers

Neck MRI (MR750; GE Medical Systems, Milwaukee, WI, USA) examination was performed with the patient in the neutral position, and MRI indicators were measured on the lateral sagittal neck MRI film (figure 1) by an experienced radiologist blinded to group allocation and not involved in intubation and anesthesia management. MRI data were evaluated using the radiography information system (Centricity RIS-IC CE V3.0; GE Healthcare, Little Chalfont, UK) of Peking University Third Hospital.

Measurements

MRI data included the shortest distance from: the skin to the hyoid bone (DSH), skin to the midpoint of the epiglottis (DSE), skin to the thyroid cartilage at the level of the vocal cords (DST), skin to the vocal cords (DSV), and skin to anterior to the trachea at the level of the suprasternal notch (DSS). All MRI indicators were measured by an experienced radiologist in batches containing all patients. The radiologist was blind to group allocation and did not participate in the anesthesia management, so bias was avoided.

Laryngoscopy

All patients received no premedication. Anesthesia was induced intravenously with sufentanil (0.3 μg/kg), propofol (2 mg/kg), and rocuronium (0.6 mg/kg). Laryngoscopy difficulty was assessed with the Cormack–Lehane scale determined during Macintosh laryngoscopy by the same senior anesthesiologist for all patients.[12] Patients with a class III or IV view were assigned to the difficult laryngoscopy group, and those with a class I or II view were assigned to the easy laryngoscopy group. Tracheal intubation was then performed with a Macintosh laryngoscope or alternative device. In patients with a difficult airway, intubation was performed according to the Difficult Airway Society 2015 guidelines.[13]

Patient and public involvement

No patients were involved in the MRI data measures, nor were they involved in developing plans for design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. Study reports will be disseminated to investigators and patients through this open-access publication.

Statistical analysis

Estimating a 24% incidence of difficult laryngoscopy,[14] the calculated sample size was 278 patients using PASS V.11.0 (NCSS LLC, Kaysville, Utah, USA) to obtain a power of 0.9 and a significance level of 0.05. In consideration of potential dropouts, 315 patients were recruited for the study. SPSS software (version 21.0; IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Categorical variables were analyzed by the χ^2 test, and continuous variables were expressed as mean ± standard deviation with an independent-samples t-test. Binary multivariate logistic regression analyses were performed to identify multivariate predictors for difficult laryngoscopy. We calculated 95% confidence intervals (CI), and $p<0.05$ was considered statistically significant.

RESULTS

A total of 315 patients comprising 200 men (63.5%) and 115 women (36.5%) were included in the study. Univariate analysis demonstrated three risk factors associated with difficult laryngoscopy: male sex ($p<0.01$), older age ($p=0.03$), and body weight ($p=0.02$). Five MRI indicators were not significantly different between the easy and difficult laryngoscopy groups, respectively: DSH (1.73 ± 0.54 cm *vs.* 1.61 ± 0.52 cm; $p=0.18$), DSE (3.76 ± 0.53 cm *vs.* 3.79 ± 0.53 cm; $p=0.72$), DST (0.66 ± 0.24 cm *vs.*

0.59 ± 0.23 cm; p=0.10), DSV (1.49 ± 0.41 cm *vs.* 1.43 ± 0.42 cm; p=0.44) and DSS (4.53 ± 0.72 cm *vs.* 4.52 ± 0.75 cm; p=0.92). The indicators are listed in table 1.

Table 1 Patients' demographic data and MRI indicators

Indicators	**Easy laryngoscopy group (n=261)**	**Difficult laryngoscopy group (*n*=54)**	**p-value**
Age (years)	52.8 ± 10.5	56.2 ± 8.6	0.03
Sex (male/female)	152(58%)/109(42%)	48(89%)/6(11%)	< 0.01
Height (cm)	166.0 ± 8.1	167.7 ± 6.8	0.16
Weight (kg)	69.0 ± 11.8	73.1 ± 9.6	0.02
DSH (cm)	1.73 ± 0.54	1.61 ± 0.52	0.18
DSE (cm)	3.76 ± 0.53	3.79 ± 0.53	0.72
DST (cm)	0.66 ± 0.24	0.59 ± 0.23	0.10
DSV (cm)	1.49 ± 0.41	1.43 ± 0.42	0.44
DSS (cm)	4.53 ± 0.72	4.52 ± 0.75	0.92

Values are presented as mean ± standard deviation or number (proportion).

Abbreviations: DSE, distance from skin to epiglottis; DSH, distance from skin to hyoid bone; DST, distance from skin to thyroid cartilage at the level of the vocal cords; DSS, distance from skin to anterior to the trachea at the level of the suprasternal notch; DSV, distance from skin to vocal cords; MRI, magnetic resonance imaging.

Adjusted by sex, age, and weight, binary multivariate logistic regression analyses for the MRI indicators identified no factor that was independently associated with difficult laryngoscopy: DSH (p=0.51), DSE (p=0.12), DST (p=0.26), DSV (p=0.09), and DSS (p=0.59). Odds ratios (95% CIs) for DSH, DSE, DST, DSV, and DSS were 0.79 (0.38–1.62), 0.56 (0.27–1.16), 0.38 (0.07–2.04), 0.44 (0.17–1.13), and 1.16 (68-1.96), respectively. Results appear in table 2.

Table 2 The five MRI predictors for difficult laryngoscopy identified by binary multivariate logistic regression (Enter) model

Variable	β	SE	p-value	OR	95%CI
DSH*	-0.24	0.37	0.51	0.79	0.38-1.62
DSE*	-0.59	0.38	0.12	0.56	0.27-1.16
DST*	-0.96	0.85	0.26	0.38	0.07-2.04
DSV*	-0.83	0.49	0.09	0.44	0.17-1.13
DSS*	0.15	0.27	0.59	1.16	0.68-1.96

*Adjusted by sex, age, and body weight.

Abbreviations: 95% CI, 95% confidence interval; DSE, distance from skin to epiglottis; DSH, distance from skin to hyoid bone; DSS, distance from skin to anterior to the trachea at the level of the suprasternal notch; DST, distance from skin to thyroid cartilage at the level of the vocal cords; DSV, distance from skin to vocal cords; MRI, magnetic resonance imaging; OR, odds ratio; SE, standard error.

DISCUSSION

To our knowledge, ours is the first study of anterior neck soft tissue thickness verified by MRI. Our results showed that the five most-popular ultrasonographic indicators had no significant difference for predicting easy and difficult laryngoscopy.

Our data demonstrated that male sex, higher body weight, and older age were associated with difficult laryngoscopy. A significantly greater proportion of difficult tracheal intubations has been reported in men and obese patients.[15,16] An association between difficult laryngoscopy and older age has also been reported.[17] Osteoarthritic changes associated with decreased thyromental distance, cervical spinal movement, interincisor distance, and grade of dentition, may be responsible for age-related increases in difficult laryngoscopy.[4]

Adding ultrasonography to airway evaluation allows for rapid visualization of structures. With appropriate depth and probe-frequency selection, ultrasound can image any structure lying superficial to the oral, pharyngeal, or tracheal air columns.[18] This includes the mouth, tongue, oropharynx, hypopharynx, hyoid bone, epiglottis, larynx, vocal cords, cricothyroid membrane, cricoid cartilages, and trachea.[19] Ultrasonography, as a portable, noninvasive, rapid, and effective examination, is increasingly used for airway assessment before surgery; however, results are inconsistent.

Adhikari *et al* [20] reported that DSH could be used to distinguish difficult and easy laryngoscopies, and found that DSH values were higher in the difficult laryngoscopy group compared with the easy laryngoscopy group (1.69 cm, 95% CI: 1.19–2.19 *vs.* 1.37 cm, 95% CI: 1.27–1.46, respectively) in a study of 51 American patients in the neutral position without a pillow. However, in a study by Reddy *et al*,[21] DSH was not a significant predictor of difficult laryngoscopy (p=0.86) and our results were consistent with Reddy *et al*'s. In our study including 315 cervical spondylosis patients in the neutral position, we found that DSH did not differ significantly between easy and difficult laryngoscopy groups (1.73 ± 0.54 cm *vs.* 1.61 ± 0.52 cm, respectively; p=0.18).

Pinto *et al* [22] studied 74 Portuguese patients in the neutral position and found that DSE can be used effectively to predict difficult laryngoscopy; DSE was greater in the difficult laryngoscopy group compared with the easy laryngoscopy group (2.83 ± 0.44 cm *vs.* 2.33 ± 0.39 cm, respectively; p<0.01). Soltani *et al* [23] studied 53 Iranian patients in the supine position with active maximal head-tilt and chin-lift and found that the correlation between the depth of the pre-epiglottic space and Cormack–Lehane grade III was weak, with a regression coefficient of 0.13 (95% CI: 0.70–1.71; p=0. 40). In our study, DSE did not differ significantly between easy and difficult laryngoscopy groups (3.76 ± 0.53 cm *vs.* 3.79 ± 0.53 cm, respectively; p=0.72).

Komatsu *et al* [24] studied 64 obese American patients in the neutral position without a pillow and found that DST in the difficult laryngoscopy group was shorter than that in the easy laryngoscopy group (2.0 ± 0.3 cm *vs.* 2.2 ± 0.4 cm, respectively; p<0.05), but multivariate regression indicated that DST was not an independent predictor of difficult laryngoscopy (p=0.13). Therefore, the authors concluded that DST was not a good predictor and that it failed to predict difficult laryngoscopy in obese patients. In our study, we found that DST did not differ significantly between easy and difficult laryngoscopy groups (0.66 ± 0.24 cm *vs.* 0.59 ± 0.23 cm, respectively; p=0.10).

Ezri *et al* [15] studied 50 obese Israeli patients and found that DSV and DSS in the difficult laryngoscopy group were both greater than values in the easy laryngoscopy group (2.8 ± 0.3 cm *vs.* 1.8 ± 0.2 cm, respectively; p<0.01 and 3.3 ± 0.4 cm *vs.* 2.7 ± 0.7 cm, respectively; p=0.01). Reddy *et al* [21] also found that DSV in the difficult laryngoscopy group was greater than that in the easy laryngoscopy group (0.35 ± 0.18 cm *vs.* 0.25 ± 0.11 cm, respectively; p=0.01) and that DSV >0.23 cm was a potential predictor of difficult intubation with 85.7% sensitivity, 57% specificity, and 61% accuracy. However, Adhikari *et al* [20] found no significant differences for DSV and DSS between easy and difficult laryngoscopy groups. We also found that DSV and DSS did not differ significantly between easy and difficult laryngoscopy groups (1.49 ± 0.41 cm *vs.* 1.43 ± 0.42 cm, respectively; p=0.44 and 4.53 ± 0.72 cm *vs.* 4.52 ± 0.75 cm, respectively; p=0.92).

Ultrasonography is convenient and useful for bedside examination, and five indicators of anterior neck soft tissue thickness at different levels measured using ultrasonography have been discussed previously. To obtain better soft tissue images with lower radiation hazard, we chose MRI to measure the related soft tissues. We found that none of the five indices could predict difficult laryngoscopy in patients with cervical spondylosis regardless of whether sex, age, and body weight were adjusted with a binary multivariate logistic regression. The reasons for different results between our study and previous studies are as follows: (1) the five MRI indicators focused only on the local anatomy and could not reflect cervical activity and changes in head position (from neutral to extended). Therefore, these may not be meaningful indicators; however, no defined gold standard indicators exist. (2) These indices have been measured previously using ultrasonography, but measurements were not taken using standardized procedures, which have not been determined.

Ultrasonographic measurements obtained by the primary investigator might have been associated with bias, and the measurement results were related to the operator's experience. The lack of a standardized reference and methods for obtaining these ultrasonographic measurements in previous studies also indicates the potential for operator error. Patients' necks were also positioned differently across studies, which could result in measurement error. (3) Patients' ethnicity and operation type might also affect results. Our study participants were Asian, and previous studies included American, Portuguese, or Iranian patients; studies have documented differences in neck fat tissue distribution between different ethnic groups. [20] (4) Our patients had cervical spondylosis, and the presence of this condition was not mentioned for patients in previous studies. (5) Considering superficial measurements reflecting anatomical variation in an extremely anterior airway and the small sample size in previous studies, results might be skewed.

Limitations of the study

Our study has limitations. First, measurements in some previous studies were taken in the head-extended position to facilitate ultrasonographic examination. In our study, during MRI examination, all measurements were taken with patients in the neutral position, and no measurements were taken in the intubation position. Although we positioned all patients in the same position, there is a difference between the MRI examination position and the intubation position, and a deficiency of MRI is that it is not a dynamic measurement method. Second, we did not perform simultaneous MRI and ultrasonographic examinations in the same patient; we used MRI only to verify previously-reported ultrasonographic indicators. Third, MRI is a routine preoperative examination in patients undergoing surgery for cervical spondylosis; therefore, we verified the five most-popular ultrasonographic indicators in these specific patients to best use data to predict a difficult airway without additional expense. However, our results might not be suitable for other patients, and further research is needed.

CONCLUSION

Our study suggests that the ultrasonographic indices (DSH, DSE, DST, DSV, and DSS) used to evaluate anterior neck soft tissue thickness at different levels, measured by MRI, could not predict difficult laryngoscopy in patients with cervical spondylosis. In future studies of ultrasonographic assessment, patients' ethnicity, position, operators' qualifications, and standardized operation procedures all must be considered. Based on high-quality and large-sample-size studies, the most accurate ultrasonographic indicator for difficult laryngoscopy may be determined.

Contributors Yongzheng Han and Mao Xu designed and coordinated the study, collected and interpreted data, and drafted the manuscript. Xiangyang Guo participated in the study design. Jingchao Fang participated in measuring radiological indicators. Hua Zhang analyzed the data and performed statistical analysis. All authors discussed the results, and read and approved the final manuscript.

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Disclaimer The funders were not involved in the study design, data analysis or manuscript preparation.

Competing interests None declared.

Patient consent Obtained.

Ethics approval The study was approved by Peking University Third Hospital Medical Science Research Ethics Committee (IRB00006761-2015021).

Provenance and peer review Not commissioned; externally peer reviewed.

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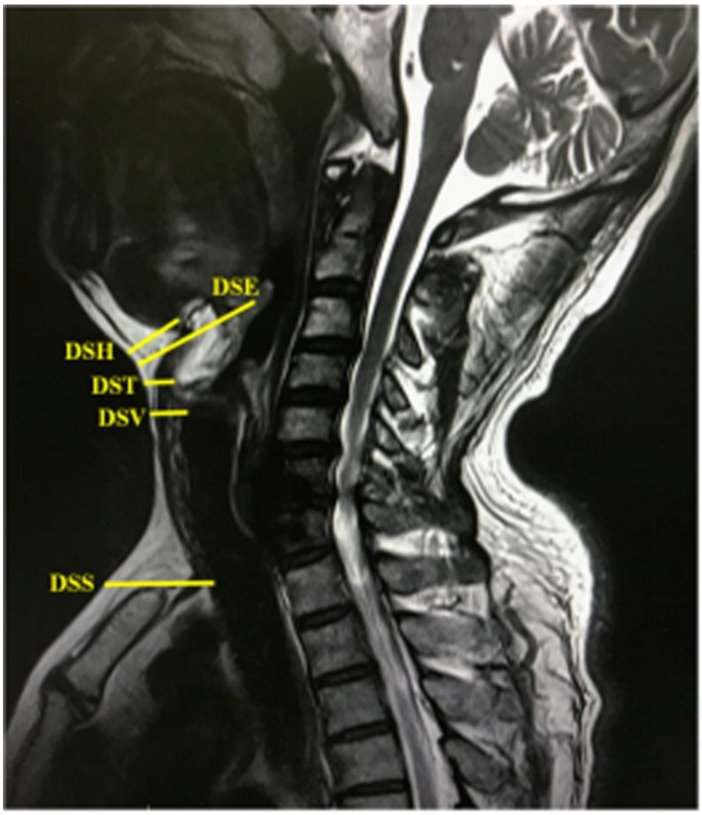
Figure Legend

Figure 1 Indicators on lateral sagittal neck MRI image.

DSE: distance from skin to epiglottis; DSH: distance from skin to hyoid bone; DSS: distance from the skin to anterior to the trachea at the level of suprasternal notch; DST: distance from skin to thyroid cartilage at the level of the vocal cords; DSV: distance from skin to vocal cords.



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	**Item #**	**Recommendation**	**Reported on page #**
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	6
		(*e*) Describe any sensitivity analyses	6
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	6
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6,7,8
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations			11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Anterior neck soft tissue thickness for airway evaluation measured by magnetic resonance imaging in patients with cervical spondylosis: a prospective cohort study

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ABSTRACT

Objectives Anterior neck soft tissue thickness, usually measured by ultrasound, is increasingly being investigated to predict difficult laryngoscopy, but results have not been validated. Considering the conflicting measurement data, different measuring body positions, and lack of a standard ultrasound procedure, we used magnetic resonance imaging (MRI) to verify the efficacy of these popular ultrasonographic parameters.

Design Prospective cohort study.

Setting A tertiary hospital in Beijing, China.

Methods We enrolled 315 adult patients who underwent cervical spinal surgery in Peking University Third Hospital from April 2016 to October 2016. We analyzed MRI data to predict difficult laryngoscopy. 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 male sex ($p<0.01$), older age ($p=0.03$), and body weight ($p=0.02$) were associated with difficult laryngoscopy. MRI data consisted of five common ultrasonographic variables used to predict difficult laryngoscopy, but none was a valuable predictor: skin to hyoid ($p=0.18$), skin to midpoint of epiglottis ($p=0.72$), skin to thyroid cartilage at the level of the vocal cords ($p=0.10$), skin to vocal cords ($p=0.44$), or skin to anterior to the trachea at the level of suprasternal notch ($p=0.92$). Adjusted by sex, age, and body weight, none of the five MRI indicators had predictive value ($p>0.05$).

Conclusion The five most-commonly-studied ultrasonographic indicators of anterior soft tissue thickness appeared unreliable to predict difficult laryngoscopy in patients with cervical spondylosis. Further study is needed to validate the most valuable indicator to predict difficult laryngoscopy.

Trial registration number ChiCTRROC-16008598.

Keywords difficult laryngoscopy, cervical spondylosis, ultrasound, magnetic resonance imaging

Strengths and limitations of this study

- Preoperative airway assessment is essential for difficult laryngoscopy in patients with cervical spondylosis.
- Indicators for predicting difficult laryngoscopy measured by ultrasound were increasingly studied.
- The results of anterior neck soft tissue thickness for airway evaluation are inconsistent.
- This might be the first MRI study to evaluate anterior neck soft tissue thickness for predicting difficult laryngoscopy.
- The MRI technical limitation is that it is not a dynamic measurement method and all measurements were taken with patients in the neutral position instead of the intubation position.

INTRODUCTION

The rate of difficult laryngoscopy and intubation ranges widely from 0.5% to 24% of patients undergoing general anesthesia among difficult studies.[1-4] Patients with cervical spondylosis have a higher incidence of difficult laryngoscopy compared with patients without cervical spondylosis [5,6] and in patients with cervical spondylosis, anesthesiologists may encounter a large percentage of unexpected difficult airways, which are associated with increased morbidity and mortality.

Airway examination is an essential component of the preoperative assessment. Preoperative assessment of a patient's airway enables the anesthesiologist to predict the ease of visualizing the glottis and performing intubation. Predictors have variable sensitivities and specificities for identifying a difficult airway.[7] Common bedside physical airway assessment tests include interincisor gap (IIG), thyromental distance, and Mallampati test.[8] However, these measurements have high interobserver variability, and predictive accuracy is too low to identify patients with the most difficult laryngoscopy.[9-12] To increase the accuracy of preoperative evaluation, recent studies have measured anterior neck soft tissue thickness using ultrasound. Ultrasonographic measurements are rapid and convenient to perform, but ultrasonographic findings in studies of preoperative difficult airway assessment are inconsistent. This may be attributed to the operator's skill in ultrasonographic scanning, target image recognition and measurement, patient positioning during ultrasonographic scanning, and patients' ethnic differences and operation type. Ultrasonographic predictors of anterior neck soft tissue thickness are usually performed in neck maximum extension which may be dangerous for patients with cervical spondylosis. It should be emphasized that no ultrasound study was performed in such patients with cervical spine pathology. Whether these measurements are appropriate as difficult laryngoscopy predictors requires further evaluation. To verify the accuracy of ultrasonographic measurements proposed by other studies in patients with cervical spondylosis, we used magnetic resonance imaging (MRI) to quantify anterior neck soft tissue thickness, which is more accurate than ultrasonography for evaluating soft tissues.

MATERIALS AND METHODS

Study participants

Patients aged 20–70 years, mentally competent, American Society of Anesthesiologists' physical status I or II, who were scheduled for elective cervical spinal surgery under general anesthesia from April 2016 to October 2016 were recruited in this prospective cohort study. Written informed consent was obtained from all patients. We excluded patients who were pregnant, experienced cervical spinal instability, or who had an oropharyngeal mass.

Equipment and researchers

Neck MRI (MR750; GE Medical Systems, Milwaukee, WI, USA) examination was performed with the patient in the neutral position, and MRI indicators were measured on the lateral sagittal neck MRI film (Figure 1) by an experienced radiologist blinded to group allocation and not involved in intubation and anesthesia management. MRI data were evaluated using the radiography information system (Centricity RIS-IC CE V3.0; GE Healthcare, Little Chalfont, UK) of Peking University Third Hospital.

Measurements

MRI data included the shortest distance from: the skin to the hyoid bone (DSH), skin to the midpoint of the epiglottis (DSE), skin to the thyroid cartilage at the level of the vocal cords (DST), skin to the vocal cords (DSV), and skin to anterior to the trachea at the level of the suprasternal notch (DSS). All MRI indicators were measured by an experienced radiologist in batches containing all patients. The radiologist was blind to group allocation and did not participate in the anesthesia management, so bias was avoided.

Laryngoscopy

All patients received no premedication. Anesthesia was induced intravenously with sufentanil (0.3 μg/kg), propofol (2 mg/kg), and rocuronium (0.6 mg/kg).

Laryngoscopy difficulty was assessed with the Cormack–Lehane scale determined during Macintosh laryngoscopy, in all patients in the sniff position, by the same senior anesthesiologist for all patients.[13] Patients with a class III or IV view were assigned to the difficult laryngoscopy group, and those with a class I or II view were assigned to the easy laryngoscopy group. Tracheal intubation was then performed with a Macintosh laryngoscope or alternative device. In patients with a difficult airway, intubation was performed according to the Difficult Airway Society 2015 guidelines.[14]

Patient and public involvement

No patients were involved in the MRI data measures, nor were they involved in developing plans for design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. Study reports will be disseminated to investigators and patients through this open-access publication.

Statistical analysis

Estimating a 24% incidence of difficult laryngoscopy,[4] the calculated sample size was 278 patients using PASS V.11.0 (NCSS LLC, Kaysville, Utah, USA) to obtain a power of 0.9 and a significance level of 0.05. In consideration of potential dropouts, 315 patients were recruited for the study. SPSS software (version 21.0; IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Categorical variables were analyzed by the χ^2 test, and continuous variables were expressed as mean ± standard deviation with an independent-samples t-test. Binary multivariate logistic regression analyses were performed to identify multivariate predictors for difficult laryngoscopy. We calculated 95% confidence intervals (CI), and $p<0.05$ was considered statistically significant.

RESULTS

A total of 328 were initially enrolled in the study and 315 were included in the final analysis. The allocation process was presented in Figure 2. Patients comprising 200 men (63.5%) and 115 women (36.5%) were included in the study. Univariate analysis demonstrated three risk factors associated with difficult laryngoscopy: male sex ($p<0.01$), older age ($p=0.03$), and body weight ($p=0.02$). Five MRI indicators were not significantly different between the easy and difficult laryngoscopy groups, respectively: DSH (1.73 ± 0.54 cm *vs.* 1.61 ± 0.52 cm; $p=0.18$), DSE (3.76 ± 0.53 cm *vs.* 3.79 ± 0.53 cm; $p=0.72$), DST (0.66 ± 0.24 cm *vs.* 0.59 ± 0.23 cm; $p=0.10$), DSV (1.49 ± 0.41 cm *vs.* 1.43 ± 0.42 cm; $p=0.44$) and DSS (4.53 ± 0.72 cm *vs.* 4.52 ± 0.75 cm; $p=0.92$). The indicators are listed in table 1.

Table 1 Patients' demographic data and MRI indicators

Indicators	**Easy laryngoscopy group (n=261)**	**Difficult laryngoscopy group (*n*=54)**	**p-value**
Age (years)	52.8 ± 10.5	56.2 ± 8.6	0.03
Sex (male/female)	152(58%)/109(42%)	48(89%)/6(11%)	< 0.01
Height (cm)	166.0 ± 8.1	167.7 ± 6.8	0.16
Weight (kg)	69.0 ± 11.8	73.1 ± 9.6	0.02
DSH (cm)	1.73 ± 0.54	1.61 ± 0.52	0.18
DSE (cm)	3.76 ± 0.53	3.79 ± 0.53	0.72
DST (cm)	0.66 ± 0.24	0.59 ± 0.23	0.10
DSV (cm)	1.49 ± 0.41	1.43 ± 0.42	0.44
DSS (cm)	4.53 ± 0.72	4.52 ± 0.75	0.92

Values are presented as mean ± standard deviation or number (proportion).

Abbreviations: DSE, distance from skin to epiglottis; DSH, distance from skin to hyoid bone; DST, distance from skin to thyroid cartilage at the level of the vocal cords; DSS, distance from skin to anterior to the trachea at the level of the suprasternal notch; DSV, distance from skin to vocal cords; MRI, magnetic resonance imaging.

Adjusted by sex, age, and weight, binary multivariate logistic regression analyses for the MRI indicators identified no factor that was independently associated with difficult laryngoscopy: DSH (p=0.51), DSE (p=0.12), DST (p=0.26), DSV (p=0.09), and DSS (p=0.59). Odds ratios (95% CIs) for DSH, DSE, DST, DSV, and DSS were 0.79 (0.38–1.62), 0.56 (0.27–1.16), 0.38 (0.07–2.04), 0.44 (0.17–1.13), and 1.16 (68-1.96), respectively. Results appear in table 2.

Table 2 The five MRI predictors for difficult laryngoscopy identified by binary multivariate logistic regression (Enter) model

Variable	β	SE	p-value	OR	95%CI
DSH*	-0.24	0.37	0.51	0.79	0.38-1.62
DSE*	-0.59	0.38	0.12	0.56	0.27-1.16
DST*	-0.96	0.85	0.26	0.38	0.07-2.04
DSV*	-0.83	0.49	0.09	0.44	0.17-1.13
DSS*	0.15	0.27	0.59	1.16	0.68-1.96

*Adjusted by sex, age, and body weight.

Abbreviations: 95% CI, 95% confidence interval; DSE, distance from skin to epiglottis; DSH, distance from skin to hyoid bone; DSS, distance from skin to anterior to the trachea at the level of the suprasternal notch; DST, distance from skin to thyroid cartilage at the level of the vocal cords; DSV, distance from skin to vocal cords; MRI, magnetic resonance imaging; OR, odds ratio; SE, standard error.

DISCUSSION

To our knowledge, ours is the first study of anterior neck soft tissue thickness verified by MRI. Our results showed that the five most-popular ultrasonographic indicators had no significant difference for predicting easy and difficult laryngoscopy.

Our data demonstrated that male sex, higher body weight, and older age were associated with difficult laryngoscopy. A significantly greater proportion of difficult tracheal intubations has been reported in men and obese patients.[15,16] An association between difficult laryngoscopy and older age has also been reported.[17]

Osteoarthritic changes associated with decreased thyromental distance, cervical spinal movement, interincisor distance, and grade of dentition, may be responsible for age-related increases in difficult laryngoscopy.[5]

Adding ultrasonography to airway evaluation allows for rapid visualization of structures. With appropriate depth and probe-frequency selection, ultrasound can image any structure lying superficial to the oral, pharyngeal, or tracheal air columns.[18] This includes the mouth, tongue, oropharynx, hypopharynx, hyoid bone, epiglottis, larynx, vocal cords, cricothyroid membrane, cricoid cartilages, and trachea.[19] Ultrasonography, as a portable, noninvasive, rapid, and effective examination, is increasingly used for airway assessment before surgery; however, results are inconsistent.

Adhikari *et al* [20] reported that DSH could be used to distinguish difficult and easy laryngoscopies, and found that DSH values were higher in the difficult laryngoscopy group compared with the easy laryngoscopy group (1.69 cm, 95% CI: 1.19–2.19 *vs.* 1.37 cm, 95% CI: 1.27–1.46, respectively) in a study of 51 American patients in the neutral position without a pillow. However, in a study by Reddy *et al*,[21] DSH was not a significant predictor of difficult laryngoscopy (p=0.86) and our results were consistent with Reddy *et al*'s. In our study including 315 patients with cervical spondylosis in the neutral position, we found that DSH did not differ significantly between easy and difficult laryngoscopy groups (1.73 ± 0.54 cm *vs.* 1.61 ± 0.52 cm, respectively; p=0.18).

Pinto *et al* [22] studied 74 Portuguese patients in the neutral position and found that DSE can be used effectively to predict difficult laryngoscopy; DSE was greater in the difficult laryngoscopy group compared with the easy laryngoscopy group (2.83 ± 0.44 cm *vs.* 2.33 ± 0.39 cm, respectively; p<0.01). Soltani *et al* [23] studied 53 Iranian patients in the supine position with active maximal head-tilt and chin-lift and found that the correlation between the depth of the pre-epiglottic space and Cormack–Lehane grade III was weak, with a regression coefficient of 0.13 (95% CI: 0.70–1.71; p=0. 40). In our study, DSE did not differ significantly between easy and difficult laryngoscopy groups (3.76 ± 0.53 cm *vs.* 3.79 ± 0.53 cm, respectively; p=0.72).

Komatsu *et al* [24] studied 64 obese American patients in the neutral position without a pillow and found that DST in the difficult laryngoscopy group was shorter than that in the easy laryngoscopy group (2.0 ± 0.3 cm *vs.* 2.2 ± 0.4 cm, respectively; p<0.05), but multivariate regression indicated that DST was not an independent predictor of difficult laryngoscopy (p=0.13). Therefore, the authors concluded that DST was not a good predictor and that it failed to predict difficult laryngoscopy in obese patients. In our study, we found that DST did not differ significantly between easy and difficult laryngoscopy groups (0.66 ± 0.24 cm *vs.* 0.59 ± 0.23 cm, respectively; p=0.10).

Ezri *et al* [15] studied 50 obese Israeli patients and found that DSV and DSS in the difficult laryngoscopy group were both greater than values in the easy laryngoscopy group (2.8 ± 0.3 cm *vs.* 1.8 ± 0.2 cm, respectively; p<0.01 and 3.3 ± 0.4 cm *vs.* 2.7 ± 0.7 cm, respectively; p=0.01). Reddy *et al* [21] also found that DSV in the difficult laryngoscopy group was greater than that in the easy laryngoscopy group (0.35 ± 0.18 cm *vs.* 0.25 ± 0.11 cm, respectively; p=0.01) and that DSV >0.23 cm was a potential predictor of difficult intubation with 85.7% sensitivity, 57% specificity, and 61% accuracy. However, Adhikari *et al* [20] found no significant differences for DSV and DSS between easy and difficult laryngoscopy groups. We also found that DSV and DSS did not differ significantly between easy and difficult laryngoscopy groups (1.49 ± 0.41 cm *vs.* 1.43 ± 0.42 cm, respectively; p=0.44 and 4.53 ± 0.72 cm *vs.* 4.52 ± 0.75 cm, respectively; p=0.92).

Ultrasonography is convenient and useful for bedside examination, and five indicators of anterior neck soft tissue thickness at different levels measured using ultrasonography have been discussed previously. The results of the five ultrasonographic predictors are inconsistent. Considering that MRI has higher resolution than ultrasound, to obtain better soft tissue images with lower radiation hazard, we chose MRI to measure the related soft tissues. We found that none of the five indices could predict difficult laryngoscopy in patients with cervical spondylosis regardless of whether sex, age, and body weight were adjusted with a binary multivariate logistic regression. The reasons for different results between our study and previous studies are as follows: (1) the five MRI indicators focused only on the local anatomy and could not reflect cervical activity and changes in head position (from neutral to extended). Therefore, these may not be meaningful indicators; however, no defined gold standard indicators exist. (2) These indices have been measured previously using ultrasonography, but measurements were not taken using standardized procedures, which have not been determined. Ultrasonographic measurements obtained by the primary investigator might have been associated with bias, and the measurement results were related to the operator's experience. The lack of a standardized reference and methods for obtaining these ultrasonographic measurements in previous studies also indicates the potential for operator error. Patients' necks were also positioned differently across studies, which could result in measurement error. (3) Patients' ethnicity and operation type might also affect results. Our study participants were Asian, and previous studies included American, Portuguese, or Iranian patients; studies have documented differences in neck fat tissue distribution between different ethnic groups. [20] (4) Our patients had cervical spondylosis, and the presence of this condition was not mentioned for patients in previous studies. (5) Considering superficial measurements reflecting anatomical variation in an extremely anterior airway and the small sample size in previous studies, results might be skewed.

Limitations of the study

Our study has limitations. First, measurements in some previous studies were taken in the head-extended position to facilitate ultrasonographic examination. In our study, during MRI examination, all measurements were taken with patients in the neutral position, and no measurements were taken in the intubation position. Although we positioned all patients in the same position, there is a difference between the MRI examination position and the intubation position, and a deficiency of MRI is that it is not a dynamic measurement method. Second, this study did not have the same design as previous ultrasound studies. We did not perform ultrasonography and MRI simultaneously in the same patients; we used MRI to verify whether the ultrasonographic parameters of anterior neck soft tissue thickness suitable for patients with cervical spondylosis. In this patient cohort, ultrasonography derived measurements reflecting cervical mobility (such as hyo-mental distance ratio) might be more valuable compared to anterior neck soft tissue thickness. Third, although MRI costs more than ultrasound and time required, MRI is a routine preoperative examination in patients undergoing surgery for cervical spondylosis; therefore, we verified the five most-popular ultrasonographic indicators in these specific patients to best use data to predict a difficult airway without additional expense. However, our results might not be suitable for other patients, and further research is needed.

CONCLUSION

Our study suggests that the ultrasonographic indices (DSH, DSE, DST, DSV, and DSS) used to evaluate anterior neck soft tissue thickness at different levels, measured by MRI, could not predict difficult laryngoscopy in patients with cervical spondylosis. In future studies of ultrasonographic assessment, patients' ethnicity, position, operators' qualifications, and standardized operation procedures all must be considered. Based on high-quality and large-sample-size studies, the most accurate ultrasonographic indicator for difficult laryngoscopy may be determined.

Contributors Yongzheng Han and Mao Xu designed and coordinated the study, collected and interpreted data, and drafted the manuscript. Xiangyang Guo participated in the study design. Jingchao Fang participated in measuring radiological indicators. Hua Zhang analyzed the data and performed statistical analysis. All authors discussed the results, and read and approved the final manuscript.

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Disclaimer The funders were not involved in the study design, data analysis or manuscript preparation.

Competing interests None declared.

Patient consent Obtained.

Ethics approval The study was approved by Peking University Third Hospital Medical Science Research Ethics Committee (IRB00006761-2015021).

Provenance and peer review Not commissioned; externally peer reviewed.

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Data sharing statement A full anonymised dataset is available from the corresponding author on request.

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Figure legends

Figure 1 Indicators on lateral sagittal neck MRI image.

DSE: distance from skin to epiglottis; DSH: distance from skin to hyoid bone; DSS: distance from the skin to anterior to the trachea at the level of suprasternal notch; DST: distance from skin to thyroid cartilage at the level of the vocal cords; DSV: distance from skin to vocal cords.

Figure 2 Allocation process. MRI, magnetic resonance imaging.

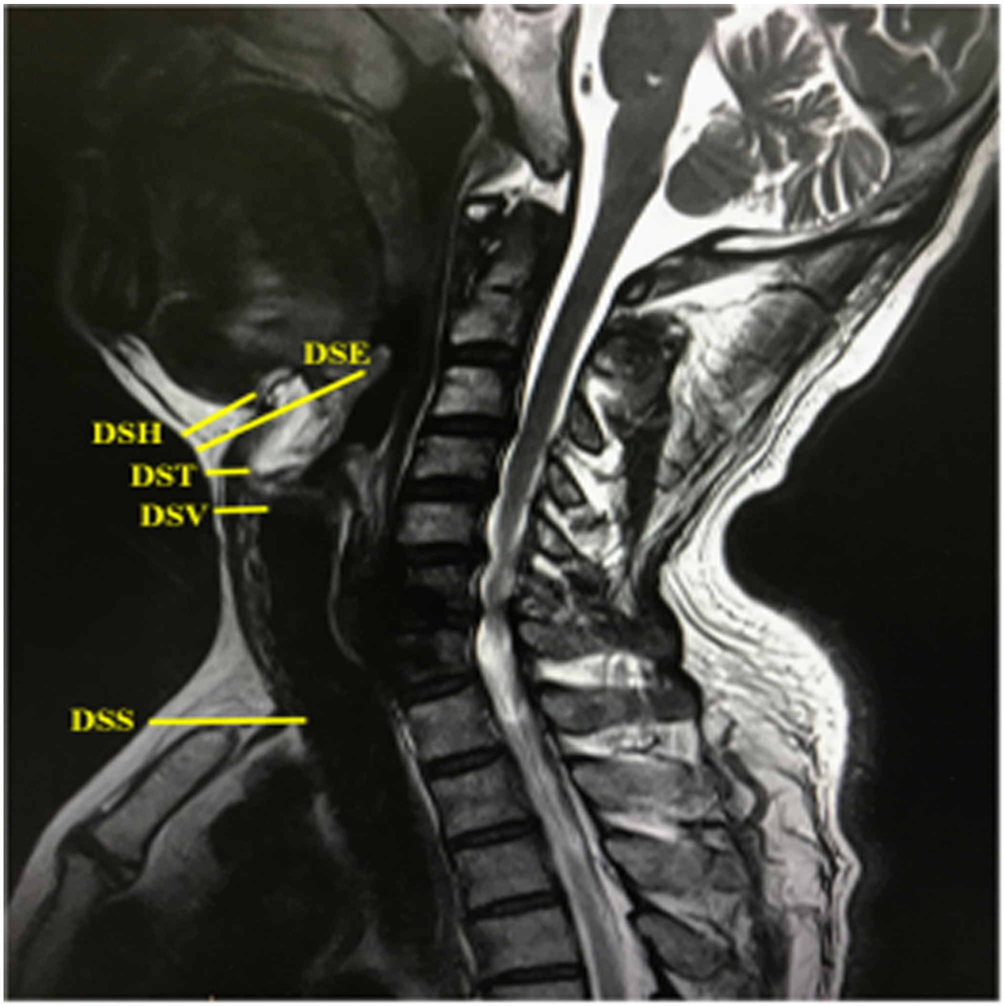

Figure 1 Indicators on lateral sagittal neck MRI image.

90x90mm (300 x 300 DPI)

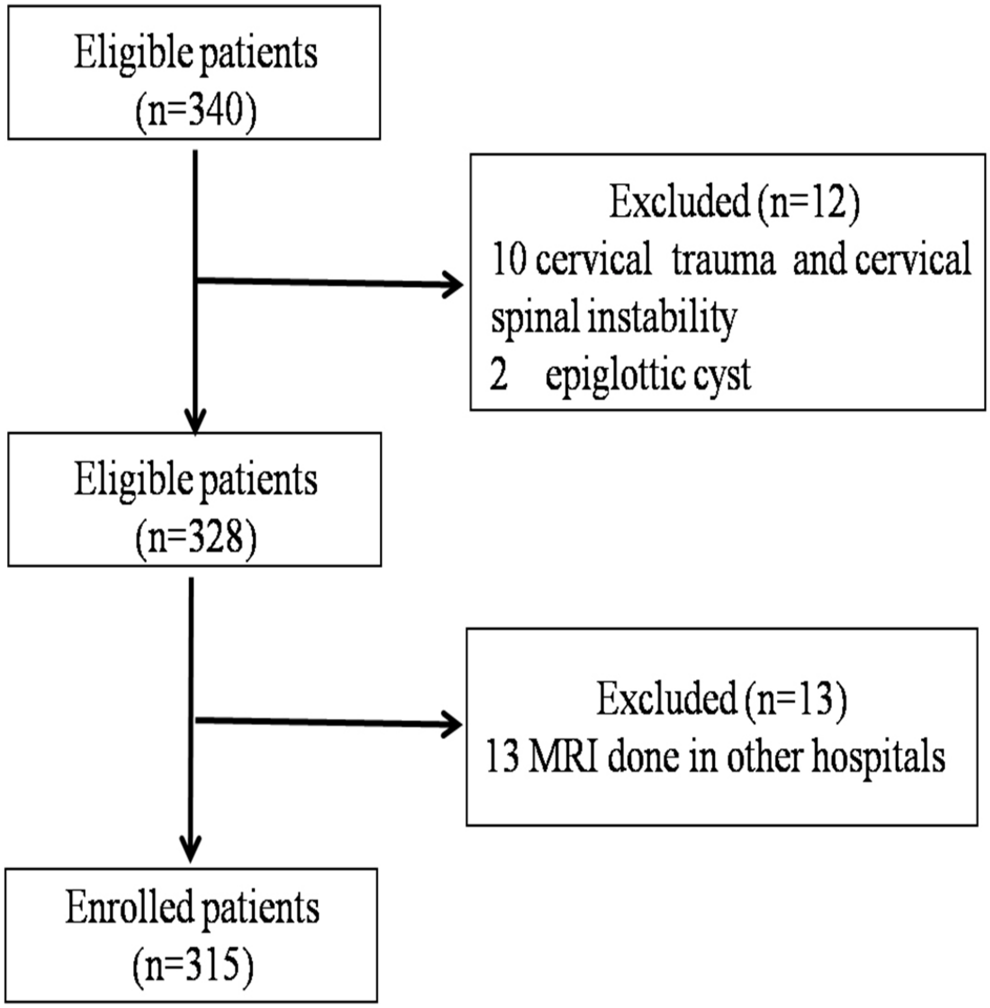

Figure 2 Allocation process.

90x90mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			**4**
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			**5-6**
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not Applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5,6
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	6
		(*e*) Describe any sensitivity analyses	6
Results			6-8

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6,7
		(b) Indicate number of participants with missing data for each variable of interest	Not Applicable
		(c) Summarise follow-up time (eg, average and total amount)	Not Applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7,8
		(*b*) Report category boundaries when continuous variables were categorized	Not Applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not Applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not Applicable
Discussion			8-11
Key results	18	Summarise key results with reference to study objectives	9-11
Limitations			11,12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			12,13
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Anterior neck soft tissue thickness for airway evaluation measured by magnetic resonance imaging in patients with cervical spondylosis: a prospective cohort study

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ABSTRACT

Objectives Anterior neck soft tissue thickness, usually measured by ultrasound, is increasingly being investigated to predict difficult laryngoscopy, but results have not been validated. Considering the conflicting measurement data, different measuring body positions, and lack of a standard ultrasound procedure, we used magnetic resonance imaging (MRI) to verify the efficacy of these popular ultrasonographic parameters.

Design Prospective cohort study.

Setting A tertiary hospital in Beijing, China.

Methods We enrolled 315 adult patients who underwent cervical spinal surgery in Peking University Third Hospital from April 2016 to October 2016. We analyzed MRI data to predict difficult laryngoscopy. 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 male sex ($p<0.01$), older age ($p=0.03$), and body weight ($p=0.02$) were associated with difficult laryngoscopy. MRI data consisted of five common ultrasonographic variables used to predict difficult laryngoscopy, but none was a valuable predictor: skin to hyoid ($p=0.18$), skin to midpoint of epiglottis ($p=0.72$), skin to thyroid cartilage at the level of the vocal cords ($p=0.10$), skin to vocal cords ($p=0.44$), or skin to anterior to the trachea at the level of suprasternal notch ($p=0.92$). Adjusted by sex, age, and body weight, none of the five MRI indicators had predictive value ($p>0.05$).

Conclusion The five most-commonly-studied ultrasonographic indicators of anterior soft tissue thickness appeared unreliable to predict difficult laryngoscopy in patients with cervical spondylosis. Further study is needed to validate the most valuable indicator to predict difficult laryngoscopy.

Trial registration number ChiCTRROC-16008598.

Keywords difficult laryngoscopy, cervical spondylosis, ultrasound, magnetic resonance imaging

Strengths and limitations of this study

- This might be the first MRI study to evaluate anterior neck soft tissue thickness for predicting difficult laryngoscopy.
- The protocol of ultrasound predictors for anterior neck soft tissue have not been standardized.
- Ultrasound predictors of anterior neck soft tissue thickness are usually performed in neck maximum extension which may be dangerous for patients with cervical spondylosis.
- In our study, ultrasound and MRI were not performed at the same time.
- The limitation of MRI in airway assessment is that it could not be used for dynamic detection and all measurements were taken with patients in the neutral position instead of the intubation position.

INTRODUCTION

The rate of difficult laryngoscopy and intubation ranges widely from 0.5% to 24% of patients undergoing general anesthesia among difficult studies.[1-4] Patients with cervical spondylosis have a higher incidence of difficult laryngoscopy compared with patients without cervical spondylosis [5,6] and in patients with cervical spondylosis, anesthesiologists may encounter a large percentage of unexpected difficult airways, which are associated with increased morbidity and mortality.

Airway examination is an essential component of the preoperative assessment. Preoperative assessment of a patient's airway enables the anesthesiologist to predict the ease of visualizing the glottis and performing intubation. Predictors have variable sensitivities and specificities for identifying a difficult airway.[7] Common bedside physical airway assessment tests include interincisor gap (IIG), thyromental distance, and Mallampati test.[8] However, these measurements have high interobserver variability, and predictive accuracy is too low to identify patients with the most difficult laryngoscopy.[9-12] To increase the accuracy of preoperative evaluation, recent studies have measured anterior neck soft tissue thickness using ultrasound. Ultrasonographic measurements are rapid and convenient to perform, but ultrasonographic findings in studies of preoperative difficult airway assessment are inconsistent. This may be attributed to the operator's skill in ultrasonographic scanning, target image recognition and measurement, patient positioning during ultrasonographic scanning, and patients' ethnic differences and operation type. Ultrasonographic predictors of anterior neck soft tissue thickness are usually performed in neck maximum extension which may be dangerous for patients with cervical spondylosis. It should be emphasized that no ultrasound study was performed in such patients with cervical spine pathology. Whether these measurements are appropriate as difficult laryngoscopy predictors requires further evaluation. To verify the accuracy of ultrasonographic measurements proposed by other studies in patients with cervical spondylosis, we used magnetic resonance imaging (MRI) to quantify anterior neck soft tissue thickness, which is more accurate than ultrasonography for evaluating soft tissues.

MATERIALS AND METHODS

Study participants

Patients aged 20–70 years, mentally competent, American Society of Anesthesiologists' physical status I or II, who were scheduled for elective cervical spinal surgery under general anesthesia from April 2016 to October 2016 were recruited in this prospective cohort study. Written informed consent was obtained from all patients. We excluded patients who were pregnant, experienced cervical spinal instability, or who had an oropharyngeal mass.

Equipment and researchers

Neck MRI (MR750; GE Medical Systems, Milwaukee, WI, USA) examination was performed with the patient in the neutral position, and MRI indicators were measured on the lateral sagittal neck MRI film (Figure 1) by an experienced radiologist blinded to group allocation and not involved in intubation and anesthesia management. MRI data were evaluated using the radiography information system (Centricity RIS-IC CE V3.0; GE Healthcare, Little Chalfont, UK) of Peking University Third Hospital.

Measurements

MRI data included the shortest distance from: the skin to the hyoid bone (DSH), skin to the midpoint of the epiglottis (DSE), skin to the thyroid cartilage at the level of the vocal cords (DST), skin to the vocal cords (DSV), and skin to anterior to the trachea at the level of the suprasternal notch (DSS). All MRI indicators were measured by an experienced radiologist in batches containing all patients. The radiologist was blind to group allocation and did not participate in the anesthesia management, so bias was avoided.

Laryngoscopy

All patients received no premedication. Anesthesia was induced intravenously with sufentanil (0.3 μg/kg), propofol (2 mg/kg), and rocuronium (0.6 mg/kg).

Laryngoscopy difficulty was assessed with the Cormack–Lehane scale determined during Macintosh laryngoscopy, in all patients in the sniff position, by the same senior anesthesiologist for all patients.[13] Patients with a class III or IV view were assigned to the difficult laryngoscopy group, and those with a class I or II view were assigned to the easy laryngoscopy group. Tracheal intubation was then performed with a Macintosh laryngoscope or alternative device. In patients with a difficult airway, intubation was performed according to the Difficult Airway Society 2015 guidelines.[14]

Patient and public involvement

No patients were involved in the MRI data measures, nor were they involved in developing plans for design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. Study reports will be disseminated to investigators and patients through this open-access publication.

Statistical analysis

Estimating a 24% incidence of difficult laryngoscopy,[4] the calculated sample size was 278 patients using PASS V.11.0 (NCSS LLC, Kaysville, Utah, USA) to obtain a power of 0.9 and a significance level of 0.05. In consideration of potential dropouts, 315 patients were recruited for the study. SPSS software (version 21.0; IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Categorical variables were analyzed by the χ^2 test, and continuous variables were expressed as mean ± standard deviation with an independent-samples t-test. Binary multivariate logistic regression analyses were performed to identify multivariate predictors for difficult laryngoscopy. We calculated 95% confidence intervals (CI), and $p<0.05$ was considered statistically significant.

RESULTS

A total of 328 were initially enrolled in the study and 315 were included in the final analysis. The allocation process was presented in Figure 2. Patients comprising 200 men (63.5%) and 115 women (36.5%) were included in the study. Univariate analysis demonstrated three risk factors associated with difficult laryngoscopy: male sex ($p<0.01$), older age ($p=0.03$), and body weight ($p=0.02$). Five MRI indicators were not significantly different between the easy and difficult laryngoscopy groups, respectively: DSH (1.73 ± 0.54 cm *vs.* 1.61 ± 0.52 cm; $p=0.18$), DSE (3.76 ± 0.53 cm *vs.* 3.79 ± 0.53 cm; $p=0.72$), DST (0.66 ± 0.24 cm *vs.* 0.59 ± 0.23 cm; $p=0.10$), DSV (1.49 ± 0.41 cm *vs.* 1.43 ± 0.42 cm; $p=0.44$) and DSS (4.53 ± 0.72 cm *vs.* 4.52 ± 0.75 cm; $p=0.92$). The indicators are listed in table 1.

Table 1 Patients' demographic data and MRI indicators

Indicators	**Easy laryngoscopy group (n=261)**	**Difficult laryngoscopy group (*n*=54)**	**p-value**
Age (years)	52.8 ± 10.5	56.2 ± 8.6	0.03
Sex (male/female)	152(58%)/109(42%)	48(89%)/6(11%)	< 0.01
Height (cm)	166.0 ± 8.1	167.7 ± 6.8	0.16
Weight (kg)	69.0 ± 11.8	73.1 ± 9.6	0.02
DSH (cm)	1.73 ± 0.54	1.61 ± 0.52	0.18
DSE (cm)	3.76 ± 0.53	3.79 ± 0.53	0.72
DST (cm)	0.66 ± 0.24	0.59 ± 0.23	0.10
DSV (cm)	1.49 ± 0.41	1.43 ± 0.42	0.44
DSS (cm)	4.53 ± 0.72	4.52 ± 0.75	0.92

Values are presented as mean ± standard deviation or number (proportion).

Abbreviations: DSE, distance from skin to epiglottis; DSH, distance from skin to hyoid bone; DST, distance from skin to thyroid cartilage at the level of the vocal cords; DSS, distance from skin to anterior to the trachea at the level of the suprasternal notch; DSV, distance from skin to vocal cords; MRI, magnetic resonance imaging.

Adjusted by sex, age, and weight, binary multivariate logistic regression analyses for the MRI indicators identified no factor that was independently associated with difficult laryngoscopy: DSH (p=0.51), DSE (p=0.12), DST (p=0.26), DSV (p=0.09), and DSS (p=0.59). Odds ratios (95% CIs) for DSH, DSE, DST, DSV, and DSS were 0.79 (0.38–1.62), 0.56 (0.27–1.16), 0.38 (0.07–2.04), 0.44 (0.17–1.13), and 1.16 (68-1.96), respectively. Results appear in table 2.

Table 2 The five MRI predictors for difficult laryngoscopy identified by binary multivariate logistic regression (Enter) model

Variable	β	SE	p-value	OR	95%CI
DSH*	-0.24	0.37	0.51	0.79	0.38-1.62
DSE*	-0.59	0.38	0.12	0.56	0.27-1.16
DST*	-0.96	0.85	0.26	0.38	0.07-2.04
DSV*	-0.83	0.49	0.09	0.44	0.17-1.13
DSS*	0.15	0.27	0.59	1.16	0.68-1.96

*Adjusted by sex, age, and body weight.

Abbreviations: 95% CI, 95% confidence interval; DSE, distance from skin to epiglottis; DSH, distance from skin to hyoid bone; DSS, distance from skin to anterior to the trachea at the level of the suprasternal notch; DST, distance from skin to thyroid cartilage at the level of the vocal cords; DSV, distance from skin to vocal cords; MRI, magnetic resonance imaging; OR, odds ratio; SE, standard error.

DISCUSSION

To our knowledge, ours is the first study of anterior neck soft tissue thickness verified by MRI. Our results showed that the five most-popular ultrasonographic indicators had no significant difference for predicting easy and difficult laryngoscopy.

Our data demonstrated that male sex, higher body weight, and older age were associated with difficult laryngoscopy. A significantly greater proportion of difficult tracheal intubations has been reported in men and obese patients.[15,16] An association between difficult laryngoscopy and older age has also been reported.[17]

Osteoarthritic changes associated with decreased thyromental distance, cervical spinal movement, interincisor distance, and grade of dentition, may be responsible for age-related increases in difficult laryngoscopy.[5]

Adding ultrasonography to airway evaluation allows for rapid visualization of structures. With appropriate depth and probe-frequency selection, ultrasound can image any structure lying superficial to the oral, pharyngeal, or tracheal air columns.[18] This includes the mouth, tongue, oropharynx, hypopharynx, hyoid bone, epiglottis, larynx, vocal cords, cricothyroid membrane, cricoid cartilages, and trachea.[19] Ultrasonography, as a portable, noninvasive, rapid, and effective examination, is increasingly used for airway assessment before surgery; however, results are inconsistent.

Adhikari *et al* [20] reported that DSH could be used to distinguish difficult and easy laryngoscopies, and found that DSH values were higher in the difficult laryngoscopy group compared with the easy laryngoscopy group (1.69 cm, 95% CI: 1.19–2.19 *vs.* 1.37 cm, 95% CI: 1.27–1.46, respectively) in a study of 51 American patients in the neutral position without a pillow. However, in a study by Reddy *et al*,[21] DSH was not a significant predictor of difficult laryngoscopy (p=0.86) and our results were consistent with Reddy *et al*'s. In our study including 315 patients with cervical spondylosis in the neutral position, we found that DSH did not differ significantly between easy and difficult laryngoscopy groups (1.73 ± 0.54 cm *vs.* 1.61 ± 0.52 cm, respectively; p=0.18).

Pinto *et al* [22] studied 74 Portuguese patients in the neutral position and found that DSE can be used effectively to predict difficult laryngoscopy; DSE was greater in the difficult laryngoscopy group compared with the easy laryngoscopy group (2.83 ± 0.44 cm *vs.* 2.33 ± 0.39 cm, respectively; p<0.01). Soltani *et al* [23] studied 53 Iranian patients in the supine position with active maximal head-tilt and chin-lift and found that the correlation between the depth of the pre-epiglottic space and Cormack–Lehane grade III was weak, with a regression coefficient of 0.13 (95% CI: 0.70–1.71; p=0. 40). In our study, DSE did not differ significantly between easy and difficult laryngoscopy groups (3.76 ± 0.53 cm *vs.* 3.79 ± 0.53 cm, respectively; p=0.72).

Komatsu *et al* [24] studied 64 obese American patients in the neutral position without a pillow and found that DST in the difficult laryngoscopy group was shorter than that in the easy laryngoscopy group (2.0 ± 0.3 cm *vs.* 2.2 ± 0.4 cm, respectively; p<0.05), but multivariate regression indicated that DST was not an independent predictor of difficult laryngoscopy (p=0.13). Therefore, the authors concluded that DST was not a good predictor and that it failed to predict difficult laryngoscopy in obese patients. In our study, we found that DST did not differ significantly between easy and difficult laryngoscopy groups (0.66 ± 0.24 cm *vs.* 0.59 ± 0.23 cm, respectively; p=0.10).

Ezri *et al* [15] studied 50 obese Israeli patients and found that DSV and DSS in the difficult laryngoscopy group were both greater than values in the easy laryngoscopy group (2.8 ± 0.3 cm *vs.* 1.8 ± 0.2 cm, respectively; p<0.01 and 3.3 ± 0.4 cm *vs.* 2.7 ± 0.7 cm, respectively; p=0.01). Reddy *et al* [21] also found that DSV in the difficult laryngoscopy group was greater than that in the easy laryngoscopy group (0.35 ± 0.18 cm *vs.* 0.25 ± 0.11 cm, respectively; p=0.01) and that DSV >0.23 cm was a potential predictor of difficult intubation with 85.7% sensitivity, 57% specificity, and 61% accuracy. However, Adhikari *et al* [20] found no significant differences for DSV and DSS between easy and difficult laryngoscopy groups. We also found that DSV and DSS did not differ significantly between easy and difficult laryngoscopy groups (1.49 ± 0.41 cm *vs.* 1.43 ± 0.42 cm, respectively; p=0.44 and 4.53 ± 0.72 cm *vs.* 4.52 ± 0.75 cm, respectively; p=0.92).

Ultrasonography is convenient and useful for bedside examination, and five indicators of anterior neck soft tissue thickness at different levels measured using ultrasonography have been discussed previously. The results of the five ultrasonographic predictors are inconsistent. Considering that MRI has higher resolution than ultrasound, to obtain better soft tissue images with lower radiation hazard, we chose MRI to measure the related soft tissues. We found that none of the five indices could predict difficult laryngoscopy in patients with cervical spondylosis regardless of whether sex, age, and body weight were adjusted with a binary multivariate logistic regression. The reasons for different results between our study and previous studies are as follows: (1) the five MRI indicators focused only on the local anatomy and could not reflect cervical activity and changes in head position (from neutral to extended). Therefore, these may not be meaningful indicators; however, no defined gold standard indicators exist. (2) These indices have been measured previously using ultrasonography, but measurements were not taken using standardized procedures, which have not been determined. Ultrasonographic measurements obtained by the primary investigator might have been associated with bias, and the measurement results were related to the operator's experience. The lack of a standardized reference and methods for obtaining these ultrasonographic measurements in previous studies also indicates the potential for operator error. Patients' necks were also positioned differently across studies, which could result in measurement error. (3) Patients' ethnicity and operation type might also affect results. Our study participants were Asian, and previous studies included American, Portuguese, or Iranian patients; studies have documented differences in neck fat tissue distribution between different ethnic groups. [20] (4) Our patients had cervical spondylosis, and the presence of this condition was not mentioned for patients in previous studies. (5) Considering superficial measurements reflecting anatomical variation in an extremely anterior airway and the small sample size in previous studies, results might be skewed.

Limitations of the study

Our study has limitations. First, measurements in some previous studies were taken in the head-extended position to facilitate ultrasonographic examination. In our study, during MRI examination, all measurements were taken with patients in the neutral position, and no measurements were taken in the intubation position. Although we positioned all patients in the same position, there is a difference between the MRI examination position and the intubation position, and a deficiency of MRI is that it is not a dynamic measurement method. Second, this study did not have the same design as previous ultrasound studies. We did not perform ultrasonography and MRI simultaneously in the same patients; we used MRI to verify whether the ultrasonographic parameters of anterior neck soft tissue thickness suitable for patients with cervical spondylosis. In this patient cohort, ultrasonography derived measurements reflecting cervical mobility (such as hyo-mental distance ratio) might be more valuable compared to anterior neck soft tissue thickness. Third, although MRI costs more than ultrasound and time required, MRI is a routine preoperative examination in patients undergoing surgery for cervical spondylosis; therefore, we verified the five most-popular ultrasonographic indicators in these specific patients to best use data to predict a difficult airway without additional expense. However, our results might not be suitable for other patients, and further research is needed.

CONCLUSION

Our study suggests that the ultrasonographic indices (DSH, DSE, DST, DSV, and DSS) used to evaluate anterior neck soft tissue thickness at different levels, measured by MRI, could not predict difficult laryngoscopy in patients with cervical spondylosis. In future studies of ultrasonographic assessment, patients' ethnicity, position, operators' qualifications, and standardized operation procedures all must be considered. Based on high-quality and large-sample-size studies, the most accurate ultrasonographic indicator for difficult laryngoscopy may be determined.

Contributors Yongzheng Han and Mao Xu designed and coordinated the study, collected and interpreted data, and drafted the manuscript. Xiangyang Guo participated in the study design. Jingchao Fang participated in measuring radiological indicators. Hua Zhang analyzed the data and performed statistical analysis. All authors discussed the results, and read and approved the final manuscript.

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Disclaimer The funders were not involved in the study design, data analysis or manuscript preparation.

Competing interests None declared.

Patient consent Obtained.

Ethics approval The study was approved by Peking University Third Hospital Medical Science Research Ethics Committee (IRB00006761-2015021).

Provenance and peer review Not commissioned; externally peer reviewed.

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Data sharing statement A full anonymised dataset is available from the corresponding author on request.

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Figure legends

Figure 1 Indicators on lateral sagittal neck MRI image.

DSE: distance from skin to epiglottis; DSH: distance from skin to hyoid bone; DSS: distance from the skin to anterior to the trachea at the level of suprasternal notch; DST: distance from skin to thyroid cartilage at the level of the vocal cords; DSV: distance from skin to vocal cords.

Figure 2 Allocation process. MRI, magnetic resonance imaging.

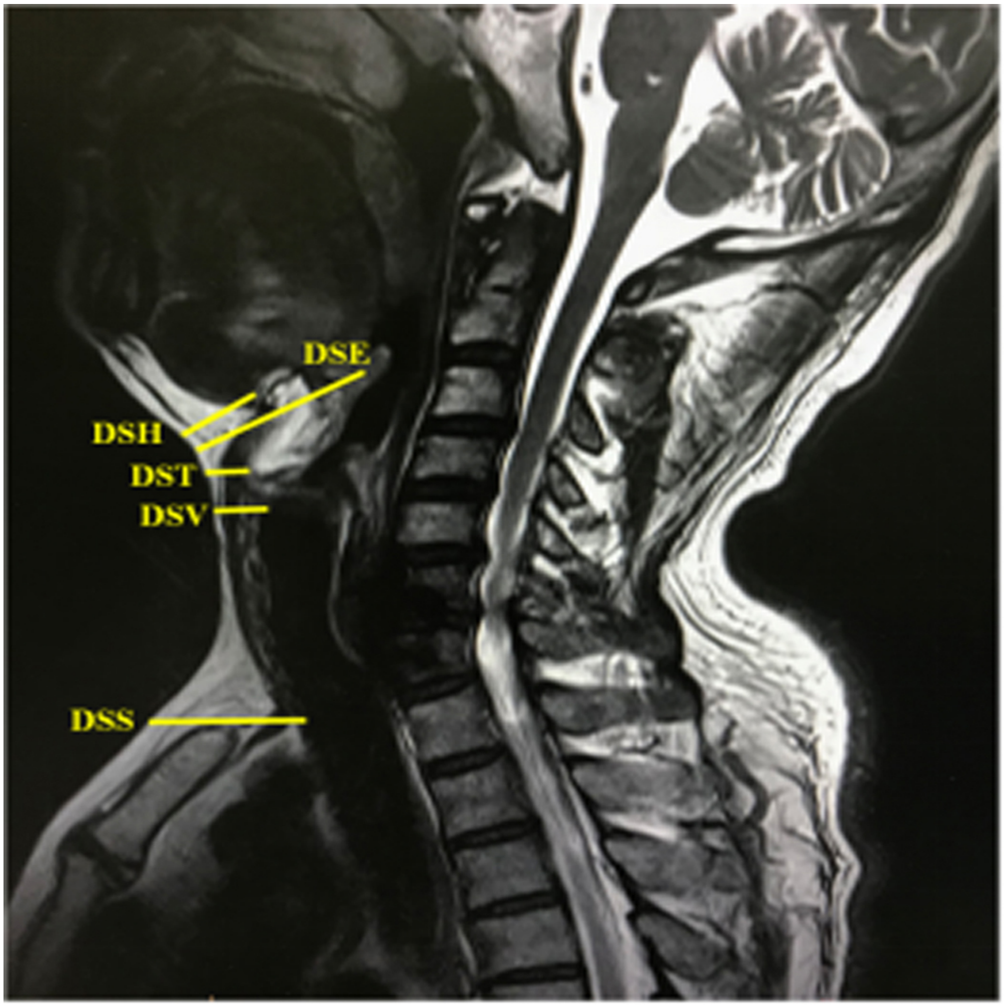

Figure 1 Indicators on lateral sagittal neck MRI image.

90x90mm (300 x 300 DPI)

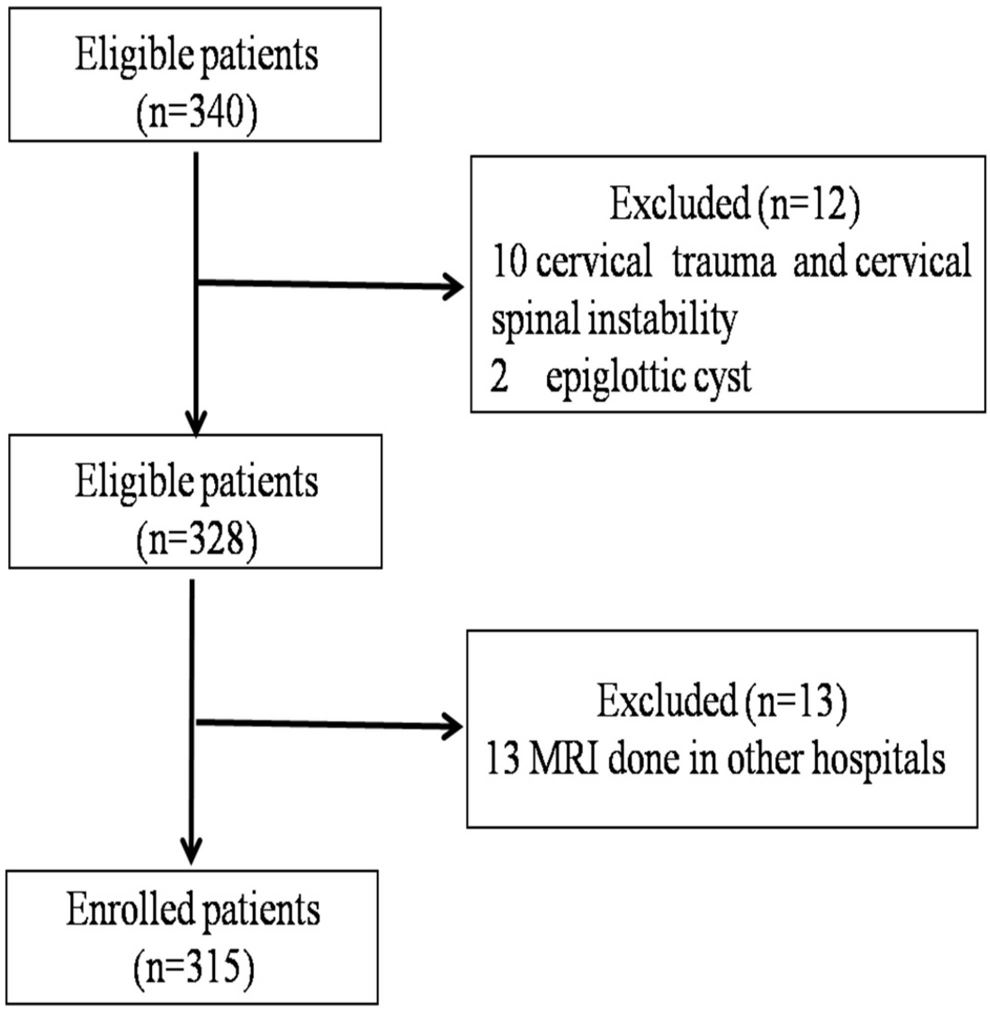

Figure 2 Allocation process.

90x90mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			**4**
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			**5-6**
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not Applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5,6
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	6
		(*e*) Describe any sensitivity analyses	6
Results			6-8

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6,7
		(b) Indicate number of participants with missing data for each variable of interest	Not Applicable
		(c) Summarise follow-up time (eg, average and total amount)	Not Applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7,8
		(*b*) Report category boundaries when continuous variables were categorized	Not Applicable
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not Applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not Applicable
Discussion			8-11
Key results	18	Summarise key results with reference to study objectives	9-11
Limitations			11,12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			12,13
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.