



Original Research Article

COMPARISON OF PREOPERATIVE ULTRASOUND-GUIDED AIRWAY
ASSESSMENT AND CLINICAL AIRWAY EXAMINATION IN PREDICTING
DIFFICULT LARYNGOSCOPY IN ELECTIVE SURGICAL PATIENTS: A
PROSPECTIVE OBSERVATIONAL STUDY

Gaurav Saxena¹

¹Senior Resident, Department of Anaesthesiology, Sardar Patel Medical College, Bikaner, Rajasthan, India.

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ABSTRACT

CORRESPONDING AUTHOR

Dr. Gaurav Saxena

Senior Resident, Department of
Anaesthesiology, Sardar Patel
Medical College, Bikaner,
Rajasthan, India.

Email: libran.gaurav95@gmail.com

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Background: The determination of difficult laryngoscopy has often been a tough task for anaesthesia. Despite these situations, standard preoperative airway evaluation is practised. Traditionally performed techniques like the modified Mallampati methods, inter-incisor distance assessment, and assessments of neck mobility have different degrees of reliability which leads to unexpected alterations in the course of anaesthetic management. Airway echography has appeared as a helpful option for the visualization of airway structures. Notably, ultrasound gives more precise measurements of airways. Nevertheless, evidence comparing the parameters obtained by ultrasound to standard clinical evaluation practices is lacking. Objective: This study intends to determine the differential accuracy of ultrasound-guided airway study and traditional clinical airway examination in foretelling difficult intubation in adult patients undergoing planned surgery in general anaesthesia.

Methods: This research was carried out at a teaching tertiary hospital for a period of 12 months. 120 adult patients aged between 18-65 years, belonging to ASA physical status I/II, were enrolled under the study. All of the patients underwent standardized clinical airway evaluation before surgery including Modified Mallampati grading, inter-incisor distance, and neck flexion-extension evaluation of the patients. The patients then underwent ultrasound examination of the airway by high-frequency linear probe to check tongue thickness (TT), skin to epiglottis distance (SED), suprasternal notch anterior neck soft tissue thickness (ANS) and tongue height-to-oral cavity height ratio (TTOHR). The anesthetist doing laryngoscopy remained unaware of the ultrasound result. Modified Cormack-Lehane grading was employed as the gold standard for figuring out challenging laryngoscopy (Grade III/IV) and the Intubation Difficulty Score (IDS) were documented. The diagnostic performance was then evaluated via Receiver Operating Characteristic (ROC) curve analysis, sensitivity, specificity, positive predictive value, negative predictive value, and area under the ROC.

Results: Of the 120 participants, difficult laryngoscopy occurred in 14 (11.7%) patients and difficulty index ≥ 3 was observed in 16 (13.3%) patients. The airway measurements taken by ultrasound were significantly higher in the patients with difficult laryngoscopy. Mean tongue thickness in patients with difficult airway was 6.02 ± 0.41 cm compared to 5.18 ± 0.29 cm in the patients with easy airway ($p < 0.001$). Skin-to-epiglottis distance and anterior neck soft tissue thickness were also greater in patients with difficult laryngoscopies ($p < 0.001$). The tongue thickness was found to have the best diagnostic ability with an AUROC of 0.91, sensitivity of 85.7%, and specificity of 88.3%, followed by skin-to-epiglottis distance with AUROC of 0.87. The traditional Modified Mallampati grading was less predictive with an AUROC of 0.67/sensitivity of 57.1%. This proves that use of ultrasound is much more reliable in aiding in identification of patients at risk for difficult laryngoscopy.

Conclusion: The use of ultrasound-guided airways before surgery provided a significantly better diagnosis of future difficult intubation than the conventional examination at the bedside. The ultrasound assessments showed high capacity for prediction particularly with regard to tongue fatness and distance between skin and epiglottis, thus making them good assistants in pre-anaesthesia examination. Although for large use, the method requires the training of the personnel, possession of the equipment, and elaboration of universal process, it may lead to considerable improvement of the safety of anaesthesia and evaluative procedures. Further multiproject investigations involving patients of different types are advisable in order to make the obtained results possible to implement in the assessment system.

Keywords: Airway ultrasound; Difficult laryngoscopy; Airway assessment; Modified Mallampati grading; Tongue thickness; Skin-to-epiglottis distance; Anterior neck soft tissue; Cormack-Lehane grading; Intubation Difficulty Score; General anaesthesia.

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INTRODUCTION

It is widely accepted that one of the core aspects of the anaesthesiologist's job involves airway management. Indeed, being able to secure the airway and ensure patient safety is among the most important elements surrounding the provision of general anaesthesia.^[1] The glottic view obtained during direct laryngoscopy must be adequate for successful tracheal intubation, as a missing knowledge regarding a potentially difficult airway can lead to complications such as multiple intubation attempts, airway damage, hypoxemia, aspiration, cardiovascular changes, emergency surgical airway procedure, neurological damage, and even death.^[2,3] Therefore, the problem of preoperative difficulties of predicting difficult laryngoscopy is a relevant and crucial clinical issue. Although airway management technologies and algorithms have progressed significantly over the timespan of the last decades, unanticipated difficult laryngoscopy still poses a considerable challenge faced by anaesthesiologists and implies the use of more accurate airway assessment techniques.^[3,4] Research findings suggest that the incidence of difficult laryngoscopy is approximately 1.5% -13%, whereas the difficult intubation is experienced in around 1 -10% of the patients going through general anaesthesia, depending on the definitions and some patient characteristics as well.^[5] The mentioned information suggests that existing preoperatively used techniques can be outdated and useless, thus bringing forward the requirement of development of predictive methods in this area.^[6] Traditionally, the examination of the airway is conducted via clinical examination during the pre-anaesthetic examination. Over the years, numerous clinical tests have been developed for that purpose.^[7] The most popular ones include Modified Mallampati (MP) grading, thyromental distance, sternomental distance, inter-incisor distance, neck circumference, upper lip bite test, thyromental height test, assessment of cervical spine motility, and assessment of the ability of the mandible to protrude.^[8,9] These assessments are cheap, quick, and do not require any specific equipment, which makes them applicable in any clinical practice. Yet each clinical feature shows different sensitivity, specificity, positive predictive value, and negative predictive value in various patient populations. Additionally, bedside tests measure only anatomical landmarks and do not assess the internal anatomy affecting the laryngoscope.^[10,11] Among the various means of assessment, the Modified Mallampati is the most widely used tool for assessing airways all over the world. Initially developed to assess oropharyngeal anatomy, the Modified Mallampati categorizes patients into 4 groups on the basis of the assessment of pharyngeal structures seen when the mouth is maximally opened and the tongue protruded.^[12,13] Although this assessment has a simple approach and is reproducible provided it is done under standard conditions, it relies on a number of patient factors, including cooperation, cognizance, experience of the examiner, cooperation, and position. Other clinical predictors like thyromental and inter-incisor distance

encounter the same limitations. The same conditions also apply to tests like thyromental distance and inter-incisor distance, where the estimate might be affected by factors such as body weight, morphology, age, or musculoskeletal disorders.^[14,15]

Many researchers argue that these assessments should be supplemented with each other, especially considering that their efficiency can be improved by using different combinations of predictors, even if the efficiency is not particularly high due to the number of studies on the efficiency of composite airway assessments.^[16]

False negatives are particularly troubling given that individuals who are thought to have a healthy airway may later go on to experience difficult laryngoscopy when anesthesia is being administered, which ultimately increases the risk for perioperative complications.^[17] The introduction of point-of-care ultrasound has positively impacted various areas of perioperative medicine, including vascular access, regional anesthesia, hemodynamic measurement, gastric volume calculation, and lung imaging. In particular, airway ultrasound has recently gained importance as a useful device that can visualize the anatomy of the upper airway without any invasive techniques.^[18]

Ultrasound is beneficial because it allows for non-intrusive and real-time imaging of the anatomical soft tissue structures without causing any pain or discomfort to the patient as opposed to traditional clinical examination. Ultrasound is able to provide high-resolution images of superficial tissue structures and adequate measurements of airway dimensions that can affect the quality of laryngoscopy, which is not possible through classic means of examination.^[19]

Ultrasound-based examination of the airway has numerous advantages when compared with traditional clinical examination as it allows obtaining precise quantitative measures instead of subjective scoring, evaluating the inner anatomy of the airway, and proving high patient tolerance while being performed directly at the bedside during pre-operative rates.^[20] Moreover, ultrasound examination of the airway doesn't expose patients to radiation and is cheap to use after purchasing the equipment, while becoming more available in some of the most popular ultrasound parameters studied are those relating to the measurement of tongue thickness, distance from skin to epiglottis, thickness of neck soft tissues at various anatomical sites, pre-epiglottic space, the distance from skin to hyoid bone, hyomental distance ratio, ratio of tongue height to oral cavity height, and the computed measurements of the vocal cords and epiglottis.^[21] It is believed that these parameters signify anatomy that defines patient positioning of the oral-pharynx-laryngeal axis in the process of direct laryngoscopy. Increased thickness of the soft tissues surrounding the airway, great volume of the tongue, or altered anatomy of the airway may hinder the visualisation of the glottis and make intubation difficult.^[22]

Among the above-mentioned ultrasound parameters, tongue thickness appears to be a very promising parameter. An enlarged tongue would occupy a bigger space in the oral cavity, thus reducing the size of the working area during laryngoscopy and complicating the

view of the glottis. An increased skin-to-epiglottis distance may be seen as an excess of soft tissue in pre-epiglottic space, thus complicating the positioning of the blade and the visualisation of the place of the larynx opening.^[23] Other parameters like anterior neck soft tissue thickness and the ratio of tongue height to oral cavity height displayed some predictive power in a number of observational studies as well. However, the diagnostic criteria and accuracy of the studies are different for various populations due to the influence of ethnicity, body habitus, operator competency, ultrasound techniques used, and the definition of the difficult airway problem.^[24]

Despite the available evidence proving the efficiency of airway ultrasound, it has not made its way into clinical practice in most cases. There are still many issues like the necessity of specific training for the operator, no standard guidelines for measuring the parameters, difficulties in making readings by several observers due to variations and a lack of the established methods of measurement for the different populations. In addition, medical studies published before have examined only one ultrasound parameter or involved only a limited number of patients, making it impossible to apply the results to the entire population.^[25]

Taking this into consideration, further studies that will compare the results achieved through using ultrasound with those obtained using classical clinical examination would be very useful. These studies should help solve the problem of whether ultrasound can bring practical advantages that would make it possible to use this method widely in the process of preoperative evaluation. This is why comparing the effectiveness of ultrasound results in predicting difficult intubation with those received through classical clinical assessment would be interesting.

Aim

The aim of this study was to determine the diagnostic accuracy of the preoperative ultrasound-guided assessment of the airway in comparison to the standard clinical assessment in predicting difficult laryngoscopy in adult patients undergoing elective surgery under general anaesthesia.

Objectives

Primary Objective

- The aim is to study the predictive ability of ultrasound-based airway parameters like tongue thickness (TT), skin to epiglottis distance (SED), anterior neck soft tissue thickness at suprasternal notch (ANS), and tongue height to oral cavity height ratio (TTOHR) for predicting difficult laryngoscopy.

Secondary Objectives

- To evaluate the effectiveness of the traditional airway evaluation techniques, which consist of Modified Mallampati grading as well as inter-incisor distance.
- To compare the accuracy of ultrasound-based airway study to the regular airway assessment by looking into its sensitivity and specificity.
- To measure how many of the patients who were diagnosed with difficult intubation based on the Modified Cormack-Lehane scale before

undergoing elective surgery under general anaesthesia.

- To analyze if ultrasound airway assessment has a connection with the Intubation Difficulty Score (IDS).
- To find the ultrasound measurement with the most pronounced diagnostic potential in terms of defining difficult intubation.

To analyze the practicality of implementing the ultrasound technique in daily anaesthetic practice to help figure out the patients having the complicated airways before the operation.

MATERIAL AND METHODS

Study Design and Setting

This prospective, double-blinded observational study was undertaken in the Department of Anaesthesiology at a tertiary care teaching hospital in North India over a period of 1 year after the receipt of clearance from the Institutional Ethics Committee. The purpose of conducting the study was to evaluate the advantage of using preoperative ultrasound-guided airway assessment against conventional clinical airway examination in detecting difficult laryngoscopy in adult individuals undergoing elective surgeries under general anaesthesia. Both the anaesthetist conducting the assessment and the anaesthetist performing the laryngoscopy were unaware about the findings of each for avoiding any chances of bias from observers.

Study Duration

The study was carried out over a period of **12 months**, including patient recruitment, perioperative data collection, and statistical analysis.

Study Population

Adults scheduled for elective surgery involving general anaesthesia and endotracheal intubation were evaluated for eligibility. The patients being included at this time were consecutively recruited to avoid selection bias.

Sample Size

The study sample was calculated utilizing findings from past studies which established the rate of difficult laryngoscopy incidence at approximately 10%. Based on the assumption of an 80% power and 5% two-tailed alpha error, the minimal sample to be used for this study was 120 subjects. Therefore, a total sample of 120 patients was used in final analysis.

Inclusion Criteria

Patients fulfilling all of the following criteria were included in the study:

- Age between 18 and 65 years.
- American Society of Anesthesiologists (ASA) physical status I or II.
- Body mass index (BMI) between 18 and 25 kg/m².
- Scheduled for elective surgery under general anaesthesia requiring oral endotracheal intubation.
- Willingness to provide written informed consent for participation in the study.

Exclusion Criteria

Patients meeting any of the following criteria were excluded:

- Anticipated difficult airway requiring an alternative airway management strategy.
- Presence of neck swelling, neck mass, airway tumour, or significant neck pathology.
- Restricted mouth opening (<2 cm).
- Emergency surgical procedures.
- Pregnancy.
- Previous upper airway surgery or major craniofacial abnormalities.
- Patients refusing participation in the study.

Preoperative Clinical Airway Assessment

An expert anesthesiologist blinded to the information obtained with the assistance of ultrasound sound carried out a thorough examination of the airway in the course of pre-anesthetic assessment. Standardized airway exam consisted of:

- Performing Modified Mallampati (MP) rating.
- Measurement of inter-incisor distance.
- Evaluation of neck flexion and extension.

Modified Mallampati rating was done in a sitting patient with the mouth wide open and tongue extended out and without any sound being made. Inter-incisor distance refers to the greatest distance between the maximum open upper and lower incisors. Cervical spine movement was assessed by evaluating neck flexion and extension movements. All parameters were documented before induction of anesthesia.

Ultrasound-Guided Airway Assessment

The ultrasound test was done prior to surgery in the preparation room with the aid of a high-frequency linear transducer with a range of 6–13 MHz. The patients were placed in a position where they are lying on their back with their heads facing either side, so as to ensure standardization in the image capturing process.

The parameters measured using ultrasound:

- The thickness of the tongue (TT).
- The distance from the skin to the epiglottis (SED).
- The distance of the soft tissues in the neck in the suprasternal notch (ANS).
- The height of the tongue compared to the height of the mouth (TTOHR).

All measurements were taken following the parameters specified. The person conducting the ultrasound remained unaware of the results of the tests previously conducted and did not take part in the laryngoscopy and intubation processes.

Anaesthetic Technique

All patients received treatment in accordance with an anesthetic protocol. The anesthetic protocol included electrocardiography, blood pressure measurement, measuring the level of oxygen in the blood, and measuring the level of carbon dioxide before the induction process.

The drugs used during the preoperative stage included glycopyrrolate (0.01 mg/kg), midazolam (0.04 mg/kg), fentanyl (2 µg/kg), and dexamethasone (8 mg).

The process of general anesthesia was initiated with the use of propofol (2 mg/kg), and the effect was enhanced with the aid of vecuronium (0.1 mg/kg).

Outcome Measures

Primary Outcome

The primary outcome was the occurrence of difficult laryngoscopy, defined as Modified Cormack–Lehane Grade III or Grade IV during direct laryngoscopy.

Secondary Outcomes

The auxiliary outcome variables comprised:

- The Intubation Difficulty Score (IDS).
- Assessment of ultrasound-derived metrics of the airway in easy vs difficult laryngoscopy cohorts.
- Evaluation of conventional methods of airway assessment in the light of ultrasound.
- Diagnostic value of unique metrics of the airway identified through Receiver Operating Characteristic (ROC) curve analysis.
- Evaluation of individual clinical parameters and ultrasound metrics in terms of sensitivity, specificity, PPV, NPV and AUROC.

Statistical Analysis

Data was organized using Microsoft Excel and analyzed with the Statistical Package for Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) while categorical variables as frequencies and percentages.

Comparisons between easy and difficult laryngoscopy patients were done using the independent Student's t-test for continuous variables while the Chi-square test and Fisher's exact test were used for categorical variables. The receiver operating characteristic (ROC) curves were designed for outcome evaluation of clinical and ultrasound evaluation. The area under the ROC curve (AUROC), the best-cut values, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and total accuracy was calculated. The two-tailed P value of less than 0.05 was considered statistically significant.

Ethical Considerations

The ethics committee approved the research protocol prior to initiating patient recruitment. The study was conducted in accordance with the ethical principles stated in the Helsinki Declaration and regulations envisaged under GCP. Consent was obtained in written format from all study participants prior to participation in the trial. The data collected during the study was anonymized for ensuring confidentiality of the patients involved in the research process.

RESULTS

A total of 120 patients undergoing elective surgery were included and completed the study. All patients underwent conventional clinical airway assessment, ultrasound-guided airway evaluation, and direct laryngoscopy. Baseline demographic characteristics were comparable across the study population. Difficult laryngoscopy (Cormack–Lehane grade III–IV) was observed in 14 patients (11.7%), while difficult intubation (IDS ≥3) occurred in 16 patients (13.3%). Ultrasound-derived airway measurements were significantly greater in patients with difficult laryngoscopy. Among all sonographic parameters, tongue thickness demonstrated the highest diagnostic accuracy, followed by skin-to-epiglottis

distance. Overall, ultrasound-guided airway assessment outperformed conventional clinical airway assessment in predicting difficult laryngoscopy.

Table 1. Baseline demographic characteristics of the study population
The study population showed balanced baseline demographic characteristics.

Variable	Overall (n=120)
Age (years), Mean $\pm$ SD	43.2 $\pm$ 11.4
Male, n (%)	62 (51.7)
Female, n (%)	58 (48.3)
BMI (kg/m ²), Mean $\pm$ SD	22.1 $\pm$ 1.9

Table 2. Incidence of difficult laryngoscopy and intubation difficulty
Difficult laryngoscopy was observed in 11.7% of patients, while difficult intubation (IDS $\geq$ 3) occurred in 13.3%.

Outcome	Number (%)
Easy laryngoscopy (CL Grade I–II)	106 (88.3)
Difficult laryngoscopy (CL Grade III–IV)	14 (11.7)
IDS <3	104 (86.7)
IDS $\geq$ 3	16 (13.3)

Table 3. Comparison of ultrasound airway parameters between easy and difficult laryngoscopy
All ultrasound airway parameters were significantly higher in patients with difficult laryngoscopy.

Parameter	Easy (n=106)	Difficult (n=14)	P value
Tongue thickness (cm)	5.18 $\pm$ 0.29	6.02 $\pm$ 0.41	<0.001
Skin-to-epiglottis distance (cm)	2.19 $\pm$ 0.21	2.58 $\pm$ 0.26	<0.001
Anterior neck soft tissue (cm)	0.94 $\pm$ 0.23	1.55 $\pm$ 0.18	<0.001
Tongue height/oral cavity height ratio	0.71 $\pm$ 0.05	0.83 $\pm$ 0.06	<0.001

Table 4. Diagnostic accuracy of ultrasound and clinical airway parameters
Tongue thickness demonstrated the highest diagnostic accuracy for predicting difficult laryngoscopy.

Parameter	AUROC	Sensitivity (%)	Specificity (%)
Tongue thickness	0.91	85.7	88.3
Skin-to-epiglottis distance	0.87	78.5	86.7
Anterior neck soft tissue	0.84	75.0	82.4
Tongue height/oral cavity height ratio	0.82	71.4	84.9
Modified Mallampati grading	0.67	57.1	72.6

Table 5. Comparison of ultrasound-guided and conventional airway assessment
Ultrasound-guided airway assessment demonstrated superior diagnostic performance compared with conventional clinical airway examination.

Assessment method	Best parameter	AUROC	Overall performance
Ultrasound-guided airway assessment	Tongue thickness	0.91	Excellent
Conventional clinical airway assessment	Modified Mallampati grading	0.67	Moderate

Tables Summary

Table 1 showed that the study population had comparable baseline demographic characteristics, with a mean age of 43.2 years, balanced gender distribution, and a mean BMI of 22.1 kg/m². **Table 2** demonstrated that difficult laryngoscopy occurred in 11.7% of patients, while difficult intubation (IDS $\geq$ 3) was observed in 13.3%, confirming the clinical relevance of identifying predictors of difficult airway management. **Table 3** showed significantly greater tongue thickness, skin-to-epiglottis distance, anterior neck soft tissue thickness, and tongue height-to-oral cavity height ratio in patients with difficult laryngoscopy, indicating a strong association between ultrasound airway measurements and difficult laryngoscopy. **Table 4** demonstrated that tongue thickness was the most accurate ultrasound predictor of difficult laryngoscopy, followed by skin-to-epiglottis distance, whereas the Modified Mallampati grading showed substantially lower diagnostic

performance. **Table 5** confirmed the overall superiority of ultrasound-guided airway assessment over conventional clinical airway examination, supporting its value as an adjunctive tool for preoperative prediction of difficult laryngoscopy.

DISCUSSION

The present prospective observational research aimed to evaluate and compare the effectiveness of ultrasound-guided assessment before the surgery and standard clinical practice to correctly predict the occurrence of difficult laryngoscopy in adult patients subjected to elective operation under general anesthesia.^[1] The results indicated that the parameters providing through ultrasound, particularly tongue thickness and distance from skin to epiglottis, had a substantial advantage over the conventional bedside assessment of the airway.^[2] Out of all the parameters assessed through ultrasound, the

thickness of the tongue was the most effective with an AUROC of 0.91, proving to have a very good ability to differentiate patients with a higher risk of experiencing difficulties with laryngoscopy.^[3] The present research supports the emerging evidence that proves the effectiveness of ultrasound technique in acquiring precise anatomical data enabling better assessment of the airway before the operation and detection of potentially problematic situations during the operation quicker.

In the present research, it was found that patients were diagnosed with difficult laryngoscopy in 11.7% of cases. The frequency of this diagnosis is within the limits indicated by studies assessing elective surgical patients.^[5] The differences among the frequencies presented in the studies can be explained by patient characteristics, body structure, race, assessment of the airway, experience of the operator, and what is considered difficult laryngoscopy.^[6] The low incidence of difficult laryngoscopy in this research can be explained by the inclusion of only ASA I and ASA II patients, who have normal BMI and undergo elective surgery. Therefore, it is a typical case of low-risk patients.^[7]

Despite a small proportion of occurrences, the results of the present research prove that the importance of thorough assessment of the airway before the operation cannot be underestimated. Tongue thickness was significantly higher in patients undergoing difficult direct laryngoscopy than in patients undergoing easy direct laryngoscopy.^[8] This means that a greater volume of the oral cavity is taken up by tongue tissue, leaving less room for carrying out direct laryngoscopy and restricting motion of soft tissues.^[9] Hence, visualization of the glottis becomes harder and Cormack-Lehane scores are higher due to this. The very good AUROC for tongue thickness obtained in this study agrees with recent studies indicating tongue thickness as a reliable predictor of laryngoscopy difficulty.^[10]

The obtained results are similar to the findings of Nandi et al. who highlighted excellent predictive value of tongue thickness in difficult airway evaluation in adults. In addition, this study indicates that tongue thickness was significantly greater in patients with difficult laryngoscopy than in patients undergoing easy laryngoscopy, pointing out that tongue thickness is a better predictor compared to standard clinical assessment.^[9,11]

The distance from the skin to the epiglottis showed excellent predictive ability as well. During difficult laryngoscopy, the distance from the skin to the epiglottis was significantly more pronounced than during laryngoscopy without complications.^[12] Increased volume of pre-epiglottic soft tissue might limit the upward movement of the epiglottis, thus making visualization of the vocal cords impossible.^[13] Since this parameter reflects internal characteristics of airways, its value for the specialists is very high. Such results are in line with the results reported by Falcetta et al., who found that distance skin-to-epiglottis is one of the most accurate predictors of difficult intubation as assessed with ultrasound technology.^[8] In their receiver operating characteristic analysis, they showed that skin-to-epiglottis distance outperformed the conventional airway assessment methods in terms of diagnostic accuracy.

Likewise, Andrews et al. reported similar findings and claimed that higher measurements in the anterior airway soft tissue contribute to poor visualization of the larynx during direct laryngoscopy.^[11,14,15]

The thickness of the soft tissues of the neck at the suprasternal notch as well as tongue height-to-oral cavity height ratio also had statistically significant correlations with difficult intubation in this study. The performance of these parameters was a little lower than that of tongue thickness and skin-to-epiglottis distance but both parameters still demonstrated good sensitivity and specificity.^[16] The results above show that different sonographic measures help to find out the anatomical features that make difficult intubation possible. In addition, it was found that increased thickness in the soft tissues of the neck prevents the laryngoscope from getting in its best position which, is similar to higher tongue height-to-oral cavity height ratio that shows the amount of space in the oral cavity during intubation process.^[17] On the contrary, traditional Modified Mallampati scale showed a rather low performance in terms of sensitivity and specificity compared to all other parameters obtained with the help of ultrasound.^[18] Despite Mallampati grading being among the most common airway assessment techniques used by doctors, critics have raised important concerns about its efficacy due to interobserver variability, depending on patient cooperation, and no true evaluation of internal airway structure. The lower AUROC value posited in this research echo earlier systematic reviews that found Mallampati grading not to be a reliable technique for the prediction of difficult intubation.^[19,20]

Findings of this study confirm the findings presented by Roth et al. in their Cochrane systematic review stating that there is no single clinical airway evaluation technique that is sufficient for providing adequate predictive results for difficult intubation. The authors stressed that conventional techniques usually show limited sensitivity and may miss many individuals whose airways are difficult to intubate. Such drawbacks necessitated searching for alternative techniques such as imaging techniques allowing assessing anatomical features of airways.^[4,5]

In the same vein, Rao et al. stated that the measurements received through the ultrasound technique are better in predicting the likelihood of encountering difficulties in intubation as compared with conventional measurements.^[7] The researchers found statistically significant associations linking the thickness of the tongue and the measurement of the soft tissue of the anterior neck with the difficult glottic visualization; similarly, Rastogi et al. received favorable results showing higher effectiveness of ultrasound in predicting the outcome of intubation in comparison with conventional techniques.^[10]

A significant advantage of this research is its prospective double-blinded design that eliminated the bias of observers because the anaesthetist responsible for ultrasound evaluation did not know the results of the clinical examination of airways and the anaesthetist, who performed intubation procedures, was not aware of the ultrasound results.^[21,22] The uniformity of the anaesthetic protocols, same method of conducting ultrasound and measuring several sonography parameters contributed to

the validity of the research findings. The simultaneous evaluation of conventional parameters along with ultrasound data has made the assessment more comprehensive with the findings grounded on numerous parameters under comparison.^[23-25]

Nevertheless, some limitations should be indicated as well. The fact that the study was conducted at a single institution limits the possibility of using the findings for other health care settings. Apart from that, a small sample of patients suffering from difficult airway or difficult intubation made statistical analysis of the obtained results less powerful, and exclusion of patients with several conditions such as obesity, propensity to difficult airway, pregnancy, and other serious conditions limits the implications of the research. Besides, it is important to indicate that achieving the reproducible results, it is vital to ensure proper training of people dealing with the ultrasound evaluation of the airways because the effectiveness of the ultrasound investigation depends on the operator. There are two main problems hindering broader implementation of the ultrasound technologies into the routine practice of anaesthetists, including the lack of uniform ultrasound techniques and cut-off value definitions.

The future studies should encompass larger and diverse populations to determine standardized ultrasound measurement techniques, and cut-off values. Further studies should also investigate the role of artificial intelligence in image interpretation as well as the prospects of three-dimensional ultrasound in predicting the need for intubation.

CONCLUSION

The ultrasound assessment of the airways before the surgical procedure showed a better rate of diagnosing than the traditional methods of evaluating the airways in adults undergoing surgeries. The features derived from ultrasound, namely skin-to-epiglottis distance and tongue thickness, achieved a highly credible status when it comes to sensitivity and specificity and overall prediction capability which exceeds that of the Modified Mallampati system. The information obtained suggests that the ultrasound evaluation of the airways is an objective method of assessment of their anatomy and serves as a good addition to the habitual practice of evaluation of airways before a surgical procedure. Nonetheless, for a wider application of the method, special training of the doctors is required due to the narrow usage of ultrasound equipment currently. Hence, usage of the method may increase the level of preparedness for surgeries.

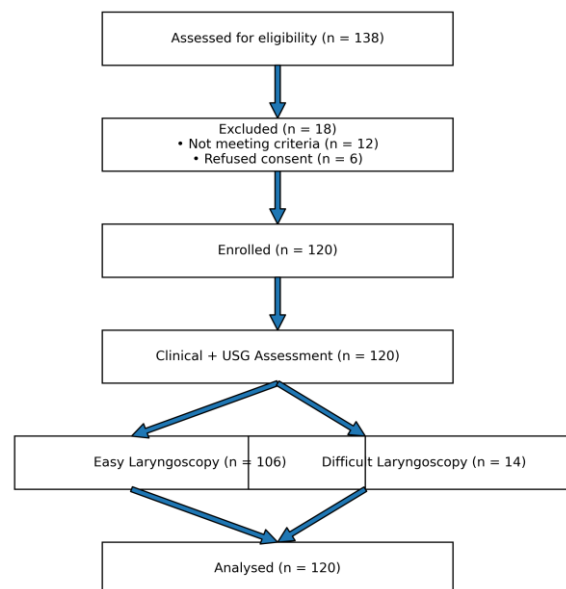


Figure 1. CONSORT Flow Diagram Illustrating Participant Recruitment, Enrollment, Airway Assessment, and Analysis

The recruiting process and the continuity of participants in the study are shown in the flow-chart in Figure 1. Before the study commenced, 138 patients were contacted in terms of eligibility. Of them, a total of 12 patients were ruled out according to the inclusion criteria and 6 patients did not agree to provide consent. The rest of the participants (n = 120) took part in the study whereby both a clinical airway examination and an ultrasound-guided airway assessment were performed. Following a general anaesthesia, a direct laryngoscopy was carried out whereby 106 participants were identified as having an easy intubation according to Cormack-Lehane grades, whereas 14 patients were classified as having a difficult intubation according to Cormack-Lehane grades.

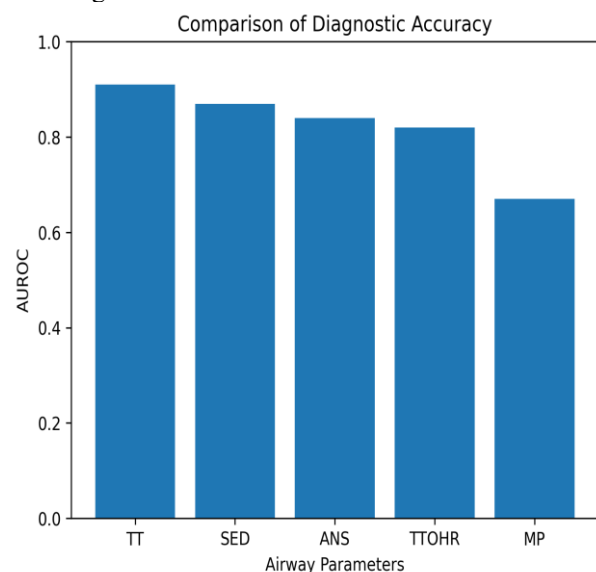


Figure 2. Comparison of the Diagnostic Accuracy (Area Under the Receiver Operating Characteristic Curve) of Ultrasound-Derived Airway Parameters and Modified Mallampati Grading for Predicting Difficult Laryngoscopy

The bar chart in Figure 2 illustrates the efficiency, in terms of the area under curve (AUC), of each of the airway assessment parameter tested in this report. The parameter with the highest AUC is Tongue thickness (TT) with a value of 0.91, followed by Skin-to-epiglottis distance (SED), which had an AUC of 0.87, Anterior soft tissue neck thickness (ANTS) with an AUC of 0.84 and Tongue height-to-oral cavity height ratio (TTOHR) with an AUC of 0.82 respectively. In contrast to the other diagnoses, Modified Mallampati (MP) grade has produced the least performance with a value of AUC equal to 0.67. Thus, the ultrasound measurements of the airways seem more effective in diagnosing the hard intubation in patients who undergo elective surgery under general anesthesia than the conventional airway assessment.

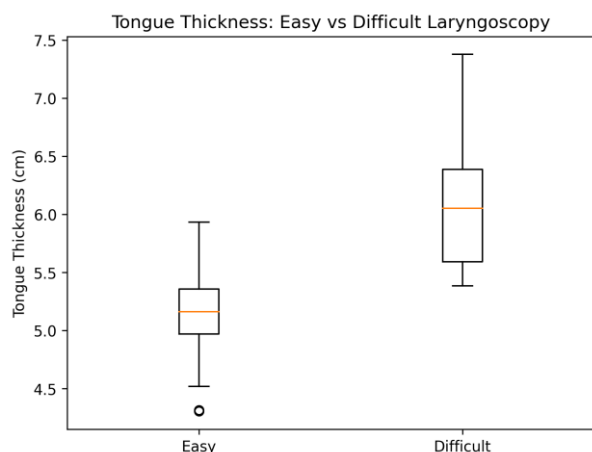


Figure 3. Distribution of Tongue Thickness Between Patients with Easy and Difficult Laryngoscopy

Figure 3 presents a box-and-whisker plot illustrating tongue thickness (TT) that was measured preoperatively by ultrasound in both groups of patients having easy and difficult laryngoscopy. It can be seen that tongue thickness in patients with difficult laryngoscopy was statistically significantly higher than in those patients where laryngoscopy was easy, measuring 6.02 ± 0.41 cm and 5.18 ± 0.29 cm, respectively ($P < 0.001$). From the box plot, we can see the distribution of the data, where the box indicates interquartile range (IQR), the horizontal line inside each box represents the median of the data set, while the whiskers indicate the range of values without outliers and isolated points indicating the outlier(s). The analysis shows that higher tongue thickness is strongly correlated with difficult laryngoscopy in this study and is confirmed as the most accurate ultrasound-derived predictor of difficult airway.

Figures Summary

The illustrations presented provide various details pertaining to the study design. The first diagram depicts the whole process of recruiting participants indicating that 138 patients were assessed and finally 18 were not included so that the analysis involved 120 people who became a subject of further evaluation. The second picture shows the DIAGNOSTIC ACCURACY OF Subheadings: DATSIN INTO DIAGNOSTIC ACCURACY in terms of assessing the level of the airway AS DETERMINED BY AUROC. This indicates that the maximal accuracy belongs to the tongue

thickness (0.91) and this variable is followed by the distance from the skin to epiglottis (0.87), the anterior neck soft tissue thickness (0.84), and the tongue height (0.76). Last but not least, the following figure compares the tongue thickness in patients with easy and difficult laryngoscopy that clearly shows that patients with difficult laryngoscopy have greater dimensions of the tongue. To conclude, it can be said that the diagrams presented above help to understand the information given in tables

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