Original Article

Ultrasound-based assessment of tongue thickness for prediction of difficult laryngoscopy and intubation

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Abstract

Background and Aims: Predicting difficult airway and preparedness for the same can help prevent catastrophic situations while handling the airway. With the increasing familiarity of anaesthesiologists to the use of ultrasound machine and its easy availability and non-invasiveness, we sought to study its utility in airway assessment, by measuring the thickness of tongue, to predict difficult laryngoscopy and intubation.
Material and Methods: A total of 85 patients undergoing elective surgeries under general anaesthesia with endotracheal intubation were examined preoperatively. Tongue thickness was measured using submental ultrasonography in the median sagittal plane along with other tests of airway assessment. Cormack Lehane grade on laryngoscopy and Intubation Difficulty Scale Score was recorded. The sensitivity, specificity, positive and negative predictive value, and accuracy was calculated for tongue thickness for predicting difficult intubation.
Results: The tongue thickness in those with difficult intubation (4.83 ± 0.62) was significantly higher than those without difficult intubation (4.38 ± 0.65). The ratio of tongue thickness to thyromental distance was also significantly higher in difficult intubation group. The area under the receiver operating characteristic curve for predicting difficult laryngoscopy and intubation was higher for tongue thickness as compared to other clinical parameters. The sensitivity and specificity of tongue thickness to predict difficult laryngoscopy was 100% and 83%, respectively, and to predict difficult intubation was 72% and 59%, respectively, with an accuracy of 72%.
Conclusion: Ultrasound based assessment of tongue thickness can be a useful predictor of difficult airway along with clinical assessment of the airway.

Keywords: Airway assessment, difficult intubation, tongue thickness, ultrasonography

Introduction

Prediction of difficult airway is an important aspect of preanesthetic evaluation. Inability to anticipate difficult intubation can have dreaded consequences. This leads to an endless search for a screening test that has good sensitivity and specificity to predict difficult airway, is reliable and reproducible, and easy to use. The ability to predict a difficult tracheal intubation permits anesthesiologists to take necessary steps and precautions to decrease the risk. However, the tests of airway assessment we presently employ clinically do not precisely predict which patients will be difficult to intubate. There is no single test with good sensitivity and specificity to predict difficult intubation.

Anesthesiologists are becoming increasingly familiar with the use of ultrasound machine. Its widespread applications in anesthesiology have almost established it as a point-of-care tool.[1] It is readily available in most modern operating theaters,

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and it is now being evaluated for its utility in predicting difficult airway. Airway assessment using ultrasonography is a bedside, inexpensive, noninvasive, radiation-free, and convenient method to visualize and measure various airway parameters. Ultrasound imaging essentially relies upon assessment of the soft tissues surrounding the airways in terms of their dimensions and mobility for prediction of difficult airway.

It is known that increased tongue thickness (TT) can affect the performance of laryngoscopy and tracheal intubation. Lateral cephalograms, computerized tomography (CT), and magnetic resonance imaging (MRI) have been used for measurements of tongue dimensions.[2,3] However, these are time-consuming, expensive, and associated with radiation. Hence, they do not make a good option for routine airway assessment.

The modified Mallampati test, a bedside clinical test, reflects tongue volume to some extent. However, its limited predictive power and requirement that patients perform mandatory actions in sitting position decrease its application value for predicting difficult airway, especially in unconscious, uncooperative patients and children.

For the above reasons, this observational study was undertaken to assess the usefulness of TT measured using ultrasonography for prediction of difficult laryngoscopy and difficult intubation.

Material and Methods

Approval from the institutional ethics committee (IEC(II)/OUT/2089/18; 20/11/2018) was obtained. The study was carried out in adherence to the principles of the Declaration of Helsinki in a tertiary care center over a period of 2 years. After obtaining written informed consent from the study subjects, 85 adult patients belonging to American Society of Anesthesiologists (ASA) physical status grade I/II/III undergoing elective surgery under general anesthesia with endotracheal intubation were recruited for this study. Patients with obvious upper airway deformity/trauma/tumor, cervical spine instability, history of difficult airway, and those refusing to participate were excluded from the study.

Routine preanesthetic check-up including history and examination and assessment of airway parameters like modified Mallampati classification (MPC) grade, interincisor distance (IID), thyromental distance (TMD), ratio of height to TMD (RHTMD), and neck circumference (NC) at the level of tracheal cartilage was done.

Samsoon and Young's modification of the Mallampati test was used to record oropharyngeal structures visible upon maximal mouth opening.[4] An ultrasonography was performed by the principal investigator to assess TT. Patients were asked to lie down supine. Extension at atlanto-occipital joint and flexion at neck (sniffing position) was obtained by using a head ring. Patients were asked to keep their mouths closed with tongue relaxed and tip slightly touching the incisors (resting anatomical position of the tongue). The curvilinear probe was placed under the chin in the mid-sagittal plane vertically [Figure 1], and TT was measured in centimeters.

TT (in cm) was defined as the maximum vertical distance from mylohyoid raphe to the surface of tongue. The soft tissue above the mylohyoid raphe was not included in the measurement to avoid variations in measurements due to the pressure applied on the neck while scanning [Figure 2].

In the operating room, patients were positioned with a ring under the head, and the neck was extended. Electrocardiogram, blood pressure, and saturation on pulse oximeter were continuously monitored. After adequate preoxygenation for 3 min and induction of general anesthesia, direct laryngoscopy was done using a Macintosh laryngoscope blade by an experienced anesthesiologist, and the laryngoscopic view was evaluated without any external laryngeal manipulation. The anesthesiologist performing laryngoscopy was unaware of the ultrasound measurements. The laryngoscopic view was graded according to Cormack and Lehane's (CL) scale.[5] This was the final grade taken into consideration for the study. However, to proceed for intubation, if the laryngoscopic view was not adequate, external laryngeal pressure (backward, upward, and rightward pressure [BURP]) was applied with adjustment of head and neck position, or another technique or airway adjunct was used according to the laryngoscopist's discretion. The primary study end point was difficult intubation, which was graded using the intubation difficulty scale (IDS) as shown in Figure 3.[6] The secondary study end point was difficult

Figure 1: Placement of curvilinear ultrasound probe for measurement of tongue thickness

laryngoscopy. The study ended with confirmation of successful intubation by auscultation and capnography.

In a recent study by Yao and Wang,[7] it was observed that the sensitivity and specificity of TT in predicting difficult airway intubation were 0.75 and 0.72, respectively.

Considering the sensitivity of 0.75 and specificity of 0.72, the sample size was calculated using sensitivity = 72.03 = 72 (rounded off) and using specificity = 77.44 = 78 (rounded off).

Selecting the larger sample size of 78 that would satisfy the requirements for both sensitivity and specificity and considering a 10% dropout rate, a minimum of 85 patients were required for the study.

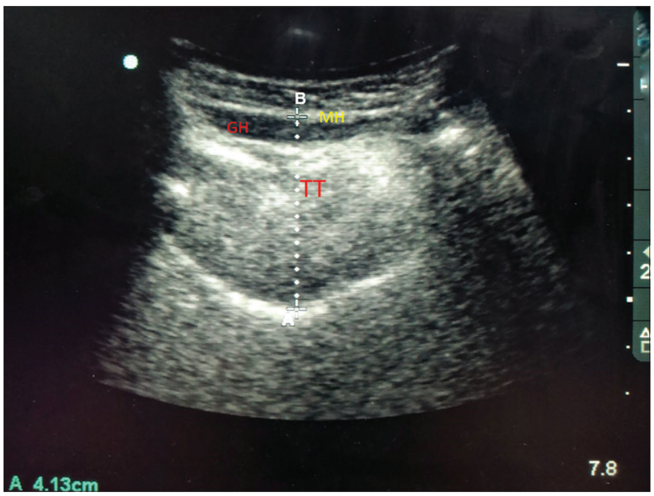


Figure 2: Measurement of TT using ultrasonography. GH = geniohyoid, MH = mylohyoid, TT = tongue thickness (dotted line from a to b)

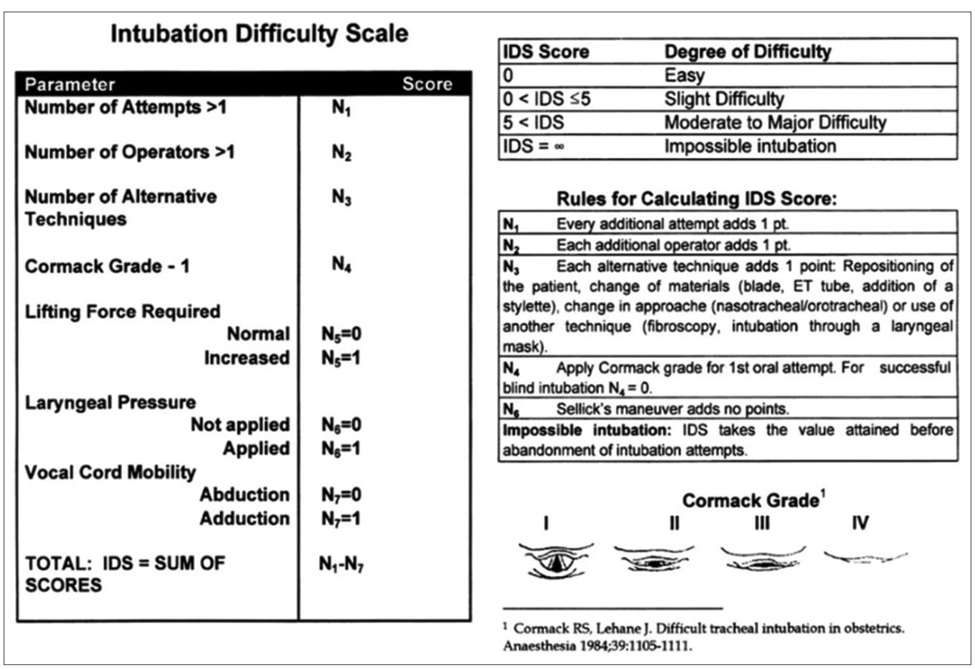
All statistical analyses were conducted using statistical software (SPSS version 25.0; IBM SPSS Inc., Chicago, IL, USA). Continuous data such as age, body mass index (BMI), IID, NC, TMD, TT, RHTMD, and ratio of TT to TMD (RTTMD) were expressed as median with interquartile range based on the distribution of data. Categorical data such as gender and MPC, Cormack Lehane grade, and IDS scores were expressed as the number of occurrences (frequency and percentage).

Continuous data such as age, sex, BMI, IID, NC, TMD, TT, RHTMD, and RTTMD were compared between easy and difficult intubation groups using an independent Student's *t*-test or Mann–Whitney U test. Chi-square test was used to compare categorical variables like gender and MPC grade. Receiver operating characteristic (ROC) curve was plotted and area under the curve (AUC) calculated for all parameters for predicting difficult laryngoscopy and difficult intubation.

Sensitivity, specificity, and positive and negative predictive values were also calculated from 2 × 2 table considering the cut-off values obtained from the ROC curve.

Results

A total of 85 patients were included in the study analysis [Figure 4]. The incidence of difficult laryngoscopy



Intubation Difficulty Scale

Parameter	Score
Number of Attempts >1	N_1
Number of Operators >1	N_2
Number of Alternative Techniques	N_3
Cormack Grade - 1	N_4
Lifting Force Required	
Normal	$N_5=0$
Increased	$N_5=1$
Laryngeal Pressure	
Not applied	$N_6=0$
Applied	$N_6=1$
Vocal Cord Mobility	
Abduction	$N_7=0$
Adduction	$N_7=1$
TOTAL: IDS = SUM OF SCORES	N_1-N_7

IDS Score	Degree of Difficulty
0	Easy
0 < IDS ≤5	Slight Difficulty
5 < IDS	Moderate to Major Difficulty
IDS = ∞	Impossible intubation

Rules for Calculating IDS Score:

N_1	Every additional attempt adds 1 pt.
N_2	Each additional operator adds 1 pt.
N_3	Each alternative technique adds 1 point: Repositioning of the patient, change of materials (blade, ET tube, addition of a stylette), change in approache (nasotracheal/orotracheal) or use of another technique (fibroscopy, intubation through a laryngeal mask).
N_4	Apply Cormack grade for 1st oral attempt. For successful blind intubation N_4 = 0.
N_6	Sellick's maneuver adds no points.
Impossible intubation:	IDS takes the value attained before abandonment of intubation attempts.

[1] Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. Anaesthesia 1984;39:1105-1111.

Figure 3: Intubation difficulty scale and Cormack Lehane grading[6]

was 2.4%. Fifty-six patients (65.9%) had an IDS score of zero and 29 patients (34.1%) had an IDS score between 1 and 5, indicating slight difficulty in intubation. Age and gender were comparable in both groups. BMI was significantly higher in those with slightly difficult intubation. TT and RTTMD were significantly higher in the difficult intubation group.[Table 1] Among the clinical parameters, only NC was significantly higher in the difficult intubation group.

The AUC for predicting difficult laryngoscopy was highest for RTTMD (0.98) followed by TT (0.92).[Table 2 and Figure 5] The AUC for TT for predicting difficult intubation was 0.69 with a sensitivity and specificity of 72% and 59%, respectively, at a cut-off value of 4.45 cm.[Table 3] RTTMD had an AUC of 0.68 for prediction of difficult intubation with a sensitivity and specificity of 72% and 59%, respectively, at a cut-off value of 0.55. Among the clinical airway parameters, NC had the highest AUC for prediction of difficult laryngoscopy (0.84) and difficult intubation (0.69).

Using a cut-off value of 4.5 cm for TT, the positive predictive value of TT for difficult intubation was 46.1% and the negative predictive value was 76.1% [Table 4].

Discussion

Various clinical parameters and scores are available for predicting difficult airway. However, despite this, there are incidents of unanticipated difficult airway. Hence, there is a constant search for more accurate, reliable, and objective tests for predicting difficult airway. In this study, we measured TT using submandibular sonography. Compared to other clinical

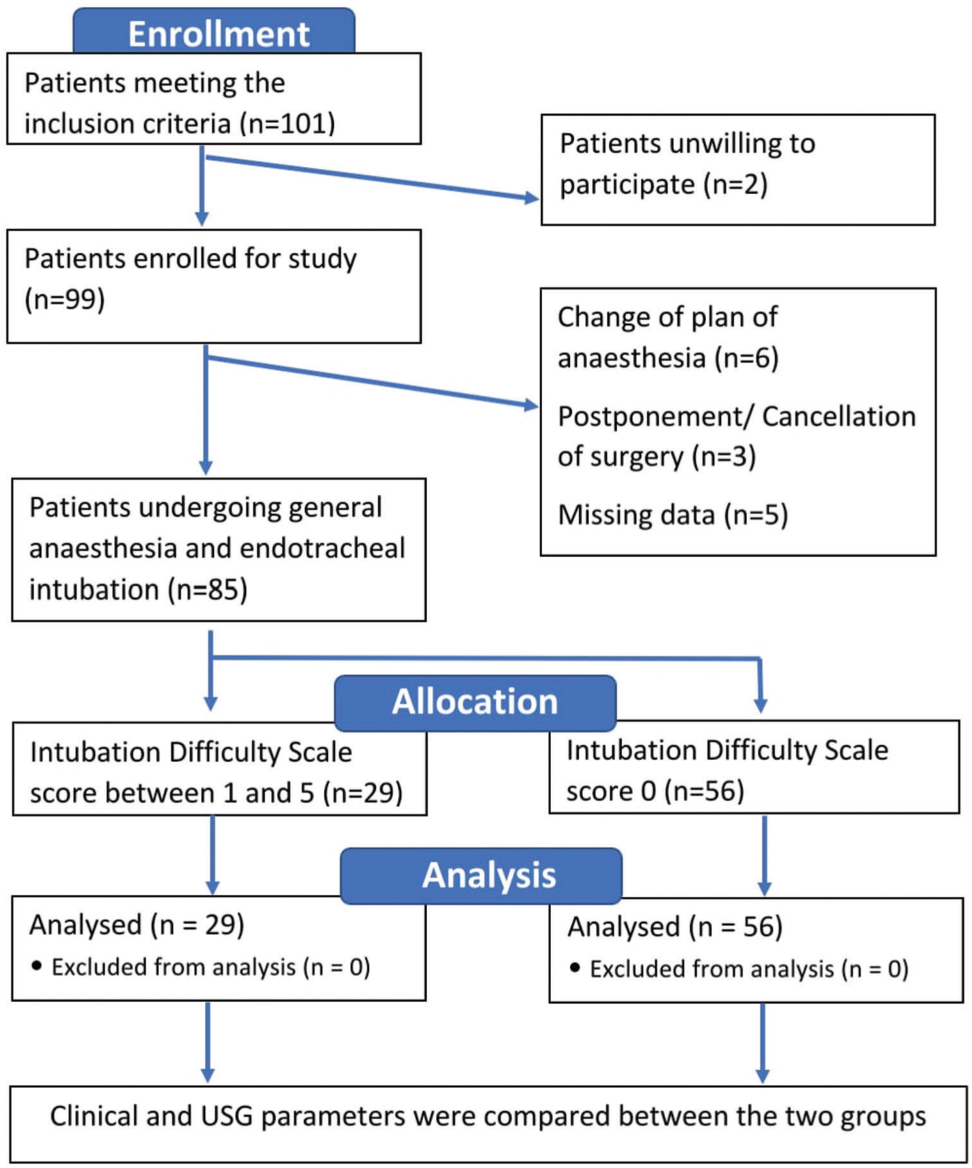


Figure 4: Study flow chart and patient outcome

Table 1: Comparison of various airway parameters in easy and difficult intubation groups

	Parameter	Easy intubation (IDS=0), *n*=56, Mean±SD	Difficult intubation (1 < IDS < 5), *n*=29, Mean±SD	*P*
1	Height (m)	1.56±0.077	1.55±0.084	0.689
2	Weight (kg)	56.42±10.80	67.58±16.52	<0.0001*
3	BMI (kg/m²)	23.11±4.07	28.14±7.25	<0.0001*
4	IID	4.161±0.546	4.19±0.45	0.807
5	MPC grade			
	MPC 1	29 (51.8%)	7 (24.1%)	0.061
	MPC 2	22 (39.3%)	20 (69.0%)	
	MPC 3	4 (7.1%)	2 (6.9%)	
	MPC 4	1 (1.8%)	0	
6	NC	34.07±3.40	36.56±3.51	0.002*
7	TMD	8.31±0.90	8.12±0.96	0.368
8	RHTMD	18.98±2.12	19.35±2.18	0.451
9	TT	4.38±0.65	4.83±0.62	0.003*
10	RTTMD	0.53±0.09	0.60±0.10	0.003*

*BMI=body mass index, IDS=intubation difficulty scale, IID=interincisor distance, MPC=modified Mallampati classification, NC=neck circumference, RHTMD=ratio of height to TMD, RTTMD=ratio of TT to TMD, SD=standard deviation, TMD=thyromental distance, TT=tongue thickness. *P<0.05 is considered significant*

Table 2: AUC of various airway parameters for predicting difficult laryngoscopy

Parameter	AUC	Sensitivity	Specificity
IID	0.735 (0.59–0.88)	1.000	0.590
NC	0.843 (0.662–1)	1.000	0.675
TMD	0.325 (0–0.759)	0.500	0.542
RHTMD	0.678 (0.447–0.908)	1.000	0.518
TT	0.916 (0.789–1)	1.000	0.831
RTTMD	0.976 (0.941–1)	1.000	0.964
MPC categories	0.458 (0.083–0.833)		

AUC=area under the receiver operating characteristic curve, IID=inter incisor distance, MPC=modified Mallampati classification, NC=neck circumference, RHTMD=ratio of height to TMD, RTTMD=ratio of TT to TMD, TMD=thyromental distance, TT=tongue thickness

Table 3: AUC of various airway parameter for predicting difficult intubation

Parameter	AUC (95% confidence interval)	Sensitivity	Specificity
MPC (>2 Yes)	0.49 (0.36–0.619)	0.069	0.91
IID)	0.505 (0.376–0.634)	0.414	0.571
NC	0.689 (0.575–0.805)	0.724	0.571
TMD	0.422 (0.295–0.550)	0.724	0.232
RHTMD	0.560 (0.430–0.692)	0.586	0.536
TT	0.692 (0.575–0.810)	0.724	0.589
RTTMD	0.678 (0.559–0.798)	0.72	0.59

AUC=area under the receiver operating characteristic curve, IID=interincisor distance, MPC=modified Mallampati classification, NC=neck circumference, RHTMD=ratio of height to TMD, RTTMD=ratio of TT to TMD, TMD=thyromental distance, TT=tongue thickness

parameters, the AUC for predicting difficult intubation was higher for TT (AUC = 0.69) measured using ultrasonography. Based on our study, TT can be used to predict difficult intubation with a sensitivity of 59% and a specificity of 72% at a cut-off value of 4.45 cm. Rounding up to a cut-off value of 4.5 cm, the sensitivity and specificity of TT were 62.1% and 62.5%, respectively; with a negative predictive value of 76.1% and a positive predictive value of 46.2%.

Airway ultrasonography can be easily performed bedside in no time. Different airway parameters studied using ultrasonography for predicting difficult airway include anterior neck soft tissue thickness at various levels from the hyoid bone to vocal cords, depth of the pre-epiglottic space, TT, tongue volume, and hyomental distance.[7-12]

We chose to study TT as it can be quickly identified and recorded bedside, does not require the patient to perform any maneuvers, and does not involve any complex calculations. In comparison to the anterior neck soft tissue thickness that is measured in millimeters, TT is measured is centimeters and in unaffected by the pressure applied while scanning, thus reducing the margin of error. It may be thought that compressing the tongue during laryngoscopy affects its thickness. However, Yao and Wang[7] demonstrated that the retained thickness of the tongue during laryngoscopy correlates well with its thickness in the natural position.

The incidence of difficult laryngoscopy (CL III) in our study was 2.4%. The incidence of slight difficult intubation (IDS 1–5) was 34.1%. This varies from 29% to 48.5% in different studies.[13-15] Various studies have reported incidence of difficult intubation ranging from 2.3% to 22.5%.[7-10,15] However, there have different definitions of difficult intubation used in these studies. Some studies have taken difficult laryngoscopy as a surrogate for difficult intubation.[8-10] We used IDS to assess intubation.

Our results were in concordance with previous studies. Yao and Wang[7] concluded that TT of more than 6.1 cm could be

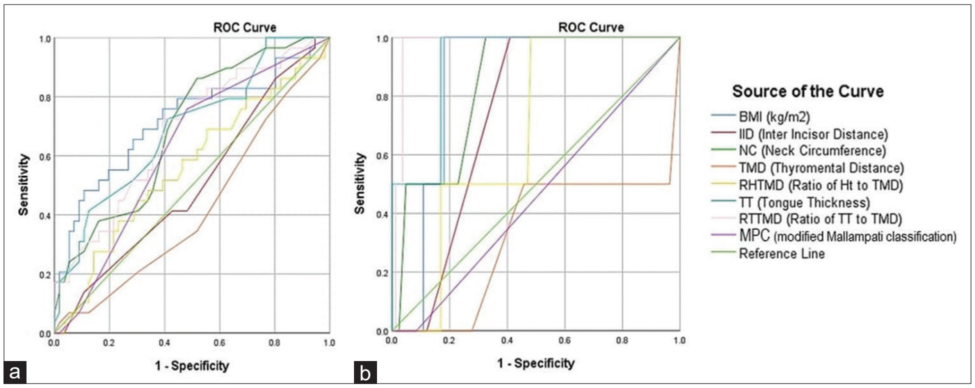


Figure 5: Receiver operating characteristic curves for predicting (a) difficult intubation and (b) difficult laryngoscopy. (BMI=Body Mass Index)

Table 4: Statistical analysis for tongue thickness for predicting difficult intubation based on the cut-off value of 4.5 cm

Statistical analysis	Value	95% CI
Sensitivity	62.07%	42.26%–79.31%
Specificity	62.50%	48.55%–75.08%
Positive likelihood ratio	1.66	1.06–2.57
Negative likelihood ratio	0.61	0.37–1.01
Positive predictive value	46.15%	35.52%–57.14%
Negative predictive value	76.09%	65.69%–84.10%
Accuracy	62.35%	51.18%–72.64%

CI=Confidence interval

used to predict difficult intubation with a sensitivity of 75%, specificity of 72%, and an AUC of 0.86, which was greater than all other clinical parameters. They also found it to be an independent predictor of difficult laryngoscopy and intubation. Yadav *et al.*[9] studied anterior neck soft tissue and TT using ultrasonography and concluded that TT could predict difficult laryngoscopy with an AUC of 0.72 and was the most sensitive parameter (sensitivity = 71%, specificity = 72%).[9] However, the AUC for predicting difficult laryngoscopy was highest for skin to hyoid bone distance and skin to thyrohyoid membrane distance in a sniffing and neutral position (0.73). In our study, the measurement was based solely on the thickness of the tongue and did not include the submandibular soft tissue, so as to avoid variations due to the pressure applied while scanning. Thus, the cut-off value obtained was lower than that found in other studies. Another reason for the differences observed in the cut-off values for TT could be ethnicity of the population. While our study was done in the Indian population, majorly from the western region of the country, Yao and Wang studied the Chinese Han population and Yadav *et al.* the South Indian population.[7,9]

Parameswari *et al.*[16] evaluated the tongue volume using ultrasonography and concluded that it could predict difficult laryngoscopy with a sensitivity and specificity of 66.7% and 62.7%, respectively. Ohri and Malhotra[12] also calculated the tongue volume using three different 2D ultrasonography methods and found that all three methods could predict difficult laryngoscopy with an AUC ranging from 0.50 to 0.56. However, it was not compared to other clinical or sonographic parameters. Contrary to the above studies, Wojtczak[11] did not find the tongue volumes to differ significantly in easy and difficult intubation groups. However, the study size was small and only obese patients were included in this study. They also compared the tongue volume using 3D ultrasonography software with 2D method and concluded that the 2D method slightly overestimates the tongue volume.[17] Compared to mid-sagittal TT assessment used in our study, calculating the tongue volume is complex and time-consuming. Tongue volume also takes into consideration the length of the tongue. However, a thick but short tongue may pose more difficulty in laryngoscopy compared to a relatively thinner but longer tongue as it has a higher tongue volume.

During laryngoscopy, the tongue is displaced into the submandibular space to visualize the glottis. Thus, a thicker tongue and/or decreased submandibular space will lead to difficulty in laryngoscopy and impair the glottic view. Thus, we calculated the ratio of TT to thyromental distance (RTTMD). The AUC for RTTMD for predicting difficult intubation was 0.68 with a sensitivity and specificity of 59% and 72%, respectively. Thus, RTTMD was better than MPC and TMD and was similar to TT alone in predicting difficult intubation. Yao and Wang[7] found that RTTMD fared better than TT, TMD, or MPC alone in predicting difficult intubation, with an AUC of 0.86 and a sensitivity and specificity of 84% and 79%, respectively.

Although TT is a good predictor of difficult airway, it cannot be used as the only test and must always be used in conjunction with other clinical parameters. There are a few limitations of this study. It was carried out in a single tertiary health-care center with a limited sample size. There were no patients with major difficulty in intubation or impossible intubation.

TT was not validated by any other imaging technique. As a single anesthesiologist was performing ultrasonography, we could not test the interobserver reliability for measurement of TT. Pregnant patients, children, and those with anticipated difficult airway were not included in the study. Larger studies are needed in patients from different populations. Further work is also needed in children who are known to have a relatively larger tongue.

Conclusions

TT measured using ultrasonography can be useful to predict difficult airway. However, as it is only one of the components of difficult airway, it should be combined with other clinical and ultrasound airway parameters.

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.

Ethical approval

Approval was obtained from the institutional ethics committee.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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