Original Article

Ultrasound measurement of anterior neck soft tissue and tongue thickness to predict difficult laryngoscopy - An observational analytical study

Address for correspondence:
Dr. Priya Rudingwa,
Department of Anaesthesia and Critical Care,
Institute Block, Jawaharlal Institute of Postgraduate Medicine and Research,
Puducherry - 605 006, India.
E-mail: priyaab8@gmail.com

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Nabin K Yadav, Priya Rudingwa, Sandeep Kumar Mishra, Sakthirajan Pannerselvam

Department of Anaesthesia and Critical Care, Institute Block, Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry, India

ABSTRACT

Background and Aims: Airway ultrasound is an emerging tool to predict difficult laryngoscopy. This study aimed to determine the utility of ultrasound measurement of the anterior soft tissue neck thickness at the level of hyoid, thyrohyoid membrane and thickness of tongue to predict difficult laryngoscopy and compare them with clinical parameters for airway assessment. **Methods:** The distance from skin to hyoid bone, skin to the thyrohyoid membrane in neutral and sniffing position and maximum tongue thickness was measured by ultrasound and correlated with Cormack Lehane (CL) laryngoscope view in 310 adult surgical patients. Receiver operating characteristic curve was plotted and the area under the curve was calculated for each parameter. The sensitivity and specificity of ultrasound-guided parameters were compared with clinical parameters like the inter-incisor gap, modified Mallampatti classification, thyromental, sternomental distance and neck circumference. **Results:** Incidence of difficult laryngoscopy (CL grade-III and IV) was 11.3%. A significant difference was observed in the ultrasound parameters between the easy and difficult laryngoscopy (*P*-value = 0.001). Sensitivity and specificity to predict difficult airway was 69.6% and 77% for tongue thickness, 68% and 73% for the skin to hyoid bone distance in a neutral position and found to be higher than clinical parameters. **Conclusion:** The ultrasound measurements of soft tissue thickness of the anterior neck and tongue thickness along with the clinical assessment of airway can be useful in predicting difficult laryngoscopy.

Key words: Airway ultrasound, difficult laryngoscopy, neck soft tissue thickness, tongue thickness

INTRODUCTION

Airway assessment is an essential aspect of preanaesthetic assessment. Presently, prediction of difficult airway is based on clinvical assessment of airway. A combination of airway assessment tests such as modified Mallampati classification, inter-incisor gap, sternomental distance, thyromental distance and neck mobility are often used to overcome their limited sensitivity to assess difficult laryngoscopy.[1] Even after using multiple clinical screening tests, a significant incidence of unanticipated difficult laryngoscopy (1%–8%) has been observed.[2] Again the clinical assessment tools play a limited role in unconscious and uncooperative individuals.[3] Presently, there is a search for noninvasive and more accurate tools for airway assessment to overcome the above limitations of clinical airway assessment tests.

Portable, non-invasive and point of care characteristics of ultrasonography can aid in airway assessment and prediction of difficult laryngoscopy.[4,5] Various

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ultrasound derived measurements of airway have been used to predict difficult laryngoscopy.

In this clinical trial, we aimed to study the sensitivity and specificity of ultrasound measurement of soft tissue thickness of anterior neck at the hyoid, thyrohyoid level and tongue thickness and compared them with conventional clinical screening tests to predict difficult laryngoscopy.

METHODS

After obtaining institute ethics committee approval [(JIP/IEC/SC/2016/30/954) dated 17.08.2016], this prospective single arm observational trial was registered in the Clinical trial registry of India (CTRI/2017/05/008541). The study was carried out in adherence to the principles of the Declaration of Helsinki in a tertiary care centre in southern part of India over a period of 2 years. In total, 310 adult surgical patients in the age group of 18–70 years, scheduled for various surgical procedures under general anaesthesia and belonging to American Society of Anesthesiologists (ASA) physical status I and II and were included in the study. Patients with facial fractures, cervical spine instability, those needing rapid sequence induction and patients with poor submandibular space compliance were excluded from the study. Patients were instructed about the study procedure and written informed consent was obtained.

In the pre-operative assessment, parameters recorded were inter-incisor gap which is the distance between the upper and lower incisors in cm, modified Mallampati classification (MMP) [Class I is visualisation of the hard palate, soft palate, fauces, uvula and pillars; Class II is visualisation of the hard palate, soft palate, fauces, and uvula; Class III is visualisation of the hard palate, soft palate and base of uvula and Class IV is visualisation of only the hard palate].[6] The thyromental distance is the distance from mental prominence to thyroid cartilage with neck fully extended, sternomental distance is the distance from suprasternal notch to mental prominence with neck fully extended and neck circumference was measured at the level of the thyroid cartilage. All measurements were recorded using a measuring scale in cm by the primary investigator who was not involved in the performance of laryngoscopy.

On the day of surgery, after positioning the patient supine with head and neck in neutral position, the distance from skin to hyoid bone (SHB) was measured by placing the linear high-frequency (16–5 MHz) ultrasound probe (Sonosite S-ICU^{R}, Bothell, WA, USA) transversely over the hyoid bone. Similarly, distance from skin to the thyrohyoid membrane (STM) was measured midway between hyoid and thyroid cartilage at the level of the epiglottis. The hyoid bone was identified as a curved echogenic structure with posterior acoustic shadow and epiglottis was identified as a curvilinear hypoechoic structure with a bright posterior air mucosal interface and hyperechoic pre-epiglottic space. Both the measurements were taken at the midline and 1 cm lateral to the midline on both sides and the average value was noted. The tongue thickness was measured by recording the geniohyoid muscle thickness using a curvilinear probe (5–2 MHz) in the midline sagittal plane [Figure 1]. Similar procedures were repeated in the sniffing position to look for any difference with change in position. All the measurements were recorded by a single anaesthesiologist trained in airway ultrasound and was blinded to laryngoscopy view.

On the day of surgery, patients were positioned in sniffing position using a standard intubating pillow. After the induction of general anaesthesia, an experienced anaesthesiologist, who was blinded to the ultrasound measurements, performed direct

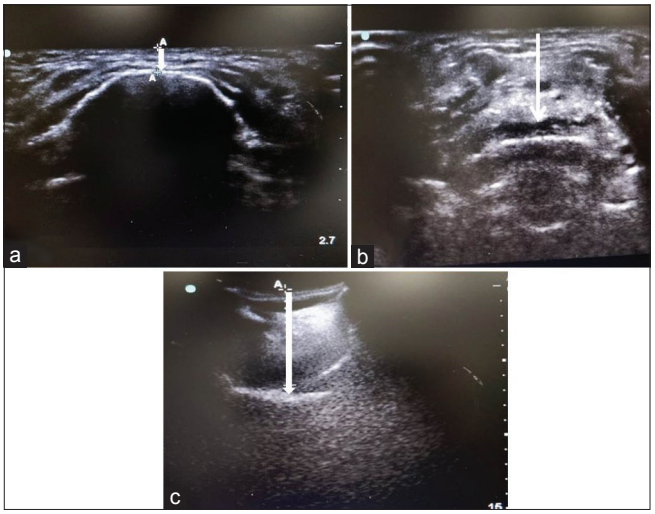

Figure 1: Ultrasound measurements of anterior neck soft tissue and tongue thickness. (a) Distance from the skin to hyoid bone. Anterior surface of hyoid bone appears hyperechoic and casts a hypoechoic shadow. (b) The epiglottis is visible through the thyrohyoid membrane as a curvilinear hypoechoic structure, and its anterior surface by hyperechoic pre-epiglottic space. Distance from the skin to the thyrohyoid membrane was measured until the anterior border of epiglottis. (c) Tongue thickness – the maximum vertical distance from the tongue surface to submental skin

laryngoscopy. The Cormack Lehane (CL) grade of larynx observed without application of any external laryngeal manipulation was recorded, (Grade I: full view of the glottis, grade II: a partial view of the glottis or arytenoids, grade III: only epiglottis visible and grade IV: with neither glottis nor epiglottis seen).[7] A CL grade I or II was considered as easy and grade III or IV as difficult laryngoscopy. The decision to use any intubation aids was made as per the attending anaesthesiologist's choice. Further anaesthetic management was continued as per the decision of the attending anaesthesiologist.

The sample size was calculated with Open Epi software version 3.01, assuming 5% significance and power of 80%; using the difference between the two means. Based on the pilot study done by Adhikari *et al*. standard deviation for the distance from skin to hyoid bone in difficult and easy laryngoscopy group was calculated using the formula below.[8]

$$SD = \frac{\sqrt{n \times (CI\ upper - CI\ lower)}}{3.96}$$

The total sample size required was 310 patients with 279 patients in easy and 31 patients in difficult laryngoscopy group with an expected proportion of difficult to easy laryngoscopy to be 1:9.[8] All statistical analysis was conducted using statistical software (SPSS version 19.0 Chicago, IL, USA). Continuous data such as age, thyromental distance, sternomental distance, distance from skin to thyrohyoid membrane, neck circumference and distance from skin to hyoid bone and tongue thickness were expressed as mean with standard deviation [SD] or median with interquartile range based on the distribution of data. Categorical data, such as gender and modified Mallampati score, are expressed as numbers of occurrences (frequency and percentage). Comparison analysis was performed using an independent Student's *t*-test or Mann–Whitney U-test for continuous data. Categorical variables were compared using the Chi-square test. Receiver operating characteristic (ROC) curve was plotted and area under the curve (AUC) was calculated for each parameter.

RESULTS

This study was done in 310 adult ASA I and II patients who underwent elective surgeries under general anaesthesia [Figure 2]. The incidence of easy laryngoscopy was 88.7% and difficult laryngoscopy was 11.3%. Demographic details such as age and gender were comparable in the easy and difficult laryngoscopy group. All ultrasound measurements of anterior soft tissue neck (SHB in neutral and sniffing position, STM in neutral and sniffing position) were found to be significantly higher in difficult laryngoscopy group with *P* value of 0.0001 [Table 1]. Among the clinical airway assessment parameters, neck circumference and MMP class were found to be statistically significant between the two groups.

Tongue thickness measured using ultrasound was not normally distributed and was expressed as a median and inter-quartile range. Mann–Whitney *U*-test was

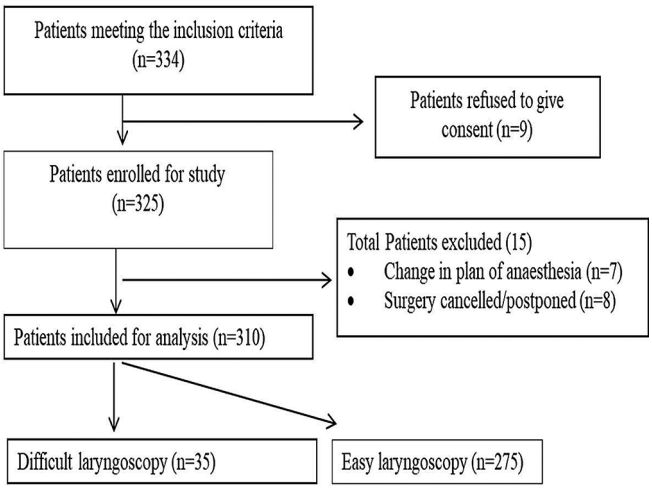

Figure 2: Study flow chart and patient outcome

Table 1: Descriptive data of clinical assessments and ultrasound parameters

Parameters	Easy laryngoscopy *n*=275 (mean±SD)	Difficult laryngoscopy *n*=35 (mean±SD)	*P*
MMP I	109 (35.1%)	9 (2.9%)	0.0001
II	98 (31.6%)	10 (3.2%)	
III	68 (21.9%)	16 (5.1%)	
Inter-incisor distance	5.38±0.57	5.56±0.56	0.73
Thyromental distance	8.06±1.09	7.86±1.10	0.30
Sternomental distance	17.75±1.52	17.29±1.34	0.085
Neck circumference	34.54±3.70	37.84±4.31	0.0001
SHB in neutral	0.56±0.19	0.74±0.23	0.0001
SHB in sniffing	0.53±0.20	0.73±0.23	0.0001
STM in neutral	1.58±0.34	1.93±0.42	0.0001
STM in sniffing	1.54±0.35	1.84±0.39	0.0001
	Median [IQR]	Median [IQR]	
Tongue thickness	5.30 [1.02]	6.1 [01.04]	0.0001

**P*-value of<0.05 is considered significant; IQR – Interquartile range, Cormack-Lehane grades of 1&2 were defined as easy laryngoscopy and grades 3&4 were defined as difficult laryngoscopy.[11,15] MMP – Modified Mallampati, SHB – Skin to hyoid bone distance (cm), STM – Skin to thyrohyoid membrane distance (cm)

used as a test of significance, which was found to be significant with *P* value of 0.0001.

ROC curve was plotted for all the clinical assessment tests and ultrasound measurements of anterior soft tissue neck and tongue thickness [Figure 3]. The cut off values obtained from the ROC curve for SHB in neutral and sniffing, STM in neutral and sniffing were 0.66 and 0.77, 2.03 and 1.9 cm respectively. The AUC was calculated to assess the validity of tests [Table 2]. The ultrasound measurements had greater AUC than the bedside clinical assessment tests, thus showing greater validity to predict difficult laryngoscopy. Sensitivity and specificity for all bedside clinical tests were found to be lesser than that of ultrasound-based parameters [Table 3].

DISCUSSION

We studied anterior neck soft tissue thickness by measuring the distance from skin to hyoid bone, skin to the thyrohyoid membrane in neutral and sniffing position and tongue thickness using ultrasound to predict difficult laryngoscopy. The mean value of skin to hyoid bone distance and skin to thyrohyoid membrane distance in a neutral and sniffing position were significantly different in the easy and difficult laryngoscopy groups. We found that the area under the ROC curve to determine difficult laryngoscopy was greater for the ultrasound measurements than the clinical airway assessment tools. Among the latter, MMP had the highest AUC but was less than the skin to hyoid distance in sniffing position and tongue thickness suggesting that these tests were better in predicting difficult laryngoscopy when compared with the clinical screening tests. The sensitivity and specificity of the ultrasound measurements were higher than those of bedside clinical test to detect difficult laryngoscopy.

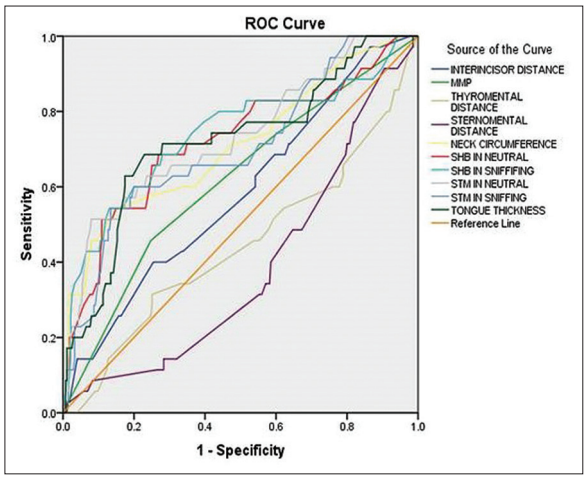

Figure 3: Receiver operating characteristic curve for all bedside tests and ultrasound measurements. Difficult laryngoscopy was taken as Cormack-Lehane grades more than II. The orange line was taken as a reference line and various values of area under the curve are given in Table 2

Previous studies on airway ultrasound have evaluated parameters such as tongue thickness, volume of tongue, skin to hyoid bone distance in supine and in neck extended position and ratio of these two distances, skin to thyrohyoid membrane distance, distance from the epiglottis to the midpoint of vocal cord (E-VC), depth of the pre-epiglottic space and ratio of these distances for predicting difficult laryngoscopy.[8-13]

We have studied the thickness of tongue, STH and STHM distance as they can be easily recorded at the bedside, do not involve complex calculations and have been found to predict difficult laryngoscopy in a previous pilot study.[8] The tissue at hyoid level needs to be lifted by the tip of the laryngoscope blade and higher CL grade is expected with increasing tissue

Table 2: Area under the curve for all bedside clinical tests and ultrasound measurements

Parameters	Area under the curve (95% CI)
Inter-incisor distance	0.58 (0.48-0.68)
MMP	0.61 (0.51-0.71)
Thyromental distance	0.44 (0.33-0.55)
Sternomental distance	0.38 (0.28-0.47)
Neck circumference	0.71 (0.61-0.81)
SHB in neutral	0.72 (0.61-0.82)
SHB in sniffing	0.73 (0.63-0.84)
STM in neutral	0.73 (0.63-0.83)
STM in sniffing	0.70 (0.60-0.80)
Tongue thickness	0.72 (0.62-0.81)

SHB – Skin to hyoid bone distance in cm, STM – Skin to the thyrohyoid membrane in cm, CI – Confidence interval

Table 3: Sensitivity and specificity of all clinical tests and ultrasound parameters to predict difficult laryngoscopy

Parameters	Sensitivity	Specificity
Inter-incisor distance	0.62	0.45
MMP	0.45	0.75
Thyromental distance	0.45	0.46
Sternomental distance	0.40	0.41
Neck circumference	0.60	0.62
SHB in neutral	0.68	0.69
SHB in sniffing	0.68	0.72
STM in neutral	0.65	0.69
STM in sniffing	0.65	0.63
Tongue thickness	0.71	0.72

SHB – Skin to hyoid bone distance in cm, STM – Skin to the thyrohyoid membrane in cm

thickness. The simplicity of the test and better results when compared to clinical screening tests allow it to be used in day-to-day setup.

Adhikari *et al*. in a pilot study found that thickness of anterior neck soft tissue at hyoid bone and thyrohyoid membrane was greater in patients with difficult laryngoscopy.[8] Similarly, Wu et at studied 203 patients and found that ultrasound measurement at the level of hyoid bone, thyrohyoid membrane and anterior commissure can independently predict difficult laryngoscopy. These parameters had a greater area under the ROC curve when compared with conventional screening tests.[11] But our values were found to be lesser than that observed by previous studies which could be due to the population involved in this study.[13] We had enrolled the patients from the southern part of India, whereas in the other two studies African American population and Chinese Han population was involved. In our study, the thickness of tongue was significantly higher in the difficult laryngoscopy group which was similar to the results of Yao *et al*.[9] Komatsu *et al*. found that the thickness of anterior neck soft tissue measured by ultrasound did not predict difficult laryngoscopy in obese patients indicating that the results of our study may not be applicable to the obese population.[14]

It is a well-known fact that the various clinical tests to predict difficult intubation are not reliable due to their poor sensitivity and specificity.[1] The sonographic measurements fared better in terms of sensitivity and specificity and AUC to detect difficult laryngoscopy which was similar to previous studies. Parameswari *et al*. measured skin to epiglottis distance in 130 patients and found that it had a higher sensitivity of 75% when compared with 66.7% sensitivity of MMP classification.[15] Similarly, Wu *et al*. observed that skin to hyoid bone distance has a sensitivity and specificity of 85.7% and 85.1%, respectively, which was greater than that of MMP and other airway predictors.[11] Unfortunately, none of the ultrasound measurements of anterior neck thickness parameters have a very high sensitivity or specificity to be used as a standalone test for detecting difficult laryngoscopy which is in concordance with previous studies.[11,15] There are few limitations in the study: first, the ultrasound derived parameters were of the population belonging to the southern part of India, and thus, the results cannot be generalised to other population groups. Second, the experience of person performing laryngoscopy may also influence the CL view obtained and alter the grading of laryngoscopy. Third, as the ultrasound measurements of anterior soft tissue neck are measured in mm, the amount of pressure applied by the ultrasound probe on the neck can cause a difference in values and may alter the results, so gentle application of the probe is warranted. The study did not include obese patients and pregnant patients where the risk of difficult laryngoscopy is greater and further studies need to be done in this population.

CONCLUSION

Thus, we can conclude that ultrasound measurements of soft tissue thickness of anterior neck at hyoid and thyrohyoid level and tongue thickness have greater sensitivity and specificity than conventional airway tests and can be used in combination with other bedside clinical tests, for better prediction of difficult laryngoscopy.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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