# COMPARISON BETWEEN CLINICAL AND ULTRASONOGRAPHIC PARAMETERS IN PREDICTING DIFFICULT AIRWAY: AN OBSERVATIONAL PROSPECTIVE STUDY

*Deepak Poudel[1*], Kumud Pyakurel[2], Birendra Prasad Sah[3], Anuja Pokhrel[4], Kanak Khanal[5], Lalit Kumar Rajbanshi[6]*

***Affiliation***

1. *Lecturer, Department of Anaesthesia and Critical Care, Birat Medical College and Teaching Hospital, Nepal*
2. *Assistant Professor, Department of Anaesthesia and Critical Care, Birat Medical College and Teaching Hospital, Nepal*
3. *Professor, Department of Anaesthesia and Critical Care, Birat Medical College and Teaching Hospital, Nepal*
4. *Lecturer, Department of Anaesthesia and Critical Care, Birat Medical College and Teaching Hospital, Nepal*
5. *Consultant, Department of Anaesthesia and Critical Care, Birat Medical College and Teaching Hospital, Nepal*
6. *Associate Professor, Department of Anaesthesia and Critical Care, Birat Medical College and Teaching Hospital, Nepal*

**ARTICLE INFO**

Received : 15 May, 2023

Accepted : 28 June, 2023

Published : 10 November, 2023



**ORA 355**

**DOI:** https://doi.org/10.3126/bjhs.v8i2.59856

**Corresponding Author**

*Dr. Deepak Poudel*
*Lecturer*
*Department of Anaesthesia and Critical Care*
*Birat Medical College & Teaching Hospital*
*Tankisinuwari, Morang, Nepal*
*Email: drdeepak.poudel@gmail.com*
*ORCID : https://orcid.org/0000-0001-9592-2750*

**Citation**

Comparison between clinical and ultrasonographic parameters in predicting difficult airway: An observational prospective study. Deepak Poudel, Kumud Pyakurel, Birendra Prasad Sah, Anuja Pokhrel, Kanak Khanal, Lalit Kumar Rajbanshi. BJHS 2023;8(2)21. 2039 - 2044.

## ABSTRACT

### Introduction

Various clinical tests are applied at the bedside to predict difficult airway during the pre-anaesthetic examination. Ultrasonography can be used to evaluate the airway and predict difficulty in laryngoscopy and endotracheal intubation.

### Objective

To compare the various clinical and ultrasonographic parameters in predicting difficult airway.

### Methodology

This prospective observational study was carried out at Birat Medical College and Teaching Hospital.The clinical parameters obtained were Modified Mallampati Grade (MMP), Upper Lip Bite Test (ULBT) and Thyromental Distance (TMD) and the ultrasonographic (USG) parameters used were Tongue Volume (TV), Hyomental Distance Ratio (HMDR) and distance of soft tissue from skin to hyoid bone (DSHB).These results were correlated with Cormack-Lehane (CL) grade during laryngoscopy of 200 patients. The sensitivity, specificity, Receiver Operating Characteristic (ROC) curve along with Area under the curve (AUC) was calculated for each parameter.

### Result

Incidence of difficult airway was 15.5%. The sensitivity and specificity of ultrasonographic tongue volume (TV) was higher among all parameters in predicting difficult airway. The specificity of HMDR and DSHB were better compared to clinical parameters.

### Conclusion

The use of ultrasound in pre-anaesthetic examination can be a viable tool along with clinical parameters for prediction of difficult airway.

## KEYWORDS

Airway ultrasonography; Anterior neck soft tissue; Difficult airway; Tongue volume.

## INTRODUCTION

Difficult airway encompasses various scenarios involving difficult face-mask ventilation, inability for placing supraglottic airway devices, limited glottis view on laryngoscopy, multiple attempts at tracheal intubation, or poorly identifiable surgical airway landmarks.[1] Difficult laryngoscopy is said to be the main cause of difficult airway.[2] This can be encountered by anesthesiologists, emergency physicians, intensivists and paramedical health care workers. Unanticipated difficult airway may be challenging to manage and may significantly increase morbidity and mortality.[3]

Various clinical and physical predictors of difficult airway have been in use with varying degree of significance. The most commonly used airway assessment parameters include Modified Mallampati Score(MMP), Upper Lip Bite Test, Inter-Incisor Gap, Thyromental Distance, Hyomental distance, Sternomental distance, Neck Mobility and Circumference either alone or in combinations.[4] Despite the assessment tools, the incidence of unanticipated difficult airway can be 2-8 %.[5] These clinical parameters may be difficult to assess in trauma, uncooperative or unconscious patients.

The use of ultrasonography, as an additional tool, in perioperative and critical care setting can help health care providers to predict difficult airway using various parameters. Being noninvasive, reproducible, portable and at the point of care helps to guide further management of the airway. Ultrasonography of the airways is feasible, informative and can be rapidly assessed.

Prediction of difficult airway results in anticipation and preparation to prevent morbidity and mortality in the operating rooms, intensive care units and emergency departments. Predicting difficult laryngoscopy is important because 30-40% of these cases have difficult tracheal intubation .[7] The rationale of this study was to provide data regarding use of ultrasonography for airway evaluation.

The objective of this study was to compare the predictive ability of various clinical parameters with that of ultrasonographic parameters. This study will help in decision making among anesthetists during pre-anaesthetic assessment of the airway.

## METHODOLOGY

After obtaining permission from Institutional Review Committee (IRC) and informed written consent, this prospective, cross-sectional and observative study was carried out in 200 patients (ASA I and II) who required general anesthesia with endotracheal intubation. The sample size was calculated according to the study by Rana et al who found the incidence of difficult intubation to be 12.5%.[8] Using Fisher's formula [$n = t^2 \times P(1 - P)/m^2$ where n = required sample size; t = confidence level at 95% (standard value of 1.96); P = 0.125; m = margin of error at 5% (standard value 0.05)]. The sample size was calculated to be 168. We enrolled 200 patients, to allow for probable dropout. Patients unwilling to participate, pregnant women, patients with oral and cervical pathology, mouth opening less than 3 cm, limited cervical spine mobility and patients unable to follow commands were excluded.

In the preoperative holding area both clinical and ultrasonographic parameters were assessed and recorded. The routine airway assessment included mouth opening, Modified Mallampati (MMP) grade, Upper lip bite test (ULBT), thyromental distance and cervical mobility. The patients meeting the inclusion criteria were further evaluated using ultrasonography.

The clinical parameters recorded were MMP grade, ULBT and thyromental distance in sitting and relaxed position. The ultrasonographic parameters were recorded using high frequency linear probe (6-13 MHz) and low frequency curvilinear probe (2-5 MHz) (Sonosite® M-Turbo, Fujifilm® Sonosite, Bothell, WA, USA). The patients were asked to lie supine with head and neck in neutral position. The linear probe was placed at the floor of mouth, midway between mentum of the mandible and hyoid bone to visualize the tongue and maximum transverse tongue width (Tw) was measured. The linear probe was then used to measure soft tissue distance from skin to hyoid bone (DSHB).The hyoid bone was identified in transverse plane as hyper echoic inverted U-shaped structure with posterior acoustic shadowing. In the neutral position curvilinear probe was placed sagittal at the floor of mouth to measure length of the tongue (TL)from tip of tongue to base of tongue .The curvilinear probe was then rotated by 90 degrees and maximum tongue height(Th) was measured transverse plane. In the same neutral position hyomental distance (HMDn) was measured with curvilinear probe. Now the patient was asked to maximally extend the head without raising the shoulders. The curvilinear probe was again placed sagittal at the floor of the mouth and hyomental distance was measured (HMDe). The tongue volume was calculated as result of multiplication of tongue length (TL), height (Th) and width (Tw). The hyomental distance ratio (HMDR) was computed as ratio between HMDe and HMDn. The hyomental distance ratio was chosen because in previous studies it has been shown that patient's age, height and BMI may have an impact on absolute hyomental distance values.[9]

The patients were then induced as per the institution protocol and laryngoscopy was performed using appropriate size Macintosh blade and Cormack-Lehane(CL) grade was assessed without external laryngeal manipulation by an anesthetist not aware of the clinical and ultrasonography findings . The laryngoscopy was classified as easy (CL Grade 1 and 2) or difficult (CL Grade 3 and 4). The trachea was intubated using appropriate size endotracheal tube. The

anesthesia was maintained and surgery proceeded according to the standard protocol. Difficulty in intubation, change of blade or use of external manipulation or gum elastic bougie or CVCI scenarios (Could not Ventilate, Could not Intubate) was noted. The CVCI scenarios are among the most dreaded conditions where in the bag and mask or endotracheal intubation are impossible and may result in significant hypoxia with organ damage or mortality.

The MS Excel® 2010 and SPSS® 22 (SPSS Inc., Chicago, IL, USA) were used for data entry and analysis. The results were averaged (mean ± standard deviation [SD]) for each parameter for continuous data. The Chi-square test was used to determine the statistical difference between the easy and difficult airway. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated to assess the predictive value of the tests. The receiver operating characteristic (ROC) graphs were plotted to assess the optimal cut-off scores, and the area under the curve (AUC) was calculated to assess the prognostic accuracy.

## RESULTS

200 patients were examined using both physical and ultrasonographic parameters, which included 133 females and 67 males. The demographic pattern and distribution of patients in easy and difficult laryngoscopy group is shown in Table 1. The distribution of CL grade is shown in figure1.Since CL grade III and IV were allotted as difficult airway group, the incidence of difficult airway was 15.5%.The 3 patients with CL grade IV were intubated on repeated attempts with help of gum elastic bougie and change of laryngoscope blade. We did not encounter “could not ventilate, could not intubate (CVCI)” scenarios.

Among the clinical parameters, MMP grade had sensitivity of 89.9%, specificity of 54.8%, Positive predictive value (PPV) of 92%, Negative predictive value (NPV) of 70.8%.The receiver operating curve (ROC) was plotted which showed area under curve (AUC) of 0.753, which was highest among the clinical parameters. The Upper Lip Bite Test (ULBT) had sensitivity of 88.2%, specificity of 19.4%, Positive predictive value (PPV) of 86.9%, Negative predictive value (NPV) of 66.7%. ROC was plotted which showed AUC of 0.588. The Thyromental Distance (TMD) had sensitivity of 80.9%, specificity of 22.6%, Positive predictive value (PPV) of 86.4%, Negative predictive value (NPV) of 29.2% and ROC showed AUC of 0.563.

Similar to the clinical parameters, ROC was plotted for the Ultrasonographic parametersUtilising receiver operating curves, the cutoff value for predicting difficult laryngoscopy for tongue volume was found to be 100.08cm$^3$ with sensitivity of 93.5% and specificity of 72.85%. The AUC for TV was found to be 0.90(95% CI: 0.83-0.966, p=0.00) which shows it to be a fairly good test to predict difficult laryngoscopy. The cut off value for HMDR was found to be 1.09 with sensitivity of 64.5% and specificity of 88.2%. The AUC for HMDR was 0.885(95% CI: 0.817-0.953, p=0.00) which depicts a fairly good predictive utility. The AUC for DSHB was found to be 0.732(95% CI: 0.636-0.872, p=0.0014) and cut off value of 0.75cm with sensitivity of 67.75% and specificity of 66%.

We correlated all clinical and ultrasonography parameters with CL grading. The MMP showed moderate positive correlation (r=0.0611 and p=0.000) where as ULBT and thyromental distance had moderate positive (r=0.0552, p=0.000) and moderate negative (r=-0.0219, p=0.0000) correlation respectively. Among the ultrasonographic parameters tongue volume showed moderate positive correlation (r=0.581, p=0.000) whereas DSHB and HMDR had moderate positive (r=0.299, p=0.000) and moderate negative (r= -0.410, p=0.000) correlations respectively.

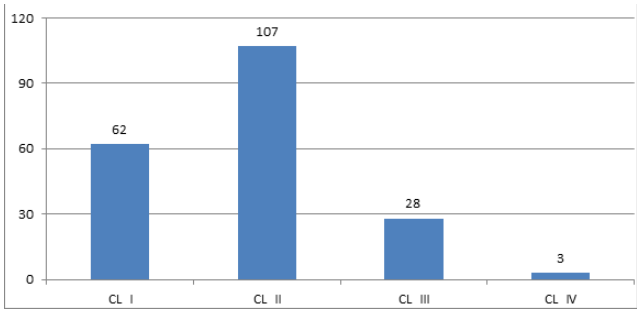


**Figure 1:** Distribution of Cormack-Lehane (CL) grade

**Table 1:** Demographic distribution of patients

| Parameters | Easy laryngoscopy | Difficult laryngoscopy | P |
|---|---|---|---|
| Number | 169 | 31 | - |
| Weight (KG) | 61.9±11.03 | 62.96±11.07 | *0.140* |
| BMI | 25.56±5.29 | 27.89±5.25 | *0.171* |
| Height(M) | 1.56±0.11 | 1.51±0.11 | *0.113* |

**Table 2:** Various parameters used for airway evaluation

| Parameters | Easy laryngoscopy | Difficult laryngoscopy | P |
|---|---|---|---|
| MMP I | 108 | 1 | *0.000* |
| MMP II | 54 | 12 | *0.000* |
| MMP III | 7 | 14 | *0.000* |
| MMP IV | - | 4 | *0.000* |
| ULBT 1 | 120 | 3 | *0.006* |
| ULBT 2 | 46 | 17 | *0.000* |
| ULBT 3 | 3 | 11 | *0.001* |
| TMD | 6.11±0.961 | 6.69±0.984 | *0.019* |
| TV in cm$^3$ | 96.04±17.20 | 123.6±17.62 | *0.021* |
| DSHB in cm | 0.70±0.162 | 0.84±0.16 | *0.037* |
| HMDR | 1.16±0.08 | 1.08±0.08 | *0.026* |

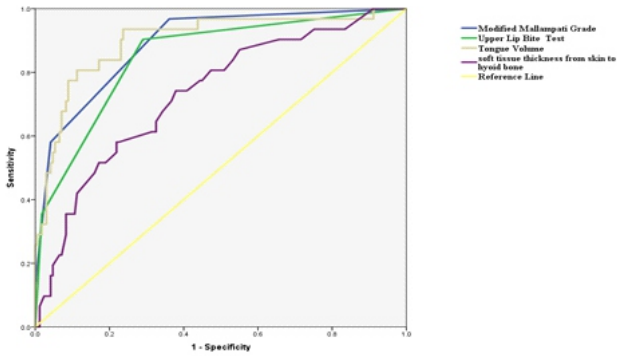


**Figure 2:** Receiver Operating Characteristics (ROC) analysis for MMP, ULBT, TV and DSHB.

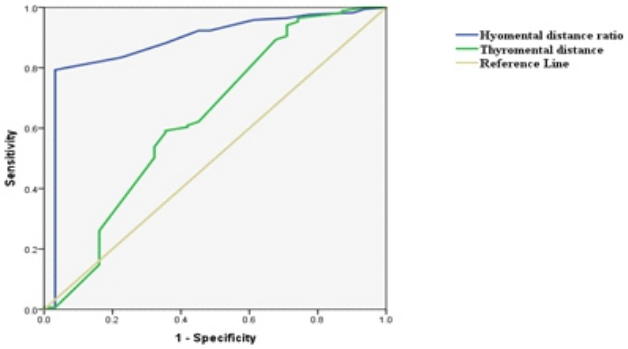


**Figure 3:** Receiver Operating Characteristics (ROC) analysis for HMDR and TMD.

**Table 3:** AUC of various clinical and ultrasonographic parameters.MMP: Modified Mallampati Grade, ULBT: Upper Lip Bite Test, TMD: Thyromental Distance, DSHB: Distance of Soft Tissue from Skin to Hyoid Bone, TV: Tongue Volume, HMDR: Hyomental Distance Ratio.

| Parameters | AUC | *P* | 95% Confidence Interval | | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|---|
| | | | Lower Bound | Upper Bound | | |
| MMP | 0.891 | 0.000 | 0.831 | 0.950 | 89.9 | 54.8 |
| ULBT | 0.850 | 0.000 | 0.775 | 0.925 | 88.2 | 19.4 |
| TMD(cm) | 0.367 | 0.019 | 0.247 | 0.487 | 80.9 | 22.6 |
| DSHB | 0.732 | 0.000 | 0.636 | 0.827 | 67.75 | 66 |
| TV | 0.900 | 0.000 | 0.834 | 0.966 | 93.5 | 72.85 |
| HMDR | 0.885 | 0.000 | 0.817 | 0.953 | 64.5 | 88.2 |

## DISCUSSION

The use of various predictive parameters can be of immense value in reducing morbidity and mortality in cases of both anticipated and unanticipated difficult airway. These parameters enable anesthetists to be aware and hence prepared to identify and manage difficult airway scenarios. Various clinical parameters rely on patients being awake and able to obey commands to assess mouth opening, Modified Mallampati grade, thyromental distance, upper lip bite test, and neck circumference and neck movement. These tests have been used with variable success rates.[10]

The availability of USG in the OR and ICUs has provided its use in management of the airway.[6] The USG can be used to measure anterior neck soft tissue thickness at levels of hyoid bone, vocal cords, epiglottis, trachea, cricothyroid membrane, predict endotracheal tube sizes , predict post extubation stridor , visualization of cricothyroid membrane during cricothyrotomy and diagnosing laryngeal abnormalities.[11-15]

Clinical parameters and CL grade prediction

In a Meta analysis conducted by, Roth D. et al. Modified Mallampati grade had sensitivity of 53%(95% CI: 0.47-0.59) and specificity of 80%(95% CI:0.74-0.85) , thyromental distance had sensitivity of 37%(95% CI:0.28-0.47) and specificity of 89%(95% CI:0.84-0.93) where as upper lip bite test had sensitivity of 67%(95% CI:0.45-0.83) and specificity of 92%(95% CI:0.86-0.95).[16]The results obtained in our study show similar trends except for the specificity of ULBT and TMD which is much lower in our study population.

In another meta- analysis, the various bedside clinical parameters for difficult airway had limited or inconsistent predictive values. The authors suggested use of multiple or combined parameters to predict difficult airway.[17] We found similar trend in our study with low specificity as MMP had specificity of 54.8%, specificity of ULBT and TMD was 19.4% and 22.6% respectively.

Ultrasonographic parameters and CL grade Prediction

In a study conducted by Ohri R. et al. in 50 adult patients, the correlation between tongue volume and difficulty in laryngoscopy was evaluated using real time 2D ultrasonography and found that larger tongue volume as measured by USG are associated with more difficult laryngoscopy.[18] This was based on the clinical assumption that size and volume of tongue might directly affect laryngoscopy and view of glottis because of insufficient room in submandibular space. This finding is similar to that of our study.

Another study conducted by Wojtczak et al. in five obese and seven morbidly obese adult patients, performed submandibular USG found that the tongue volumes did not differ statistically in easy and difficult laryngoscopy groups.[19] This finding is different from our study and the difference could be because of normal BMI in our patient population.

In another similar study conducted by Andruszkiewicz et al. in 199 adult patients using submandibular USG, tongue volume was higher in difficult laryngoscopy group which was statistically significant.[9] These findings were similar our study but with the notable difference in method used for calculating the tongue volume. We used both sagittal and ventral measurements of the tongue length, width and height and their multiplication product to calculate tongue volume which was different and less time consuming as to the method used, where in the authors used product of tongue cross sectional area(by tracking the borders of the tongue ) and width.

In a study conducted by Rana et al. in 100 patients, using point of care ultrasound found that HMDR had strong negative correlation with CL grading with an area under the curve (AUC) of 0.871 and regression coefficient of − 0.466 (95% CI : -0.956 to -0.786) .[8]These findings were similar to our study which showed similar negative correlation with regression coefficient of -0.410.

In a similar study statistically significant difference between HMDR in easy and difficult laryngoscopy groups was noted which is same as that in our study.[9]

Various studies have been conducted to assess soft tissue thickness at the anterior neck and its significance in predicting difficult airway. In a study conducted by Yadav NK et al. the sensitivity and specificity of soft tissue thickness at the level of hyoid bone was 68% and 73% respectively, in neutral position.[20] The AUC for the same was 0.72(95% CI: 0.61-0.82). In our study, the AUC for DSHB was found to be 0.732(95% CI: 0.636-0.872, p=0.0014), sensitivity of 67.75% and specificity of 66% which are comparable.

In a pilot study conducted by Adhikari et al. thickness of soft tissue at the hyoid bone and thyrohyoid membrane level was greater in patients with difficult laryngoscopy.[21] In a study conducted by Wu et al, the predictive value of anterior neck soft tissue mass at the level of hyoid, thyrohyoid membrane and anterior commisure and found these to be independent predictors of difficult laryngoscopy. [22]

## CONCLUSIONS

This study demonstrate that ultrasound derived parameters may be useful to predict difficult laryngoscopy and difficult airway. Tongue volume and hyomental distance ratio can have moderate predictive value and can be evaluated using point of care ultrasonography Further studies are needed to develop a model incorporating both clinical and ultrasonographic measurements.

## LIMITATIONS OF THE STUDY

There are several limitations in our study. Due to the low incidence of difficult airway, the number patients in difficult and easy laryngoscopy group were not equal. This inequality might have some effect on the predictive validity of the tests used. Furthermore ultrasonography is a user dependent tool and some bias might have crept in. The conduct of laryngoscopy and visualization of glottis is a complex procedure and many factors like skill and experience of anesthetist, presence of secretions and anatomic variability might play a role.

## ACKNOWLEDGEMENTS

We would like to acknowledge our study participants, staffs and colleagues for their valuable support.

## DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST

The authors state no potential conflicts of interest.

## FINANCIAL DISCLOSURE

There is no financial support for this study.

## REFERENCES

1. Law JA, Duggan LV, Asselin M, Baker P, Crosby E, Downey A, et. al. Canadian Airway Focus Group. Canadian Airway Focus Group updated consensus-based recommendations for management of the difficult airway: part 2. Planning and implementing safe management of the patient with an anticipated difficult airway. Can J Anaesth. 2021 Sep; 68(9):1405-1436. doi: 10.1007/s12630-021-02008-z. PMID: 34105065; PMCID: PMC8186352.
2. Benumof JL. Difficult laryngoscopy: obtaining the best view. Can J Anaesth .1994; 361–365 . https://doi.org/10.1007/BF03009856
3. Henderson JJ, Popat MT, Latto IP, Pearce AC. Difficult Airway Society. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. Anaesthesia. 2004 Jul;59(7):675-94. doi: 10.1111/j.1365-2044.2004.03831.x. PMID: 15200543.
4. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology. 2005 Aug; 103(2):429-37. doi: 10.1097/00000542-200508000-00027. PMID: 16052126.
5. 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 Aug; 45(8):757-76. doi: 10.1007/BF03012147. PMID: 9793666
6. Teoh WH, Kristensen MS. Utility Of Ultrasound in Airway Management, Trends in Anaesthesia and Critical Care (2014), doi: 10.1016/j.tacc.2014.05.004.
7. Ferszt P, Hill J, Larson S. Ultrasonography relative to Cormack-Lehane in predicting difficult laryngoscopy: a systematic review of diagnostic test accuracy. JBI Evid Synth. 2021 Jun; 19(6):1444-1451. doi: 10.11124/JBIES-20-00141. PMID: 33278263.
8. Rana S, Verma V, Bhandari S, Sharma S, Koundal V, Chaudhary SK. Point-of-care ultrasound in the airway assessment: A correlation of ultrasonography-guided parameters to the Cormack-Lehane Classification. Saudi J Anaesth. 2018 Apr-Jun;12(2):292-296. doi:10.4103/sja.SJA_540_17. PMID: 29628843; PMCID: PMC5875221.
9. 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 Oct;35(10):2243-52. doi: 10.7863/ultra.15.11098. Epub 2016 Aug 31. PMID: 27582532
10. Detsky ME, Jivraj N, Adhikari NK, Friedrich JO, Pinto R, Simel DL, et al. Will This Patient Be Difficult to Intubate?: The Rational Clinical Examination Systematic Review. JAMA. 2019 Feb 5; 321(5):493-503. doi: 10.1001/jama.2018.21413. Erratum in: JAMA. 2020 Mar 24; 323(12):1194. PMID: 30721300.
11. Reddy PB, Punetha P, Chalam KS. Ultrasonography - A viable tool for airway assessment. Indian J Anaesth. 2016 Nov;60(11):807-813. doi: 10.4103/0019-5049.193660. PMID: 27942053; PMCID: PMC5125183.
12. Kundra P, Mishra SK, Ramesh A. Ultrasound of the airway. Indian J Anaesth. 2011 Sep;55(5):456-62. doi: 10.4103/0019-5049.89868. PMID: 22174461; PMCID: PMC3237144.

13. Ding LW, Wang HC, Wu HD, Chang CJ, Yang PC. Laryngeal ultrasound: a useful method in predicting post-extubation stridor. A pilot study. Eur Respir J. 2006 Feb;27(2):384-9. doi: 10.1183/09031936.06.00029605. PMID: 16452597.
14. Singh M, Chin KJ, Chan VW, Wong DT, Prasad GA, Yu E. Use of sonography for airway assessment: an observational study. J Ultrasound Med. 2010 Jan;29(1):79-85. doi: 10.7863/jum.2010.29.1.79. PMID: 20040778.
15. Lee MGY, Millar J, Rose E, Jones A, Wood D, Luitingh TL et al. Laryngeal ultrasound detects a high incidence of vocal cord paresis after aortic arch repair in neonates and young children. J Thorac Cardiovasc Surg. 2018 Jun;155(6):2579-2587. doi: 10.1016/j.jtcvs.2017.12.133. Epub 2018 Feb 9. PMID: 29510943.
16. Roth D, Pace NL, Lee A, Hovhannisyan K, Warenits AM, Arrich J, et al. Airway physical examination tests for detection of difficult airway management in apparently normal adult patients. Cochrane Database Syst Rev. 2018 May 15;5(5):CD008874. doi: 10.1002/14651858.CD008874.pub2. PMID: 29761867; PMCID: PMC6404686.
17. Vannucci A, Cavallone LF. Bedside predictors of difficult intubation: a systematic review. Minerva Anestesiol. 2016 Jan; 82(1):69-83. Epub 2015 May 20. PMID: 25990431.
18. Ohri R., Malhotra K. Different 2D ultrasound calculation methods to evaluate tongue volume for prediction of difficult laryngoscopy. Indian J. Anaesth.64, (2020).doi: 10.4103/ija.IJA_843_19 PMID: 33162601
19. Law JA, Duggan LV, Asselin M, Baker P, Crosby E, Downey A, et. al. Canadian Airway Focus Group. Canadian Airway Focus Group updated consensus-based recommendations for management of the difficult airway: part 2. Planning and implementing safe management of the patient with an anticipated difficult airway. Can J Anaesth. 2021 Sep;68(9):1405-1436. doi: 10.1007/s12630-021-02008-z. Epub 2021 Jun 8. PMID: 34105065; PMCID: PMC8186352.
20. 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 Aug; 63(8):629-634. doi: 10.4103/ija.IJA_270_19. PMID: 31462808; PMCID: PMC6691631.
21. 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 Jul; 18(7):754-8. doi: 10.1111/j.1553-2712.2011.01099.x. Epub 2011 Jun 27. PMID: 21707828.
22. Wu J, Dong J, Ding Y, Zheng J. Role of anterior neck soft tissue quantifcations by ultrasound in predicting difficult laryngoscopy. Med. Sci. Monit.20, 2343–2350 (2014).doi: 10.12659/MSM.891037 PMCID: PMC4247231 PMID: 25403231