Original Article

Correlation between preoperative ultrasonographic airway assessment and laryngoscopic view in adult patients: A prospective study

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Abstract

Background and Aims: Difficult tracheal intubation is associated with serious morbidity and mortality and cannot be always predicted based on preoperative airway assessment using conventional clinical predictors. Ultrasonographic airway assessment could be a useful adjunct, but at present, there are no well-defined sonographic criteria that can predict the possibility of encountering a difficult airway. The present study was conducted with the aim of finding some correlation between preoperative sonographic airway assessment parameters and the Cormack–Lehane (CL) grade at laryngoscopic view in adult patients.
Material and Methods: This was a prospective, double-blinded study on 130 patients undergoing elective surgery under general anesthesia. Preoperative clinical and ultrasonographic assessment of the airway was done to predict difficult intubation and was correlated with the CL grade noted at laryngoscopy. The sensitivity, specificity, positive predictive value, and negative predictive values of the parameters were assessed.
Results: The incidence of difficult intubation was 9.2%. Among the clinical predictors, the modified Mallampati classification had the maximum sensitivity and specificity, and among the sonographic parameters, the skin to epiglottis distance had the maximum sensitivity and specificity to predict difficult laryngoscopy. A combination of these two tests improved the sensitivity in predicting a difficult laryngoscopy.
Conclusions: The skin to epiglottis distance, as measured at the level of the thyrohyoid membrane, is a good predictor of difficult laryngoscopy. When combined with the modified Mallampati classification, the sensitivity of the combined parameter was found to be greater than any single parameter taken alone.

Keywords: Airway, assessment, laryngoscopy, ultrasonography

Introduction

Difficult and failed tracheal intubation after direct laryngoscopy is a dreaded complication of general anesthesia as it is associated with serious morbidity and mortality.[1] There are several conventional clinical airway assessment parameters such as the modified Mallampati classification,[2,3] hyomental and thyromental distance, neck movements, interincisor distance, and neck circumference, which are usually used to predict a difficult airway[4-6] and are components of multivariate risk indices. Despite the use of these parameters, the diagnostic accuracy of a preanesthetic airway assessment in predicting difficult intubation is very low.[7] Ultrasound has been evolving as a useful device for airway assessment,[8-10] and sublingual ultrasound has been used for this purpose.[11] The ability to visualize the hyoid through sublingual ultrasound

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has been recently shown to be an objective modality for predicting difficult laryngoscopic view.[12] The present study was conducted to assess the usefulness of various sonographic airway parameters in predicting difficult laryngoscopy.

Material and Methods

This was a prospective, double-blinded study on 130 patients undergoing elective surgery under general anesthesia. After institutional ethics committee approval and informed consent, adult patients between 18 and 60 years of age, of either sex, requiring general anesthesia with endotracheal intubation for elective procedures were enrolled in the study. Patients with any feature of difficult airway such as maxillofacial anomalies, restricted neck movements, obesity (body max index [BMI] >40 kg/m^2), and limited mouth opening were excluded from the study. With an alpha error of 5%, 130 patients were required to participate in the study, with a power of 80%.

All patients underwent a detailed preoperative airway evaluation on the day before surgery. The modified Mallampati class, mouth opening, mentohyoid distance, thyromental distance, and neck circumference were noted and recorded for all patients. All patients also underwent a detailed preoperative sonographic assessment by the same anesthesiologist who was experienced in airway ultrasound.

For sonographic assessment of the airway, the patient was made to lie in the supine position with head in the neutral position without pillow, looking straight ahead with the mouth closed and the tongue on the floor of the mouth without any movement. The linear high-frequency probe (L14-5/38, frequency 14-5 MHz) and the curvilinear low-frequency probe (C5-2/60, frequency 7-3 MHz) of the ultrasound machine (Sonix Tablet, Ultrasonix, Canada) were both used to measure the different sonographic parameters. The probes were placed on the skin under the patient's chin, at different levels, to get both transverse and mid-sagittal views of the submandibular area and the upper part of the neck. The transverse view was used for measuring the width of the tongue, the cross-sectional area of the floor of the mouth, the anteroposterior thickness of the geniohyoid muscle, the skin to hyoid, and the skin to epiglottis distance. The mid-sagittal view was used for measuring the cross-sectional area of the tongue and the mentohyoid distance.

The tongue can be visualized deeper to the muscles of the floor of the mouth. The dorsal surface of the tongue has a curvilinear, hyperechoic appearance. Using a curvilinear probe placed transversely under the chin, the width of the tongue was measured between the most distant points on its upper surface by transverse scan at the midsection of the tongue [Figure 1]. With the probe placed under the chin to provide a mid-sagittal view, the cross-sectional area of the tongue was measured [Figure 2]. The tongue volume was then derived by multiplication of the mid-sagittal cross-sectional area of the tongue and the width of the tongue, according to the method followed in a previous study.[13]

The anteroposterior thickness of the geniohyoid muscle, the skin to hyoid distance, the skin to epiglottis distance at the level of the thyrohyoid membrane [Figure 3], the mentohyoid distance, and the cross-sectional area of the muscles of the floor of the mouth were measured. The muscle volume of the floor of the mouth was derived from multiplication of the cross-sectional area of the muscles of the floor of the mouth with the hyomental distance. The sonographic parameters and the way they were measured are described in detail in Table 1.

After preoperative assessment, the patients were classified as difficult or easy laryngoscopy, based on the clinical and sonographic parameters. Criteria for sonographic parameters were selected based on a pilot study done by us.

The next morning, the patient was shifted to the operating room, baseline monitors of electrocardiogram, noninvasive blood pressure, and pulse oximeter were connected and values noted. After preoxygenation with FiO_2 1 for 3 min, intravenous (IV) midazolam 1 mg and fentanyl 2 μg/kg were administered. Anesthesia was induced with injection propofol 2 mg/kg. After muscle relaxation with injection vecuronium 0.1 mg/kg IV and ventilation with oxygen and sevoflurane 2% for 3 min, direct laryngoscopy was done by an anesthesiologist using an appropriate size curved Macintosh blade, and the Cormack–Lehane (CL) laryngoscopic grade was noted.[14] The intubating anesthesiologist was not involved in preoperative clinical and sonographic airway assessment.

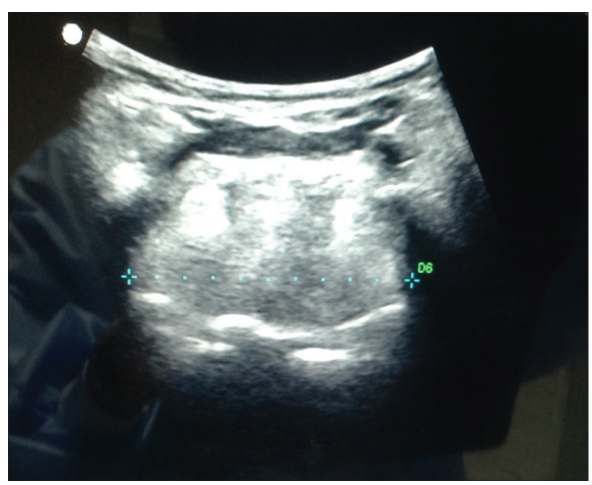

Figure 1: Blue dotted line: Width of the tongue

Table 1: Parameters assessed by ultrasound, the type of ultrasound probe used, and the view

Parameter	Probe	View	Explanation
Width of tongue	Curvilinear	Transverse	Most distant points on the upper surface of tongue
CS area of tongue	Curvilinear	Mid-sagittal	Area of the tongue measured by USG
CS area of floor of mouth	Curvilinear	Transverse	Area of geniohyoid and mylohyoid
Mentohyoid distance	Curvilinear	Mid-sagittal	Distance between hyoid and mentum (both seen as hypoechoic shadow under hyperechoic bone)
AP thickness of geniohyoid	Linear	Transverse	Thickness of geniohyoid measured
Skin to hyoid	Linear	Transverse	Distance from skin to hyoid
Skin to epiglottis	Linear	Transverse	Distance from skin to epiglottis at the level of the thyrohyoid membrane, midway between the hyoid and the thyroid

USG=Ultrasound sonography, CS=Cross-sectional, AP=Anteroposterior

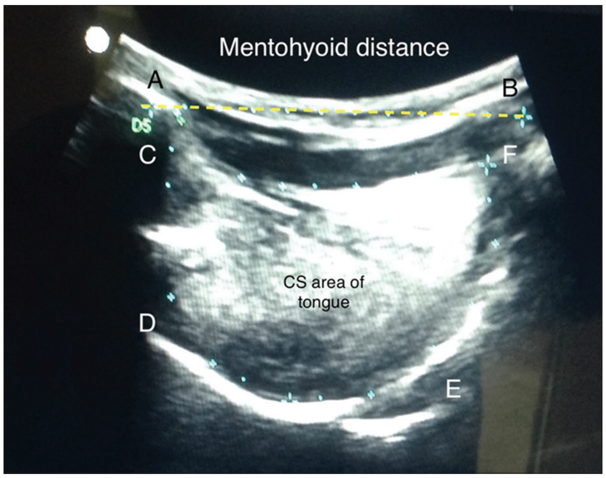

Figure 2: Blue dotted area CDEF: Cross-sectional area of the tongue; yellow dash line AB: Mentohyoid distance

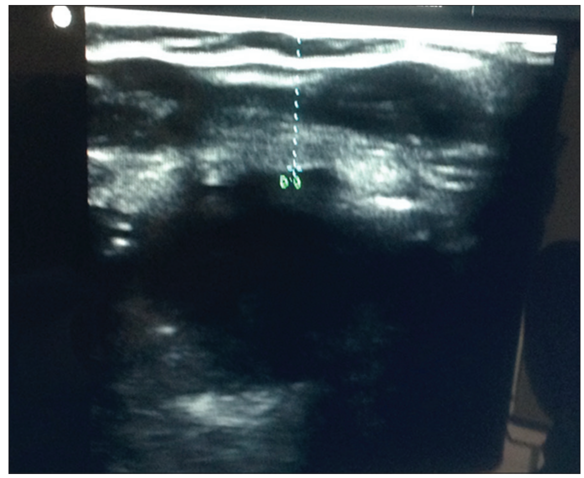

Figure 3: Skin to epiglottis distance shown by blue dotted line

CL Grade I and II were categorized as easy laryngoscopy and Grades III and IV were categorized as difficult laryngoscopy. Patients were then intubated with an appropriate sized endotracheal tube and allowed to proceed with surgery. At the end of surgery, neuromuscular block was reversed and the patient was extubated.

Statistics

Statistical analysis was done using SPSS software version 17. The sensitivity, specificity, positive predictive value, and negative predictive value were calculated for all the measured parameters. The association between different predictors and difficult laryngoscopy was evaluated using Chi-square test and Fisher's exact test. A $P < 0.05$ was considered to be significant. To determine the discriminative power of individual tests and the combination, receiver-operating characteristic (ROC) analysis was done and the area under the curve (AUC) with 95% confidence interval was calculated.

Results

One hundred and thirty patients were recruited into the study, which included 63 men (48.5%) and 67 women (51.5%), with age ranging from 18 to 60 years (mean, 37.38 years; standard deviation, 12.756 years). BMI of the patients ranged from 16.45 to 31.3. The incidence of difficult laryngoscopy in our study was 9.2% (12 patients). Table 2 shows the distribution of the patients according to the CL grade at laryngoscopy. Eighty-one patients had a CL view of Grade I (62.3%), 37 patients had a CL view of Grade II (28.5%), 12 patients had a CL view of Grade III (9.2%), and none of the patients had a CL view of Grade IV.

Table 3 shows the sensitivity, specificity, positive predictive value, and negative predictive value of the conventional clinical and sonographic parameters in predicting a difficult laryngoscopy.

Among the clinical predictors, the modified Mallampati classification was most sensitive (sensitivity of 66.7%) and the mentohyoid distance was most specific (specificity of 97.5%) in predicting difficult laryngoscopy. Among the ultrasonographic predictors, the skin to epiglottis distance was most sensitive (sensitivity of 75%) and most specific (specificity of 63.6%) in predicting difficult laryngoscopy [Figure 4]. The ROC curve is a graphical display of sensitivity and specificity, and the AUC is an effective measure for assessing the inherent validity of the test. The maximum AUC of 1 indicates a perfect diagnostic test. The AUC for modified Mallampati class was 0.727 and closest to 1 among the clinical predictors, and the AUC for the skin to epiglottis distance was 0.693 and closest to 1 among the sonographic parameters, indicating that they have the highest validity among the parameters studied. On combining both these parameters, the sensitivity increased to 100% and specificity was 52.5%, with a negative predictive value of 100%. AUC when the two parameters were used together was 0.763, which was greater than using either parameter alone.

The volume of the tongue by sonographic assessment showed a sensitivity of 66.7%, specificity of 62.7%, and a negative predictive value of 94.6%. This was the next best sonographic parameter in terms of prediction of a difficult laryngoscopy [Figure 5].

Discussion

There are several traditional indices of predicting difficult laryngoscopy, but none of them are 100% sensitive and specific. Ultrasound is a new addition to the anesthesiologist's armamentarium, which has revolutionized care in several areas. The role of ultrasound in airway assessment is still primitive, with no established standard parameters to predict a difficult laryngoscopy. The present study was designed to establish a correlation between preoperative sonographically assessed parameters and the grade of difficulty at direct laryngoscopy. The parameters assessed by ultrasound, in our study, were the volume of the tongue, the volume of the floor of the mouth, the skin to hyoid distance, the anteroposterior thickness of the geniohyoid muscle, and the skin to epiglottis distance at the level of the thyrohyoid membrane.

The prevalence of difficult intubation in our study was 9.2%, which is comparable to previous studies. Adhikari *et al*.[15] used ultrasound to determine the utility of sonographic measurements of thickness of the tongue, anterior neck soft tissue at the level of hyoid bone, and the thyrohyoid membrane in distinguishing between easy and difficult laryngoscopy. They demonstrated that sonographic measurements of anterior neck soft tissue thickness at the level of hyoid bone and thyrohyoid membrane could be used to distinguish easy from difficult laryngoscopy.

In our study, we used the skin to hyoid and skin to epiglottis distance measurements at the level of the thyrohyoid membrane, as a measure of the anterior neck soft tissue. Wu *et al*.,[16] in their study on 203 patients, have shown that the thickness of the anterior neck soft tissue can be a predictor of difficult laryngoscopy. They found that the skin to hyoid distance as well as skin to epiglottis distance were good predictors of difficult laryngoscopy. In our study, the skin to hyoid distance had a lower sensitivity and specificity, when compared to skin to epiglottis distance, for prediction of difficult laryngoscopy.

Ease of laryngoscopy also depends on the space available to displace the tongue. The size of the tongue, in relation to the oropharyngeal space, is an important determinant of ease of introduction of the laryngoscope blade. Among the traditional parameters, modified Mallampati classification is used to assess this variable but is of moderate sensitivity.[17] Using ultrasound, we calculated the width and cross-sectional area of the tongue, to calculate the tongue volume, to assess the effect of tongue size on laryngoscopy. The volume of the tongue had a reasonable sensitivity and specificity in predicting

Table 2: Distribution of patients according to the Cormack–Lehane grade of laryngoscopic view

Cormack–Lehane grade	Number of patients (%)
I	81 (62.3)
II	37 (28.5)
III	12 (9.2)
IV	None

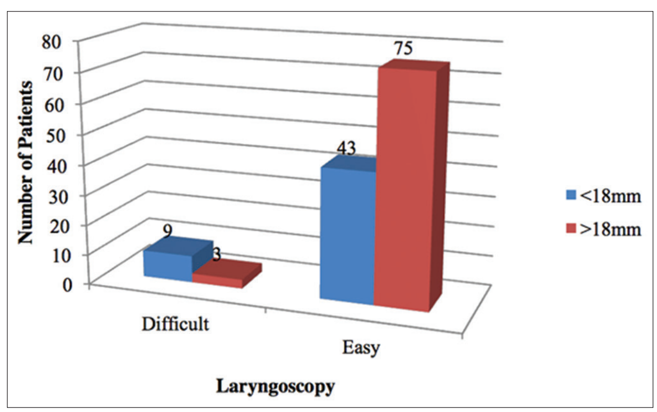

Figure 4: Prediction of difficult laryngoscopy based on skin to epiglottis distance. Patients with skin to epiglottis distance <18 mm were predicted to be difficult and those with distance >18 mm were predicted to be easy. X-axis indicates difficult or easy laryngoscopy as per Cormack–Lehane grade

Table 3: Comparison of the various sonographically assessed parameters to predict difficult laryngoscopy

Parameter	Sensitivity (%)	Specificity	Positive predictive value (%)	Negative predictive value (%)
Skin to hyoid distance	58.3	56.8	12.1	93.1
Volume of tongue	66.7	62.7	15.4	94.6
Volume of floor of mouth	50	55.9	10.3	91.7
Skin to epiglottis	75	63.6	17.5	96.2

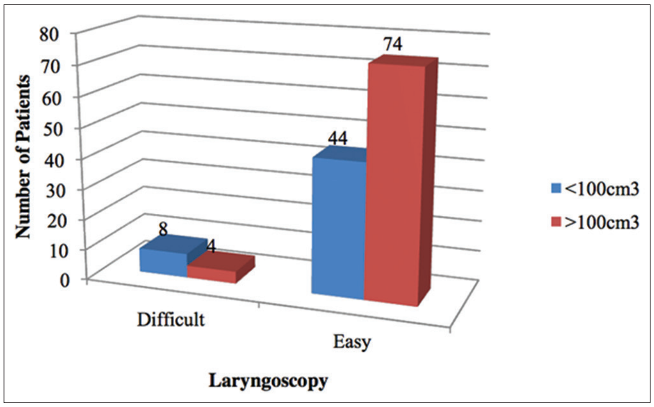

Figure 5: Prediction of difficult laryngoscopy based on tongue volume. Patients with tongue volume >100 cm^3 were predicted to be difficult and those with tongue volume <100 cm^3 were predicted to be easy. X-axis indicates difficult or easy laryngoscopy as per Cormack–Lehane grade

difficult laryngoscopy, in our study, but was not as predictive as anterior neck soft tissue thickness. Wojtczak *et al.*,[13] in their study on five obese and seven morbidly obese patients, did not find the tongue volume to differ between easy and difficult laryngoscopy. The difference could be because the tongue volume should be taken in relation to the mandibular volume.

Ezri *et al.*[18] measured the neck soft tissue distance from skin to anterior aspect of the trachea at the vocal cords, using ultrasound in fifty obese patients and found that patients with larger neck circumference and more pretracheal soft tissue had difficult laryngoscopy. Hui *et al.*[12] have recently shown that visibility of hyoid bone on a sublingual ultrasound could be predictive of easy laryngoscopy. Their technique did not take much time to perform, and they showed that the inability to visualize the hyoid bone through a sublingual sonographic scan is predictive of a difficult laryngoscopy. One of the limitations of our technique was the time taken for complete airway assessment using ultrasound. In our study, the total time for preoperative airway assessment, to measure all the sonographic variables, was approximately 10 min in each patient. This is more time consuming compared to sublingual ultrasound technique described by Hui *et al*. However, our aim was to identify all possible variables which can be measured and find which had the maximum correlation with the laryngoscopic view.

Another limitation of our study was the use of cutoff points for the different sonographically assessed variables using our own pilot study, except for tongue volume, where we chose the value of >100 cm^3 to predict a difficult laryngoscopy from the study of Wojtczak[13] RFurther research will be needed to find the exact value of these parameters which would identify a difficult laryngoscopy.

Like most other traditional airway assessment indicators, we found that the sonographically assessed indicators also had a better negative predictive value,[19] than a positive predictive value. They may be more useful to predict an easy laryngoscopy than being able to predict a difficult laryngoscopy.

We also did not assess the correlation between the volumes of tongue as assessed by ultrasound, with the modified Mallampati class. Mallampati classification is based on the space occupied by the tongue and use of ultrasound to calculate the exact volume of the tongue, and further research correlating this value with the Mallampati class could provide more information about a difficult laryngoscopy.

Conclusions

In summary, our study shows that ultrasound can be used to assess the airway preoperatively, and several sonographic parameters can be measured. The highest sensitivity and negative predictive value were shown by the skin to epiglottis distance, followed by the volume of the tongue. The exact value of these variables measured sonographically that would correlate with a difficult laryngoscopy needs to be established through future research.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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