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ULTRASOUND GUIDED MEASUREMENT OF ANTERIOR NECK TISSUE FOR THE PREDICTION OF DIFFICULT AIRWAY: A PROSPECTIVE OBSERVATIONAL STUDY

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Abstract

***Objectives:** To determine that ultrasound (US) measurements of anterior neck soft tissue thickness at hyoid bone, thyrohyoid membrane, and anterior commissure levels can be used to predict difficult laryngoscopy.*
***Materials & Methods:** The present study included 100 patients of age group 18–60 years undergoing elective surgery under general anaesthesia. It was a prospective observational study which included patients with ASA physical status I and II. Excluded patients were with facial and neck deformities, neck trauma, or those undergoing surgery of the larynx, epiglottis and pharynx. Comparison analysis was performed using t-test for continuous variables and chi-square or Fisher exact test for non-continuous variables. Correlation analysis performed using Pearson test.*
***Results:** There were 39 out of 100 patients categorised as difficult laryngoscopy. Thickness at hyoid bone (DSHB), thyrohyoid membrane (DSEM) and anterior commissure (DSAC), MMS (modified Mallampati score), and BMI (body mass index) were greater in the difficult laryngoscopy group ($p < 0.001$). TMD (thyromental distance) was less in the difficult laryngoscopy group ($p < 0.001$). There was a strong positive correlation between DSEM and DSAC ($r = 0.784$). Moderate positive correlation was between DSEM and DSHB ($r = 0.559$), DSEM and MMS($r=0.437$). The area under curve (AUC) of DSHB, DSEM, DSAC, TMD and MMS is >0.7. The optimal cut-off values for DSEM, DSHB, DSAC and TMD were 1.34 cm, 0.98 cm, 1.68 cm and 6.59 cm, respectively, in predicting difficult airway.*
***Conclusion:** Ultrasound measurement of soft tissue thickness at hyoid bone, thyrohyoid membrane, and anterior commissure of vocal cord are good independent predictors for difficult laryngoscopy. When combined with traditional screening tests it improves the ability to predict difficult laryngoscopy.*

Keywords

Airway management • difficult intubation • hyoid bone • laryngoscopy • ultrasonography

Introduction

Predicting difficult intubation by evaluation of airway is very important in anaesthesia practice. There are several clinical predictors for assessment of difficult airway. But an unanticipated difficult airway is a dreadful nightmare even for an experienced anaesthesiologist, as it can cause life-threatening anaesthesia-related morbidity and mortality [1].
A wide array of screening tests such as Mallampati score, inter-incisor gap, and thyromental distance are being used for evaluating airway, yet the rate of difficult laryngoscopy and intubation remains 1.5–13%. This points out the lack of certainty of these traditional tests and the need for more dependable test parameters [2].

Ultrasonography (USG) has evolved as a simple, non-invasive, portable, rapidly performed technique for airway assessment. Its use for regional blocks, central venous catheterization, detecting pneumothorax in the operation theatre and intensive care unit is well known. Recently its use in visualisation of airway structures has been described in various studies [3,4]. Researchers have used this development to obtain US-guided measurements of parameters such as anterior commissure, vocal cords, thyrohyoid membrane and hyoid bone to the level of skin. They have tried to find how these parameters can help in detecting a difficult airway [5,6]. The main advantage of US

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in anaesthesia seems to be related to its predictive power for difficult airway [7].
But these studies are few in number, done in small populations. Each study uses a different set of ultrasonography parameters, and no unanimous decision on the best parameter for predicting difficult airway has been confirmed. Also, there is limited literature available that compares the ultrasound (US) parameters to the Cormack-Lehane (CL) grade and physical parameters.
The present study aimed to determine the utility of ultrasonic measurements of anterior soft tissue neck thickness at the level of hyoid bone, thyrohyoid membrane, and anterior commissure in determining difficult laryngoscopies. We examined the correlation of clinical screening test, ultrasonic measurements, and laryngoscopic view (CL grade) to distinguish between easy and difficult laryngoscopies.

Materials and Methods

After attaining approval of research protocol from the institute ethics committee (VIEC/2018/APP/047) and obtaining informed written consents, 100 consecutives American Society of Anaesthesiologists (ASA) physical status I and II patients undergoing elective surgeries requiring general anaesthesia with endotracheal intubation were included in the study between year 2018 and 2019. This was a prospective observational study carried out in a tertiary care hospital. Patients between age groups 18 years to 60 years, belonging to ASA physical status I and II, undergoing elective surgery, were included in the study. Patients with deformity of face and neck, history of surgery or trauma of face, neck, larynx, pharynx and epiglottis, past history of difficult intubation, and those who are edentulous were excluded.
Pre-anaesthetic check-up was done by primary investigator before surgery. Height, weight and body mass index (BMI) were noted for all patients. For airway assessment the Modified Mallampati score (MMS), a few other conventional screenings (like thyromental distance, sternomental distance, inter-incisor gap, neck circumference, upper lip bite test) and ultrasound-guided anterior neck tissue measurements were performed.
Thyromental distance (TMD) was measured from mental prominence to thyroid cartilage with patient's neck extended fully. Sternomental distance (SD) measured from suprasternal notch to mentum with neck extended fully. Neck circumference (NC) was measured at thyroid cartilage. Inter-incisor gap (IIG) was measured from upper central incisors to lower central incisors with patient's mouth open fully. Upper lip bite test (ULBT) was done where patient was instructed to bite the upper lip.
For ultrasound measurements the primary investigator used ACUSON (Siemens Medical Solutions USA, Inc), free-style ultrasound with 8-13 hertz linear probe. The patient was placed in supine position with head and neck in neutral position. The distance from the skin to the anterior aspect of the trachea was obtained by placing the linear probe at three different levels on the neck in transverse position: at hyoid bone (DSHB), thyrohyoid membrane (DSEM), and anterior commissure (DSAC). At hyoid level minimal distance from hyoid to skin surface was measured. At thyrohyoid membrane level, distance from skin to epiglottis midway between hyoid bone and thyroid cartilage was measured. At anterior commissure level, minimal distance from skin to anterior commissure was obtained.
Patient was shifted to the operating room, multipara monitors such as electrocardiogram (ECG), pulse oximeter (SpO2), and non-invasive blood pressure (NIBP) were connected, and baseline values noted. After preoxygenation with FiO2 100% for 3 min, intravenous midazolam 0.02 mg/kg^{-1} and fentanyl 2 mcg/kg^{-1} were administered. Induction was carried out with intravenous propofol 2-2.5 mg/kg^{-1} in graded dose. Intravenous vecuronium 0.1 mg/kg^{-1} was given as muscle relaxant to facilitate intubation. Patient was ventilated with 100% O2 and 2% sevoflurane for 3 min. An anaesthesiologist with more than two years of experience and who was unaware of the ultrasound results performed all intubations. Laryngoscopy was carried out in "sniffing" position with an appropriately sized Macintosh blade and without application of any external laryngeal manipulation; Cormack Lehane (CL) grade was noted. Grade I and II are categorised as easy laryngoscopy; Grade III and IV are categorised as difficult laryngoscopy. Patients were intubated with appropriate size endotracheal tube and surgery was allowed to proceed. At the end of surgery, patient was extubated after neuromuscular block reversal.
Statistical analysis: We estimated the sample size, keeping the parameters reported by Reddy et al., [6] reported 8% sensitivity for predicting difficult intubation by anterior neck soft tissue thickness at the level of the vocal cord of >0.23. Keeping this parameter, with margin of error 7, power of 80 and alpha 5%, we estimated the sample size of 100. The MS-Excel, SPSS v22.0 software (Armonk, NY, USA: IBM Corp) package was used for data entry and analysis. Continuous data are averaged [mean ± standard deviation]. Categorical data are expressed as number of occurrences (%). Comparison analysis to determine statistical difference between easy and difficult intubation was performed using *t*-test for continuous variables and chi-square or Fischer test as appropriate for non-continuous variables.
To determine discriminative power of individual tests and combination, receiver operating characteristic analysis was

done and area under curve with 95% confidence interval was calculated. Optimal cut-off values were calculated using Youden index (sensitivity+specificity-100). Level of statistical significance was $p < 0.05$, $p < 0.0001$ was considered to be statistically highly significant.

Results

A total of 100 eligible patients posted for elective surgery under general anaesthesia, who needed endotracheal intubation, were included. 39 out of 100 patients were categorised as difficult laryngoscopy and out of 100 patients, 66.7% were males.

There were no differences in age, sex, ASA status, height, but the weight and BMI values were higher in difficult laryngoscopy group. The weight and BMI were 63.8 ± 11.6 kg ($p < 0.05$) and 25.5 ± 4.1 kg.m^{-2} ($p < 0.001$) respectively for the difficult laryngoscopy group (Table 1).

MMS, ULBT, TMD, IIG, SD, NC, DSHB, DSEM, DSAC are the Airway evaluation parameters shown in Table 2. MMS is higher in the difficult laryngoscopy group ($p < 0.001$), in the difficult laryngoscopy group 10 patients had ULBT of class 2 as compared to 0 patients in the easy laryngoscopy group ($p < 0.001$), TMD ($p < 0.001$) and SD ($p = 0.002$) were lower in the difficult laryngoscopy group, but NC was higher ($p < 0.001$). No statistical difference was found for IIG between the groups. The USG parameters DSHB, DSEM, DSAC were greater in the difficult laryngoscopy group compared to the easy laryngoscopy group ($p < 0.001$) (Table 2). The AUC of DSHB, DSEM, DSAC, TMD and MMS were above 0.7, suggestive of good parameters of difficult laryngoscopy (Table 3).

A strong positive correlation existed between DSEM and DSAC, moderate positive correlation existed between DSEM and DSHB, DSHB and DSAC, DSEM and MMS, DSEM and NC, DSHB and MMS, DSHB and NC, DSAC and MMS, DSAC and NC, MMS and NC, TMD and IIG, TMD and SD. Weak positive correlation existed between DSEM and IIG, DSAC and IIG, MMS and IIG, TMD and NC, IIG and NC, IIG and SD. The correlation coefficient and *p*-value of clinical airway assessment and screening parameters is shown in Table 4. Further assessment of MMS, TMD, IIG, SD, NC, ULBT, DSHB, DSEM, and DSAC in predicting difficult laryngoscopy was done using ROC curves (Figure 1). Laryngoscopy grade above II is the threshold of difficult laryngoscopy. As determined by Youden index, the optimal cut-off values (sensitivity, specificity) for MMS, TMD, DSHB, DSEM, DSAC, to predict difficult laryngoscopy were above 2 (90%, 72%), 6.59 cm (87%, 54%), 0.98 cm (92%, 69%), 1.34 cm (93%, 82%), 1.68 cm (100%, 95%) (Table 5).

Table 1: Demographic data of the patients with difficult and easy laryngoscopy.

Variable	Difficult (*n* = 39)	Easy (*n* = 61)	*P*-value
Age	41.05 ± 12.97	38.20 ± 10.76	0.24
Sex (M/F)	13(33.3%)/26(66.6%)	29(47.5%)/32(52.5%)	0.21
ASA (I/II)	29(74.4%)/10(25.6%)	42(68.9%)/19(31.1%)	0.61
Height	157.97 ± 5.25	157.48 ± 5.63	0.66
Weight	63.87 ± 11.61	56.89 ± 9.01	0.01
BMI	25.59 ± 4.10	22.89 ± 3.21	<0.01

Data are presented as mean ± SD or number of patients (percent).

Table 2: Airway evaluating parameters for predicting difficult laryngoscopy.

Variable	Difficult (n=39)	Easy (n=61)	P-value
MMS			<0.001
MMS 1	6 (15.4%)	24 (39.3%)	
MMS 2	5 (12.8%)	31 (50.8%)	
MMS 3	25 (64.1%)	6 (9.8%)	
MMS 4	3 (7.7%)	0 (0.0%)	
ULBT			<0.001
ULBT 1	29 (74.4%)	61 (100%)	
ULBT 2	10 (25.6%)	0 (0%)	
TMD	6.61 ± 1.02	7.62 ± 1.26	<0.001
IIG	6.29 ± 0.85	6.34 ± 0.57	0.76
SD	16.34 ± 2.41	17.60 ± 1.57	0.002
NC	35.18 ± 3.14	33.13 ± 2.64	0.001
DSHB	1.03 ± 0.20	0.82 ± 0.13	<0.001
DSEM	1.49 ± 0.11	1.14 ± 0.14	<0.001
DSAC	1.92 ± 0.15	1.43 ± 0.10	<0.001

Data are presented as mean ± SD or number of patients (percent). MMS, Modified Mallampati Score; ULBT, upper lip bite test; TMD, Thyromental distance; IIG, inter-incisor gap; SD, Sternomental distance; NC, neck circumference; DSHB, distance between skin and hyoid bone; DSEM, distance between skin and epiglottis; DSAC, distance between skin and anterior commissure.

Table 3: The area under the ROC curves (AUC) for DSEM, DSHB, DSAC, TMD, and MMS.

Variable	AUC ± SE	P-value	95% CI
DSHB	0.799 ± 0.052	<0.001	0.698 to 0.901
DSEM	0.975 ± 0.012	<0.001	0.951 to 1.0
DSAC	0.999 ± 0.001	<0.001	0.997 to 1.0
TMD	0.725 ± 0.054	<0.001	0.619 to 0.830
MMS	0.800 ± 0.051	<0.001	0.700 to 0.899

AUC ± SE, area under the ROC curves ± standard error; 95% CI, 95% confidence interval; DSHB, distance between skin and hyoid bone; DSEM, distance between skin and epiglottis; DSAC, distance between skin and anterior commissure; TMD, Thyromental distance; MMS, Modified Mallampati Score.

Table 4: Relationship between airway parameters and screening parameters.

	DSEM (cm)		DSHB (cm)		DSAC (cm)		MMS		TMD (cm)		IIG (cm)		NC (cm)		SD (cm)	
	r-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value
DSEM (cm)	-	-	.559	<0.001	.784	<0.001	.437	<0.001	-.324	.001	.007	.943	.399	<0.001	-.167	.097
DSHB (cm)	.559	<0.001	-	-	.532	<0.001	.550	<0.001	-.365	<0.001	-.016	.875	.429	<0.001	-.246	.014
DSAC (cm)	.784	<0.001	.532	<0.001	-	-	.530	<0.001	-.408	<0.001	.118	.242	.334	.001	-.310	.002
MMS	.437	<0.001	.550	<0.001	.530	<0.001	-	-	-.256	.010	.051	.615	.335	.001	-.284	.004
TMD (cm)	-.324	.001	-.365	<0.001	-.408	<0.001	-.256	.010	-	-	.349	<0.001	.065	.519	.419	<0.001
IIG (cm)	.007	.943	-.016	.875	.118	.242	.051	.615	.349	<0.001	-	-	.166	.100	.122	.228
NC (cm)	.399	<0.001	.429	<0.001	.334	.001	.335	.001	.065	.519	.166	.100	-	-	-.228	.022
SD (cm)	-.167	.097	-.246	.014	-.310	.002	-.284	.004	.419	<0.001	.122	.228	-.228	.022	-	-

r = correlation coefficient.

Table 5: Optimal cut-off values with sensitivity and specificity to predict difficult laryngoscopy.

Variable	Cut-off values	Sensitivity	Specificity
DSEM	1.34	93%	82%
DSHB	0.98	92%	69%
DSAC	1.68	100%	95%
TMD	6.59	87%	54%
MMS	2	90%	72%

Sensitivity and specificity are in percentages. Cut-off values are in cm except for MMS.

Discussion

USG has become a significant tool regularly used by anaesthesiologists for procedures such as regional nerve blocks, central venous catheter placements, in critical care for detection of pneumothorax, and more [8,9]. Studies on USG for airway evaluation are few and still evolving, as there are no fixed parameters for predicting difficult laryngoscopy, and cut-offs of each parameter vary in different studies [10,11].

USG has potential in airway evaluation and management. This has been proven by its use in confirming endotracheal tube placement in trachea, endotracheal size detection, recognising anomalies in airway anatomy, locating important structures like cricothyroid membrane for cricothyroidotomy [7]. Our study measurement of airway structures – skin to hyoid bone, thyrohyoid membrane, and anterior commissure, respectively – has been done with help of USG to predict difficult laryngoscopy, a new application [12].

In this study, done on 100 Asian patients, we found strong positive linear correlation existed among DSHB, DSEM and DSAC. USG and traditional screening tests were compared in predicting difficult laryngoscopy. It was found the AUCs of DSHB, DSEM, DSAC, MMS and TMD were >0.7 indicating good parameters to predict difficult laryngoscopy. But IIG, SD, NC, ULBT had AUCs <0.7, making them poor parameters for difficult laryngoscopy prediction.

There are many factors which play an important role in visualizing glottis and intubation. Though the anaesthesiologist's skill and experience are important, factors such as mouth opening, big tongue, oropharyngeal space, neck mobility, neck circumference, mentum to thyroid distance, mentum to sternum distance, upper lip bite by lower jaw teeth, all play a definitive role in this complicated procedure [13,14]. The role of the above preoperative tests in difficult airway recognition has been studied and researched over the years.

The Mallampati score was first introduced by Mallampati et al. in 1985 and was modified by Samsoon and Young in 1987 [15,16]. Its division into four classes makes airway evaluation easy and hence it is one of the most commonly used tools to predict difficult airway. But limiting factors such as patient cooperation and body position have diminished its use as a stand-alone predictor of difficult laryngoscopy and intubation [17].

A recent meta-analysis involving 1,77,088 patients demonstrates MMS when used with collection of other preoperative airway tests is of more value, rather than when it is used as a single screening test [18]. Our result also confirms this conclusion. TMD has been reported to be a good predictor of difficult laryngoscopy and intubation.

In our study TMD has AUC >0.7 and p value < 0.001. Our result on TMD is similar to a previous study by Tamire et al., but different from a study by Wu et al. [19,12] AUC value of SD in our study is less than 0.7, making it a poor predictor of difficult laryngoscopy, which is not in accordance to results of Tamire et al. [19]. The AUC value of IIG is <0.7, which is similar to the study by Wu et al. and Savva, showing it is a poor parameter of difficult laryngoscopy prediction [12,20]. NC in our study has proven to be poor predictor of difficult laryngoscopy, which is different from results reported by Ezri et al. [21].

ULBT has been used as screening test in our study but as AUC <0.7 it is not useful as a screening test for difficult laryngoscopy. This contradicts the result obtained in a study by Honarmand et al., where ULBT has been proven to be a more specific test in predicting difficult laryngoscopy among group of five conventional screening tests [22].

CT and MRI, though, have greater accuracy in measuring thickness of anterior neck soft tissue; they have limited use, as they are expensive and not accessible to operating rooms. However, USG is portable, inexpensive and provides almost as accurate measurements as the abovementioned imaging techniques [23]. Adhikari et al. measured the anterior neck soft tissue at level of hyoid and thyrohyoid membrane. They found US measurement of 2.8 cm at thyrohyoid membrane was a good independent predictor of difficult laryngoscopy [24]. Wu et al. measured anterior neck soft tissue at three levels – hyoid, thyrohyoid membrane, and anterior commissure. The US values of hyoid, thyrohyoid membrane and anterior commissure were 1.51 cm, 2.39 cm, 1.30 cm respectively in the difficult laryngoscopy group and were greater than the easy laryngoscopy group. The three parameters are good independent predictors of difficult laryngoscopy.

Our study results show thickness of anterior neck soft tissue at level of hyoid, thyrohyoid membrane and anterior commissure are greater in difficult laryngoscopy group. The values of the three parameters (difficult vs. easy) are hyoid (1.30 cm ± 0.20 vs. 0.82 cm ± 0.13 cm), thyrohyoid membrane (1.49 cm ± 0.11 cm vs. 1.14 cm ± 0.14) and anterior commissure (1.92 cm ± 0.15 cm vs. 1.43 cm ± 0.10 cm). The ranges of hyoid and thyrohyoid membrane values were smaller than seen in the study by Wu et al., but the range of anterior commissure was greater. These three parameters were found to be independent predictors of difficult laryngoscopy.

Several limitations exist in our study. Glottis exposure is affected by many objective factors such as airway anatomy and pathological changes, and by subjective factors such as provider skill, environment, instrument comfort. Small sample size might limit the study conclusion. The investigators might have observed some clinical signs of difficult laryngoscopy which could have caused bias during US measurement. This study has been done in an Asian population; hence, results may vary in other ethnic groups.

Conclusion

Anterior neck soft tissue thickness measured with US at hyoid, thyrohyoid membrane and anterior commissure are good independent predictors of difficult laryngoscopy. Conventional screening tests alone have low predictive power but when combined with USG measurements might increase the ability to predict difficult laryngoscopy.

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