Original Article

Evaluation of ultrasound measured tongue thickness, tongue thickness–thyromental distance ratio, and skin-to-epiglottis distance in predicting unanticipated difficult laryngoscopy

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Abstract

Background and Aims: The contemporary literature review suggests upper airway ultrasound can help us to diagnose an unanticipated difficult airway before laryngoscopy. The primary objective of this study was to compare ultrasonography (USG) and clinical airway indices across easy and difficult laryngoscopy groups.

Material and Methods: This prospective observational study included 258 patients scheduled to undergo surgery under general anesthesia with endotracheal intubation. Ultrasonographic upper airway parameters, viz., tongue thickness (TT), skin-to-epiglottis distance (DSE), and tongue thickness to thyromental distance ratio (TT/TMD) were measured. Patients were identified as easy or difficult laryngoscopy groups based on their Cormack Lehane (CL) grading.

Results: Out of 258 patients, 20 (7.75%) had difficult laryngoscopy, and 238 (92%) had easy laryngoscopy. The USG measured TT mean, and median values were 6.16 ± 0.39 [6.10] cm in difficult and 5.41 ± 0.36 [5.40] cm in easy laryngoscopy groups. The USG measured mean and median value of DSE were 2.75 ± 0.09 [2.74] in difficult and 2.27 ± 0.23 [2.27] in easy laryngoscopy groups. The ratio of TT/TMD with mean and median values of 0.98 ± 0.07 [0.99] in difficult and 0.84 ± 0.13 [0.82] in easy laryngoscopy. Using the inputs, the diagnostic accuracy of the ultrasound-measured significant variables was calculated in terms of their area under the curve using the receiver operating characteristic curve.

Conclusions: This study revealed a relationship between sonographic measurements like TT, DSE, and TT/TMD ratio for easy and difficult laryngoscopy identification. Including these sonographic parameters and their cut-off values may enhance our ability to predict an unanticipated difficult laryngoscopy.

Keywords: Airway, laryngoscopy, ultrasound

Introduction

Difficulty in airway management is a significant cause of morbidity and mortality in anesthesia, intensive care, and emergency medicine practice.[1] Recognizing patients at risk of difficult tracheal intubation is essential, especially in patients with apparently normal-looking airways. Difficult laryngoscopy (DL) is considered a surrogate indicator of difficult intubation.

The incidence of DL ranges between 1.5 and 13%, and the primary goal of the anesthesiologist is to recognize the difficult airway (DA) and to reduce or eliminate potential risks linked

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to its precise management.[2-4] Inadequate airway protection or insufficient patient oxygenation during interventional procedures is associated with an overall accretion in mortality and morbidity. Routine clinically measured airway indices, like thyromental distance, Mallampati grading, etc., have significant negative predictive value for exclusion of the DA.[2,5,6] However, every once in a while, an anesthesiologist encounters an unanticipated difficult intubation, which leads to stressful clinical situations, especially in resource-poor high-volume centers. A device that radiologists use is now a commonly used gadget in the emergency department, the intensive care unit, and the operating theatres for predicting DAs.[7-9]

The principle behind this is that the upper airway is a superficial structure formed by a predictable arrangement of sonographically identifiable structures, making them optimal for ultrasound evaluation. Unlike clinically measured airway indices, ultrasound measurements may offer deeper insight into airway anatomy and theoretically may help us detect unanticipated DL more reliably. The laryngoscopy involves the introduction of a laryngoscope blade into the mouth and further displacement of the tongue into the sub-glossal space, with the lifting of the epiglottis and hyoid bone. Any increase in anterior neck tissue thickness or fat pad impairs the mobility of the pharyngeal structures, and this is reflected through parameters like tongue thickness (TT), thyromental distance (TMD), and skin-to-epiglottis distance (DSE).[10-12] Despite much literature about preoperative upper airway ultrasound, it is still unclear whether these parameters are enough to predict a DA in adults without apparent anatomical abnormalities or unanticipated DL. Parameters such as TT distance from skin to epiglottis have been used in various studies to predict DAs; however, the current literature is limited to small studies and further restricted because of the low incidence of DAs.[1,13-19]

The present study evaluated the potential of ultrasound-measured variables like TT, DSE, and TT/TMD ratio in predicting DL. Although many other ultrasound parameters have already been assessed in various studies in conjunction with clinical parameters, we have considered these parameters as these dimensions are easy to perform, and sonological landmarks are easily identifiable, leading to low interobserver variability and better fidelity. We hypothesized that these ultrasonography (USG)-measured variables would be able to predict unanticipated DL more reliably compared to clinically measured airway indices, which are routinely measured. Hence, this study was done to study the performance of these indices in the airway assessment.

Our study's primary objective was to compare USG and clinical airway indices across easy and DL groups. The secondary objective was the computation of diagnostic accuracy with appropriate cut-offs of USG-measured indices in predicting DL along with the time of intubation and use of adjuvants in both groups.

Material and Methods

After obtaining Institute Ethics Committee approval [2021-175-MD-EXP-40] and Clinical Trial Registry (CTRI/2021/10/037576), this prospective single-arm observational trial was carried out in adherence to the principles of the Declaration of Helsinki. A written informed consent was taken from all the participants before enrolling them for the study. All consenting American Society of Anesthesiologists (ASA) I and II patients of both genders of 18 and 60 years of age scheduled to undergo elective surgeries under general anesthesia with endotracheal intubation were assessed for inclusion in the study. Patients' features suggestive of anticipated DL like modified Mallampati (MMP) grade III or IV, body mass index (BMI) >35 kg/m^2, previous DA history, thyromental distance < 5 cm, inter incisor distance < 2 cm, restricted neck movements, maxillofacial anomalies/anatomical deformities, previous history of trauma, and surgery to upper airway were excluded. All patients underwent a detailed clinical preoperative airway evaluation in the preanesthetic clinic. The MMP class, mouth opening, thyromental distance, and mentohyoid distance were recorded during the preanesthetic check-up with the help of a flexible measuring tape.

All patients underwent airway sonographic assessment by the anesthesiologist (who had at least 5 years of experience in airway ultrasound). For the sonographic evaluation, the patient was made to lie supine. The mouth was closed, and the tongue tip touched the incisors. The tongue was relaxed, and the patient was asked not to phonate during an assessment. A curvilinear USG probe (2–5 MHz) was placed under the chin in the median sagittal plane, and the view was adjusted to visualize the entire tongue clearly on screen. The maximum vertical dimension from the tongue's surface to the submental skin was measured and defined as TT [Figure 1a and b]. Further, a linear probe (5–10 MHz) was used in the transverse plane from cephalad to caudad to visualize epiglottis and arytenoids along with the posterior vocal fold. After freezing the image, the DSE was measured [Figure 1c and d]. Due care was taken to apply only minimum pressure on the neck so that measurements were not distorted due to pressure on the neck by the USG probe during sonographic image acquisition. The next day, the patient was shifted to the operating room, baseline monitors of electrocardiogram, noninvasive blood pressure, and pulse oximetry were connected, and values were noted.

After preoxygenation for 3 min, intravenous (IV) midazolam 0.2 mg/kg and fentanyl 2 mcg/kg were administered. Anesthesia was induced with Inj. Propofol 2–3 mg/kg (titrated) to body weight. After muscle relaxation with Inj. Vecuronium 0.1 mg/kg and ventilation with oxygen and sevoflurane 2% for 3 min, direct laryngoscopy was performed by an experienced anesthesiologist using a curved Macintosh Blade, and the grading of laryngoscopic view was noted. In this study, laryngoscopy was defined as easy if the CL grade on laryngoscopy was I or II, and it was described as difficult if the CL grade was III or IV. The use of adjuncts like bougie or stylet, if required for endotracheal intubation, was noted.

Anesthesiologists performed all laryngoscopies with at least 5 years of experience. Patients were intubated with an appropriately sized endotracheal tube, and surgery was allowed to proceed. At the end of the surgery, the patient was extubated following the reversal of neuromuscular blockade or shifted intubated to the anesthesia care unit as per indications.

Sample size estimation and statistical analysis

Based on the pilot data of the same setting, to differentiate between difficult and easy laryngoscopy, the minimum area under the receiver operating characteristic (AUROC) curve for TT, skin-to-epiglottis, and TT/TMD ratio was expected to be 80%. At a minimum, two-sided 95% confidence interval and 80% power of the study, the minimum estimated sample size was 217. Finally, 258 patients were included in this study. The sample size was estimated using the power analysis software PASS-16. Continuous variables were presented in mean ± SD along with median. The categorical variables were presented in frequency and percentage. An independent sample *t*-test/Chi-square test was used to compare the means/proportions between the difficult and easy laryngoscopic groups. When there was a difference in means between the groups, receiver operating characteristic (ROC) was used to assess the diagnostic accuracy in terms of AUROC curve, its 95% confidence interval, and appropriate cut-off values with corresponding specificity and sensitivity. Software Package for Statistical Services (SPSS) version 23 was used for data analysis. P value < 0.05 was considered as significant.

Figure 1: Sonographic measurements of skin-to-epiglottis distance (a) along with curvilinear probe position (b) and tongue thickness (c) along with curvilinear probe position (d)

Results

In our study, 258 patients were included. The incidence of DL was 7.75% in our study, with 20 patients categorized as Group 1 (DL) and 238 patients categorized as Group 2 (easy laryngoscopy) [Figure 2]. Both groups were comparable in demographic data (age, sex, and BMI) [Table 1].

All USG-measured airway indices TT, TT/TMD ratio, and DSE were significantly higher in DL patients as compared to the easy laryngoscopy group ($P < 0.001$). Both mentohyoid ($P = 0.141$) and TMD ($P = 0.061$) were lower in DL groups, but their difference was not statistically significant [Table 1].

The USG-measured mean and median value TT was 5.47 ± 0.42 [5.45] with values of 6.16 ± 0.39 [6.10] in DL and 5.41 ± 0.36 [5.40] in easy laryngoscopy. The USG-measured mean and median value of DSE were 2.39 ± 0.24 [2.39] with values of 2.75 ± 0.09 [2.74] in DL and 2.27 ± 0.23 [2.27] in easy laryngoscopy. The ratio of TT/TMD mean and median value of 0.85 ± 0.13 [0.83] with values of 0.98 ± 0.07 [0.99] in DL and 0.84 ± 0.13 [0.82] in easy laryngoscopy. The ratio was significant between easy laryngoscopy and DL [Table 1].

Using the above inputs, the diagnostic accuracy of the significant variables was calculated in terms of their AUC using the ROC curve. Cut-off values for these variables were calculated individually, with a strategy to achieve at least > 50% sensitivity

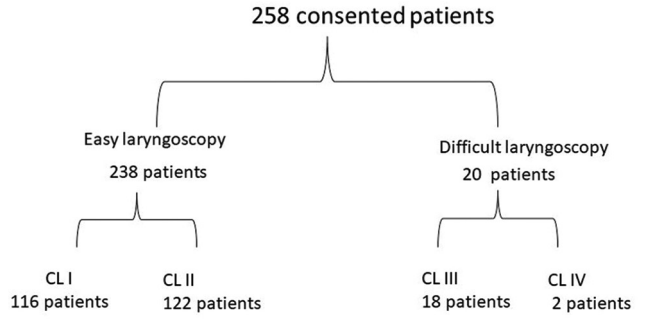

Figure 2: Patient flow in the study

and specificity each at the chosen corresponding cut-off value. The TT cut-offs were 5.79 and 5.88 cm with sensitivity and specificity of 90% and 75.6%, 85% and 85.3%, respectively, along with the AUC of 0.93 [Table 2 and Figure 3]. With DSE cut-off values of 2.62 and 2.63 cm with sensitivity and specificity of 95% and 88%, 90% and 93%, respectively, along with an AUC of 0.96. With the TT/TMD ratio, the cut-off values were 0.90 and 0.95, with sensitivity and specificity of 95.5%, and 72.7%, 80% and 82.8%, respectively, with an AUC of 0.86. The use of adjuncts was significant in the DL group, with 90% of cases in the DL group and only 10% in the easy laryngoscopy group.

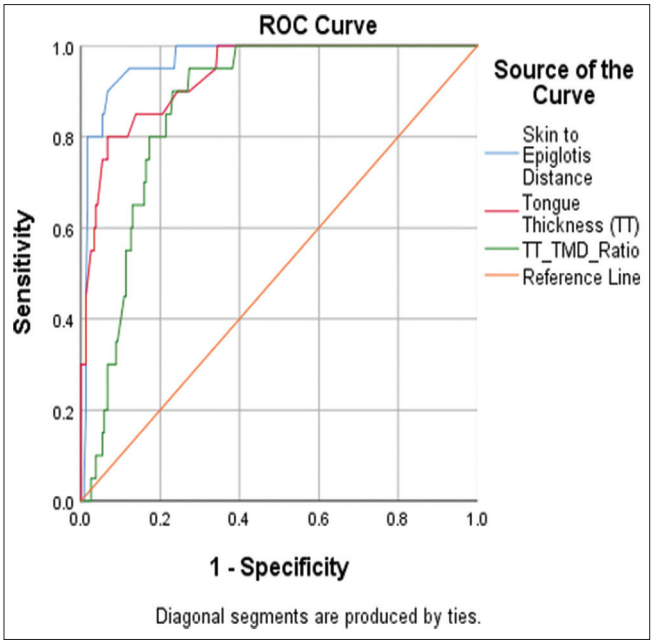

Figure 3: Area under the curve diagram showing the diagnostic accuracy of the measurements for predicting the difficult laryngoscopy

Discussion

Ultrasound is now considered a "visual stethoscope" of the anesthesiologist. Its use is well established in regional blocks and central venous catheter insertion, and presently, it is increasingly used in anticipation of DAs. It complements the classical approach of clinical airway assessment and allows more objective airway evaluation.[20] The incidence of DL ranges between 1.5% and 13%, and the primary goal of anesthesiologists is to recognize the DA and to reduce or eliminate potential risks linked to its precise management.[2-4] In our study we found DL incidence of 7.5% which is along expected lines. Prediction of DA with ultrasound-measured distance from skin to epiglottis helps predict DL, especially in unanticipated airways, which is available in the literature.[1,10,11,21-25] However, the results of these studies are often contradictory. This study found that DSE may correlate with Cormack-Lehane (CL) scores at direct laryngoscopy, which could help to diagnose unpredicted DAs. Our results showed that in the US-measured DSE, the cut-off point was ≥2.62 cm with a sensitivity of 95% and specificity of 88%. With a cut-off value of ≥2.63 cm, the sensitivity and specificity are 90% and 93%, respectively. These cut-off values of DSE are highly variable in various studies. Wu *et al.*[25] studied the cut-off point, which was 1.78 cm. Adhikari *et al.*[10] studied 51 patients in the African American population. Six patients among 51 were categorized as DL; their US-DSE cut-off for DL was 2.8 cm. One Italian study showed a cut-off value of 2.54 cm of DSE with a sensitivity of 82% and specificity of 91%.[12] A similar study in Portugal by Pinto *et al.*[1] showed a DSE of 2.75 cm could be used as a cut-off point for DL with a sensitivity of 64.7% and specificity of 77.1%. Martínez-García *et al.* concluded that DSE ≥3 cm could predict a DL with a sensitivity of 56.3% and specificity of

Table 1: Distribution of the demographic and clinical variables between easy and difficult laryngoscopy [*n*=258]

Variable	Total *n*=258	Difficult *n*=20	Easy *n*=238	*P*
Age [years]	40.41±13.36 [40]	39±12.96 [37]	40.53±13.42 [40]	0.623
BMI	22.95±1.31 [23.0]	23.67±2.35 [23.1]	22.89±1.17 [23.0]	0.158
Male	113 [43.8%]	7 [6.2%]	106 [93.8%]	
Female	145 [56.2%]	13 [9%]	132 [91%]	
TMD [in cm]	6.50±0.78 [6.6]	5.39±0.32	5.73±0.81	0.061
Mentohyoid [in cm]	5.86±0.81 [5.8]	4.79±0.27	5.06±0.83	0.141
Intubation [in sec]	39±8.44 [38]	58.05±10.31 [61]	37.39±5.96 [36]	<0.001
TT [in cm]	5.47±0.42 [5.45]	6.16±0.39 [6.10]	5.41±0.36 [5.40]	<0.001
Skin epiglottis [in cm]	2.39±0.24 [2.39]	2.75±0.09 [2.74]	2.27±0.23 [2.27]	<0.001
TT/TMD ratio	0.85±0.13 [0.83]	0.98±0.07 [0.99]	0.84±0.13 [0.82]	<0.001
Adjuncts: Yes	10 [3.9%]	9 [90%]	1 [10%]	<0.001
Adjuncts: No	248 [96.1%]	11 [4.4%]	237 [95.6%]	
CL I	116 [5%]	0	116 [100%]	<0.001
CL II	122 [47.3%]	0	122 [100%]	
CL III	18 [7%]	18 [100%]	0	
CL IV	2 [0.8%]	2 [100%]	0	

Independent samples t-test/Chi-square test/Fisher exact test used. P<0.05 significant

Table 2: Diagnostic accuracy of the ultrasound measurements for discriminating between difficult and easy intubation [*n*=258]

Variables	AUROC	95% CI	Cut-off	Sensitivity (%)	Specificity (%)
TT	0.93	0.88–0.98	≥5.73	90	75.6
			≥5.88	85	85.3
Skin-to-epiglottis distance	0.96	0.94–0.99	≥2.62	95	88
			≥2.63	90	93
TT/TMD ratio	0.86	0.81–0.91	≥0.90	95	72.7
			≥0.95	80	82.8

Receiver operating characteristics curve P<0.05 significant, TMD=thyromental distance, TT=tongue thickness

88.2%.[23] An Indian subcontinent study done by Parameswari *et al*.[24] on 130 patients with 12 difficult laryngoscopies showed that patients with DSE <1.8 cm were predicted difficult, and those with distance >1.8 cm were predicted to be easy with a sensitivity of 75% and specificity of 63.6%. This study contrasts with the present literature, which may be due to interobserver variation in ultrasound readings and the sonographer's experience. Martínez-García *et al*.[23] also opined that the nonapplication of external laryngeal pressure may influence the CL grades. So, there are conflicts of cut-off values, which depend on various factors like sonographic landmarks, demography, and anthropometric differences among different races and populations and the sonographer's experience. Carsetti *et al*.[26] meta-analysis found that distance from skin to epiglottis was the most extensively assessed index test in literature and seemed accurate in predicting DL. They believed that DSE >2.5 cm may have a role in case of doubt for potential difficulties after considering the other tests routinely applied. Standardization is required when we take cut-off value from any study for its clinical pragmatic use. We did all airway assessments before induction of anesthesia because post anesthesia induction, there are changes that occur in airway anatomy due to the hypotonic effects of induction agents, which will alter the ultrasonic measurements.[27] However, the CL grade evaluation was only possible after induction of anesthesia.

The tissue at the hyoid level needs to be lifted by the tip of the laryngoscope blade, and a higher CL grade is expected with increasing tongue tissue thickness. Increased TT has been well related to DL.[18,19] In all ultrasound scans, the measurements vary per anatomical landmarks chosen in each study. Agarwal *et al*.,[13] in their prospective, observational, double-blinded cohort trial, preoperatively measured the TT in the mid-sagittal plane to obtain values of the thickest portion of the entire tongue. Their ROC analysis showed that TT >5.8 cm predicted the risk of DI with a sensitivity of 84.5% and specificity of 78.1%.

With the increase in the TT and decrease in the TMD, there is an increase in the incidence of difficulty in the airway.[19] Yao and Wang *et al*.[19] did a study in 2254 patients and calculated ratios of TT (in centimeters) to TMD (in centimeters) and utilized them to predict DL. They demonstrated that the proportions of these two variables may be a balanced selection. The AUC of TT/TMD ratio for predicting difficult tracheal intubation or laryngoscopy was remarkable compared to TT and TMD. They found that increased TT >6.1 cm was an independent predictor for difficult tracheal intubation [sensitivity 0.75, 95% confidence interval (CI) 0.60–0.86; specificity 0.72, 95% CI 0.70–0.74] also increased ratios of TT to TMD (>0.87) presented a considerable AUC (0.86, 95% CI 0.84– 0.87), sensitivity (0.84, 95% CI 0.71–0.93), and specificity (0.79, 95% CI 0.77–0.81).

Combined with clinical tests, the simplicity of these ultrasound-measured indices, the growing ubiquity of ultrasound, and possible synergistic accuracy justify their routine use in clinical practice. These measurements can be easily done in emergency department and ICU settings with the patient in the supine position as point-of-care tests of the airway. DSE requires minimal neck movement; hence is useful in suspected trauma patients.

In our study, the thickness of the tongue was significantly higher in the DL group, and with the TT cut-off of 5.73 and 5.88 cm, the sensitivity and specificity are 90% and 75.6% and 85% and 85.3%, respectively with the AUC of 0.93. The TT/TMD ratio of the cut-off values were 0.90 and 0.95 with sensitivity and specificity of 95.5%, 72.7% and 80% and 82.8%, respectively, with AUC of 0.86. Yadav *et al*.[18] studied the thickness of the tongue along with other ultrasound measurements of the neck. They found that these measurements can be quickly recorded at the bedside and do not involve complex calculations.

Prevailing medical literature and the present study demonstrate that many factors affect the formation of an unanticipated DA.[18,28-30] Reliance upon a single parameter of high predictive yield can be misleading. A combination of parameters improves the capacity to predict DAs significantly. However, this comes with a caveat that only a few variables would miss many DAs by reducing the sensitivity and, in a trade-off, increasing the specificity. In the present study, BMI was identified as a weak predictor, and this finding is congruent with many previous studies.[19] The use of adjuncts was significant in DL, evident in the DA.

There is an enormous need for literature on the possibility of a single airway ultrasound measurement that can delineate

all unanticipated DAs with high accuracy, sensitivity, and specificity. Our study had a few limitations; anterior neck soft tissue varies with sex and age of the patient. For uniformity in the survey, we have anticipated DAs; significantly obese and pregnant patients were not included in the study. We have also excluded the patients with MMP grades 3 and 4 to identify the threshold for DAs that clinical examination could not anticipate. So, this makes our results specific to the unpredicted DA, and the real predicted DA is not considered. The investigators in the presented study were not blinded, which could have led to bias in our measurements. The ultrasound measurements of the anterior soft tissue neck are measured in mm, and the amount of pressure by the ultrasound probe may cause alteration in values and might alter the results. The generalized uniform pressure application in all patients is impossible for obvious reasons. However, this discrepancy can be rectified by a validation study correlating ultrasound measurements with MRI/CT measurements. Future research should address these limitations, focusing on a larger sample size combined with a formalized ultrasound scanning protocol.

Conclusions

Our study revealed a correlation between sonographic measurement of TT, DSE, and TT/TMD ratio for differentiation between easy and difficult laryngoscopy. Including these sonographic parameters in our clinical practice may enhance our ability to predict a DL, particularly in emergency operative rooms and emergency medicine centers. However, further focused, more extensive sample-size studies across different patient populations, combined with formalized ultrasound scanning protocols, are required to clarify whether these ultrasonographic airway parameters can deliver significant clinical progress.

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Conflicts of interest
There are no conflicts of interest.

References

1. Pinto J, Cordeiro L, Pereira C, Gama R, Fernandes HL, Assuncao J. Predicting difficult laryngoscopy using ultrasound measurement of distance from skin to epiglottis. J Crit Care 2016;33:26-31.
2. Cattano D, Panicucci E, Paolicchi A, Forfori F, Giunta F, Hagberg C. Risk factors assessment of the difficult airway: An Italian survey of 1956 patients. Anesth Analg 2004;99:1774-9.
3. Crosby ET, Cooper RM, Douglas MJ, Doyle DJ, Hung OR, Labrecque P, *et al*. The unanticipated difficult airway with recommendations for management. Can J Anaesth 1998;45:757-76.
4. Koh W, Kim H, Kim K, Ro YJ, Yang HS. Encountering unexpected difficult airway: Relationship with the intubation difficulty scale. Korean J Anesthesiol 2016;69:244-9.
5. Crawley S, Dalton A. Predicting the difficult airway. BJA Educ 2014;15:253-7.
6. Narkhede HH, Patel RD, Narkhede HR. A prospective observational study of predictors of difficult intubation in Indian patients. J Anaesthesiol Clin Pharmacol 2019;35:119-23.
7. Kristensen MS, Teoh WH, Graumann O, Laursen CB. Ultrasonography for clinical decision-making and intervention in airway management: From the mouth to the lungs and pleurae. Insights Imaging 2014;5:253-79.
8. Prasad A, Yu E, Wong DT, Karkhanis R, Gullane P, Chan VW. Comparison of sonography and computed tomography as imaging tools for assessment of airway structures. J Ultrasound Med 2011;30:965-72.
9. Wojtczak JA. Submandibular sonography: Assessment of hyomental distances and ratio, tongue size, and floor of the mouth musculature using portable sonography. J Ultrasound Med 2012;31:523-8.
10. Adhikari S, Zeger W, Schmier C, Crum T, Craven A, Frrokaj I, *et al*. Pilot study to determine the utility of point-of-care ultrasound in the assessment of difficult laryngoscopy. Acad Emerg Med 2011;18:754-8.
11. Ezri T, Gewürtz G, Sessler DI, Medalion B, Szmuk P, Hagberg C, *et al*. Prediction of difficult laryngoscopy in obese patients by ultrasound quantification of anterior neck soft tissue. Anaesthesia 2003;58:1111-4.
12. Falcetta S, Cavallo S, Gabbanelli V, Pelaia P, Sorbello M, Zdravkovic I, *et al*. Evaluation of two neck ultrasound measurements as predictors of difficult direct laryngoscopy: A prospective observational study. Eur J Anaesthesiol 2018;35:605-12.
13. Agarwal R, Jain G, Agarwal A, Govil N. Effectiveness of four ultrasonographic parameters as predictors of difficult intubation in patients without anticipated difficult airway. Korean J Anesthesiol 2021;74:134-41.
14. Andruszkiewicz P, Wojtczak J, Sobczyk D, Stach O, Kowalik I. Effectiveness and validity of sonographic upper airway evaluation to predict difficult laryngoscopy. J Ultrasound Med 2016;35:2243-52.
15. Hui CM, Tsui BC. Sublingual ultrasound as an assessment method for predicting difficult intubation: A pilot study. Anaesthesia 2014;69:314-9.
16. Kasinath MPR, Rastogi A, Priya V, Singh TK, Mishra P, Pant KC. Comparison of airway ultrasound indices and clinical assessment for the prediction of difficult laryngoscopy in elective surgical patients: A prospective observational study. Anesth Essays Res 2021;15:51-6.
17. Reddy PB, Punetha P, Chalam KS. Ultrasonography - A viable tool for airway assessment. Indian J Anaesth 2016;60:807-13.
18. Yadav NK, Rudingwa P, Mishra SK, Pannerselvam S. Ultrasound measurement of anterior neck soft tissue and tongue thickness to predict difficult laryngoscopy - An observational analytical study. Indian J Anaesth 2019;63:629-34.
19. Yao W, Wang B. Can tongue thickness measured by ultrasonography predict difficult tracheal intubation? Br J Anaesth 2017;118:601-9.
20. Jain K, Yadav M, Gupta N, Thulkar S, Bhatnagar S. Ultrasonographic assessment of airway. J Anaesthesiol Clin Pharmacol 2020;36:5-12.
21. Ellard L, Wong DT. Preoperative airway evaluation. Curr Anesthesiol Rep 2020;10:19-27.
22. Hall EA, Showaihi I, Shofer FS, Panebianco NL, Dean AJ. Ultrasound evaluation of the airway in the ED: A feasibility study. Crit Ultrasound J 2018;10:3.
23. Martinez-Garcia A, Guerrero-Orriach JL, Pino-Galvez MA. Ultrasonography for predicting a difficult laryngoscopy. Getting closer. J Clin Monit Comput 2021;35:269-77.
24. Parameswari A, Govind M, Vakamudi M. Correlation between preoperative ultrasonographic airway assessment and laryngoscopic

view in adult patients: A prospective study. J Anaesthesiol Clin Pharmacol 2017;33:353-8.
25. Wu J, Dong J, Ding Y, Zheng J. Role of anterior neck soft tissue quantifications by ultrasound in predicting difficult laryngoscopy. Med Sci Monit 2014;20:2343-50.
26. Carsetti A, Sorbello M, Adrario E, Donati A, Falcetta S. Airway ultrasound as predictor of difficult direct laryngoscopy: A systematic review and meta-analysis. Anesth Analg 2022;134:740-50.
27. Chemtob EV, Lin DH, Lee E, Heinz ER. Utilization of submandibular ultrasound in assessing upper airway changes following the administration of propofol. J Anaesthesiol Clin Pharmacol 2023;39:583-6.
28. Khan ZH, Mohammadi M, Rasouli MR, Farrokhnia F, Khan RH. The diagnostic value of the upper lip bite test combined with sternomental distance, thyromental distance, and interincisor distance for prediction of easy laryngoscopy and intubation: A prospective study. Anesth Analg 2009;109:822-4.
29. Merah NA, Wong DT, Foulkes-Crabbe DJ, Kushimo OT, Bode CO. Modified Mallampati test, thyromental distance and inter-incisor gap are the best predictors of difficult laryngoscopy in West Africans. Can J Anaesth 2005;52:291-6.
30. Salimi A, Farzanegan B, Rastegarpour A, Kolahi AA. Comparison of the upper lip bite test with measurement of thyromental distance for prediction of difficult intubations. Acta Anaesthesiol Taiwan 2008;46:61-5.