Preoperative ultrasonographic prediction of difficult airway in patients undergoing surgery under general anaesthesia

Sharma M,[1] Dhungel S,[2] Piya B,[1] Gautam R[3]

[1]Mona Sharma, Assistant Professor, Department of Anaesthesiology, Kathmandu Medical College Teaching Hospital, Sinamangal, Kathmandu, Nepal; [2]Saurya Dhungel, Researcher, Department of Epidemiology, School of Public Health, University of Washington, Seattle, Washington, United States of America;[1] Buna Piya, Lecturer, Department of Anaesthesiology, Sinamangal, Kathmandu Medical College Teaching Hospital, Sinamangal, Kathmandu, Nepal; [3]Ritika Gautam, MBBS Intern, KIST Medical College and Teaching Hospital, Imadol, Lalitpur, Nepal.

Abstract

Background: Preoperative assessment of the airway with ultrasound has come up as a viable option to aid the preanaesthetic airway assessment.

Objectives: To identify reliable ultrasound parameters as predictors of difficult airway in patients undergoing surgery under general anaesthesia.

Methods: A prospective analytical cross-sectional study was conducted at Kathmandu Medical College in 99 consecutive patients scheduled for elective surgery with general anaesthesia and endotracheal intubation from July 2019 to June 2020 after ethical clearance. Three ultrasound parameters were used for this study. Distance from the skin to the anterior aspect of trachea at the level of vocal cords (ANS-VC), the depth of the pre-epiglottic space (PreE), the distance from the epiglottis to the midpoint of vocal cords (EVC) was measured. The PreE/EVC and hyomental distance ratio (HMDR), which is the distance ratio of hyomental distance at neutral and extended head position were calculated. These ultrasonographic parameters were used to predict difficult laryngoscopy Cormack-Lehane (CL) grading 3, 4.

Results: Difficult intubation was seen in 23 (23.2%) as CL grade 3. The authors did not encounter CL grade 4. HMDR and PreE/EVC have been shown to have significant association with CL grading, with a specificity of 71% and 77% respectively and a high negative predictive value of 84.3% and 84.2% respectively. Therefore, it is valuable in predicting difficult intubation. ANS-VC did not have a significant correlation.

Conclusion: Diagnostic predictability of difficult airway is better with HMDR and PreE/E-VC.

Key words: Airway; General anaesthesia; Ultrasound

INTRODUCTION

Airway assessment is mandated for all the patients preoperatively. It helps the anaesthesiologists to predict the ease of mask ventilation and intubation. Despite many clinical predictors and scoring systems, incidences of unanticipated difficult airway are not uncommon.[1] These tests are very subjective and lack uniformity among examiners.[2] They are difficult to perform in obtunded, uncooperative patients, and in emergency scenarios.[3]

Ultrasound has proven to be a useful adjunct for airway management.[4] It helps in diagnosing pathologies of the airway,[5] identifying the cricoid membrane, predicting appropriate diameter of endotracheal, endobronchial or tracheostomy tube,[6] and measuring gastric content.[7] However, for predicting difficult airway, there have been just a handful research.[8-11]

Many ultrasound parameters have been studied over the years, few have shown to have good predictability with Cormack-Lehane (CL) grading like ANS-VC (distance from skin to anterior aspect of trachea at the level of vocal cords),[8] PreE/EVC [ratio of depth of pre-epiglottic space (PreE) to the distance from epiglottis to midpoint of vocal cords (EVC)][12] and, hyomental distance ratio (HMDR).[9] However, when repeated, the results sometimes could not be reproduced.[10,11] Therefore, the authors aimed to determine the predictability of preoperative assessment of the airway with ultrasound in current study population.

METHODOLOGY

After approval by the Kathmandu Medical College Institutional Review Committee (KMC-IRC, Ref. 310520113 dated 31st March, 2019) and obtaining written informed consent, 100 consecutive patients from July 2019 to June 2020 undergoing elective surgery under general anaesthesia with endotracheal intubation were included in the study. The present study is a prospective, analytical cross-sectional study conducted in the operating theatre of Kathmandu Medical College Teaching Hospital. Patients above the age of 18 and below 65 years without any known airway pathologies were included in the study. Patients with history of cervical spine pathology, neck surgery, pregnancy, uncooperative patients, and those requiring rapid sequence induction were excluded from the study.

Preanaesthetic evaluation of the patient was done one day before the surgery. Patient airway assessment were carried out in two stages. The research assistant (anaesthesiologist) noted the thyromental distance (TMD, the distance from mentum to thyroid notch) and modified Mallampati scoring (MMP).

On the day of surgery; the principal investigator obtained the ultrasound (US) measurements in the preoperative room. A portable ultrasound machine (Mindray Z6) was used for the study. Initial assessment was done with the high frequency linear transducer. The patient was placed in sniffing position, the probe was placed in midline in the submandibular area, and the US probe was rotated in transverse plane from cephalad to caudad direction, until simultaneous visualisation of epiglottis and posterior fold of vocal folds with arytenoids as described by Gupta et al.[13] Epiglottis was visible as a hypoechoic curvilinear structure. The PreE space was hyperechoic and its border anteriorly was marked by air mucosal interface. The vocal cords with arytenoid were hyperechoic "V" shaped structure. The PreE and EVC were measured. Then the ratio of PreE/EVC was calculated. Afterwards, the anterior neck soft tissue thickness was measured as the ANS-VC.

Then, low frequency, curved transducer was used to visualise the hyoid bone and the mentum. The hyomental distance was measured from the upper border of hyoid bone to the lower border of mentum in neutral and extended head position. Then its ratio would be calculated as HMDR.

In the operating room, standard monitors were attached to the patients. The patients were induced with 2 mcg/kg of fentanyl, 2 mg/kg of propofol and 0.1 mg/kg of vecuronium. A senior anaesthesiologist, not involved in the study, with more than five years of experience post-qualification, intubated them. Direct laryngoscopy was performed using a Macintosh blade (size-3 blade in female patients and medium sized male patients and size-4 blade in well-built male patients) and the CL grade was noted. Airway was classified as easy for CL grades 1 and 2 or difficult for CL grades 3 and 4. Endotracheal tube (ETT) was inserted and anaesthesia was maintained with isoflurane. Total number of attempts required for intubation was noted. Requirement of alternative pathway for intubation was always made available and if required was noted.

A total sample size of 100 was arrived after using Fischer's formula, according to Reddy et al. where the incidence of difficult intubation was reported 14%.[10] According to the formula: $n = t^2 \times P(1-P)/m^2$; where n = required sample size; t = confidence interval at 95% (standard value of 1.96); P = 0.14; m = margin of error = 0.07 (7%). The sample size was calculated to be 95. The authors enrolled 100 patients, to allow dropouts. Final calculation was done in 99 patients.

All statistical analyses were performed using IBM SPSS Statistics for Windows, version 20 (IBM Corp., Armonk, N.Y., USA). The results were averaged [mean ± standard deviation (SD)] for each parameter for continuous data. The Chi-square test was used to determine whether there was a statistical difference between the patients with easy and difficult intubations. The predictive value of the tests was assessed by calculating the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy. To assess the optimal cut-off scores, a relative operating characteristics (ROC) curve was plotted and the area under the curve were calculated to assess the prognostic accuracy.

RESULTS

One hundred patients, undergoing elective surgery under general anaesthesia with endotracheal intubation were included in the study; however, one patient declined to be included after initial examination and refused the ultrasound scan and hence was excluded. Therefore, 99 patients were analysed. The study comprised of 30 (30.3%) male and 69 (69.7%) female population. The age group included was 18 years to 65 years. The body mass index (BMI) of study population was 25.28 ± 4.09 kg/m². Among current study population, 29 (29.3%) had CL grade 1, 47 (47.5%) had CL grade 2, and 23 (23.2%) had CL grade 3 (Table 1). The authors did not encounter any CL grade 4.

Among the ultrasound parameters, ANS-VC of patients with easy intubation (CL grading 1 and 2) was 0.84 ± 0.4 cm and difficult intubation (CL grading 3) was 0.86 ± 0.27 cm, there was no statistical significant difference between the groups (p-value = 0.36). The number of laryngoscopic attempt in CL grade 1 and 2 was 1 ± 0 and for CL 3 was 1.43 ± 0.5.

The association of ultrasound parameters and physical parameters with CL grading are presented in Table 2. ROC curve was plotted for all the ultrasound parameters of the study. For ANS-VC the authors found a cut off of 0.79 cm, associated with difficult intubation, AUC (area under the curve) = 0.52 . Similarly, for PreE/EVC, cut off of >1.77 was calculated with ROC curve AUC = 0.59. For HMDR, the AUC was O.64 and a cut off was <1.18 (Figure 1).

The sensitivity, specificity, NPV, PPV, accuracy, and prevalence of ultrasound parameters to predict difficult airway are shown in Table 3.

Table 1: Comparison of physical parameters with CL grading in numbers

CL grading, n (%)	CL 1 and 2 76 (76.8%) Easy airway	CL3 23 (23.2%) Difficult airway	p-value	Odds ratio	Confidence interval
MMP I, II, n (%)	57 (57.6)	15 (15.1)	0.42	1.42	0.68-2.96
MMP III, IV, n (%)	19 (19.2)	8 (8.1)			
TMD ≤6.5, n (%)	2 (2)	6 (6.1)	0.002	4.01	2.23-7.21
TMD >6.5, n (%)	74 (74.7)	17 (17.2)			

*CL Cormack Lehane, † MMP Modified Mallampati classification, ‡TMD Thyromental distance.

Table 2: The association of ultrasound parameters and physical parameters with CL grading

	CL 1 and 2, n (%)	CL 3, n (%)	p-value	Odds ratio
ANS-VC >0.79	38 (73.1)	14 (26.9)	0.47	1.55 (0.6-4.02)
ANS-VC <0.79	38 (80.9)	9 (19.1)		
PreE/EVC >1.77	17 (58.6)	12 (41.4)	0.009*	2.63 (1.3-5.2)
PreE/EVC <1.77	59 (84.3)	11 (15.7)		
HMDR >1.18	54 (84.4)	10 (15.6)	0.024*	2.3 (1.16-4.8)
HMDR <1.18	22 (62.9)	13 (37.1)		
TMD <6.5	2 (25)	6 (75)	0.002*	4.01 (2.23-7.2)
TMD >6.5	74 (81.3)	17 (18.7)		
MMP 3,4	19 (70.4)	8 (29.6)	0.42	1.42 (0.6-2.9)
MMP 1,2	57 (79.2%)	15 (20.8%)		

Table 3: Predictive value of US and clinical test (%)

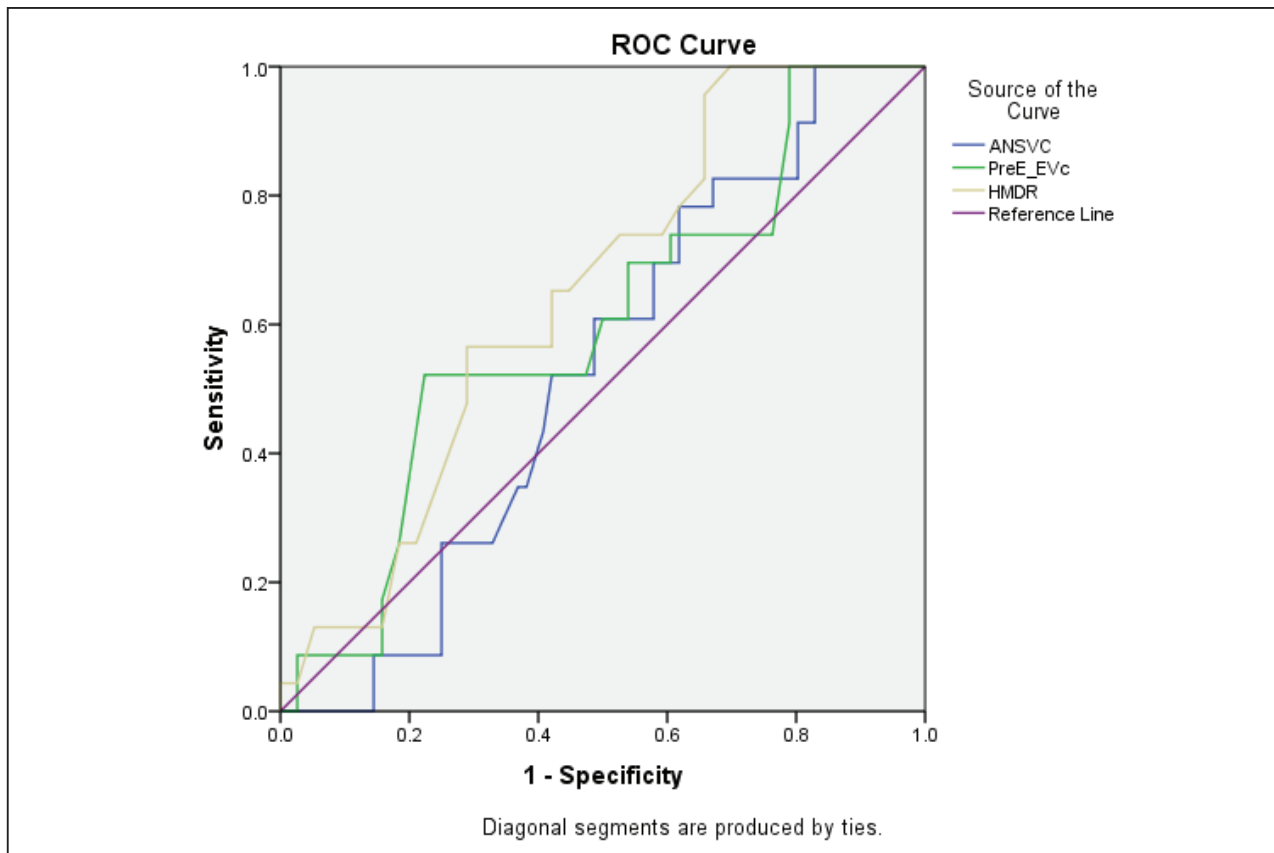| Parameters	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
ANS-VC	60	50	26.9	76.7	52.5
PreE/EVC	52.2	77.6	41.3	84.2	71.7
HMDR	56.52	71.05	37.14	84.37	67.6
TMD	26.08	97.3	75	81.3	80.8

Figure 1: Relative operating characteristics (ROC) curve

DISCUSSION

The possibility of intubating a patient is by visualisation of the vocal cords. Various factors are associated with the best view, such as inter-incisor gap, Mallampati score, neck circumference, mandibular space, skill of the practitioner, etc. One of those factors is extension of the neck. The stylohyoid ligament retains the distance between the occiput and hyoid bone. During the neck extension below the occiput, the mentum moves away from the hyoid bone and extending the hyomental distance (HMD). Had there been no increase in this HMD, the forward movement of laryngeal structure which lowers cervical spine extension would take the vocal cords away from the line of vision.[9]

The HMDR in current study has been found to have significant correlation with CL grading with a cut off of <1.18 with higher CL grade, with a sensitivity of 56.52% and specificity of 71.05%, negative predictive value of 84.37% and accuracy of 67.6%. A recent metanalysis has quoted that mean difference of HMDR was 0.07 cm lower in difficult than easy airway, which was significant.[14] The cut off value of 1.08 has been calculated by studies, with

sensitivity of 75% and specificity of 85%.[12] The HMDR can serve as an important aspect of ultrasound parameters for difficult airway, even for obese and super obese patients had an HMDR of 1-1.05.[9]

Ratio of depth of PreE and EVC, the PreE/EVC has also been shown to be quite effective in detecting difficult airway. Most of the studies have concluded that a higher mean PreE/EVC is recorded in difficult airway.[10,12,15] Current study had an AUC of 0.59 with a cut off value of 1.77 with a specificity of 77.6% and negative predictive value of 84.2%. Current study cut off matches with previously conducted study, which also had a cut off of 1.77 both with sensitivity and specificity of 80.2% and 80% respectively.[12] Other study conducted by Koundal et al.,[15] had a cut off of 1.87 with sensitivity and specificity of 82% and 83%. However, these studies had a higher AUC than current study, which is better result. Some studies with different results were conducted by Reddy et al,[10] the value of PreE/EVC for difficult airway was 1.29 ± 0.44, with unknown cut off value. Likewise, Gupta et al.[13] had a cut off of 1.49. Some authors have also published the predictability grading of PreE/EVC.[12,15]

The thickness at the anterior soft tissue at the vocal cords (ANS-VC) has been used to assess difficult airway, with most of the studies depicting higher the thickness more difficult the airway.[8,10] Whereas, others have come to a contrasting conclusion like in current study.[11] This study had a cut off of >0.79 cm for difficult airway (AUC = 0.52) with no significant correlation with CL grading with sensitivity of 60% and specificity of 50%. Falcetta et al.,[16] Fulkerson et al.,[17] and Martinez-Garcia et al.[18] have previously reported finding similar to current study. However, studies have shown much lesser cut off value of 0.23 cm[10] and 0.27 cm,[8] these results are both in non-obese and obese patients respectively.

The common practice for routine assessment of airway may not always predict the CL grading during direct laryngoscopy. Therefore, ultrasound scanning for difficult airway has been quite a topic for research. Different ultrasound parameters have been examined over the past years. Among the ones the authors have studied, HMDR and PreE/EVC has been shown to have significant correlation with CL grading, with a specificity of 71% and 77% and a high negative predictive value of 84.3% and 84.2% respectively. Therefore, it is valuable

in predicting difficult intubation. ANS-VC did not have a significant correlation, and hence was not a useful parameter in current population. However, among all the predictors, clinical and US, TMD has shown to have highest specificity of 97% in current study. None of current study parameters had a high sensitivity.

Limitation of this study was that the authors included 99 patients of Nepali population, who were not very obese. The mean BMI was 25 kg/m^2. The incidence of difficult intubation was 23.2%. The authors did not encounter CL grade 4. Interpatient variation, practitioner familiarity with US; patient position can be a major source of data discrepancy. Further research should be done including patients with difficult airway such as obesity, pregnancy.

CONCLUSION

Ultrasound should be incorporated in routine preanaesthetic checkup for prediction of difficult airway. TMD, PreE/EVC and HMDR serve as good predictors of difficult airway.

Conflict of interest: None
Source(s) of support: None

REFERENCES

1. Reed MJ, Dunn MJG, McKeown DW. Can an airway assessment score predict difficulty at intubation in the emergency department? Emerg Med J. 2005 Feb;22(2):99-102. [PubMed | Full Text | DOI]

2. 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. [PubMed | Full Text | DOI]

3. Rucklidge M, Hinton C. Difficult and failed intubation in obstetrics. Contin Educ Anaesth Crit Care Pain. 2012 Apr 1;12(2):86-91. [Full Text]

4. Kristensen MS. Ultrasonography in the management of the airway: Ultrasonography and the airway. Acta Anaesthesiol Scand. 2011 Nov;55(10):1155-73. [PubMed | Full Text | DOI]

5. Lixin J, Bing H, Zhigang W, Binghui Z. Sonographic diagnosis features of Zenker diverticulum. Eur J Radiol. 2011 Nov;80(2):e13-9. [PubMed | Full Text | DOI]

6. Osman A, Sum KM. Role of upper airway ultrasound in airway management. J Intensive Care. 2016;4:52. [PubMed | Full Text | DOI]

7. Perlas A, Mitsakakis N, Liu L, Cino M, Haldipur N, Davis L, et al. Validation of a mathematical model for ultrasound assessment of gastric volume by gastroscopic examination. Anesth Analg. 2013 Feb;116(2):357-63. [PubMed | Full Text | DOI]

8. Ezri T, Gewürtz G, Sessler DI, Medalion B, Szmuk P, Hagberg C, et al. Prediction of difficult laryngoscopy in obese patients by ultrasound quantification of anterior neck soft tissue. Anaesthesia. 2003 Nov;58(11):1111-4. [PubMed | Full Text | DOI]

9. Wojtczak JA. Submandibular sonography: assessment of hyomental distances and ratio, tongue size, and floor of the mouth musculature using portable sonography. J Ultrasound Med. 2012 Apr;31(4):523-8. [PubMed | Full Text | DOI]

10. Reddy PB, Punetha P, Chalam KS. Ultrasonography - A viable tool for airway assessment. Indian J Anaesth. 2016 Nov;60(11):807-13. [PubMed | Full Text | DOI]

11. Komatsu R, Sengupta P, Wadhwa A, Akça O, Sessler DI, Ezri T, et al. Ultrasound quantification of anterior soft tissue thickness fails to predict difficult laryngoscopy in obese patients. Anaesth Intensive Care. 2007 Feb;35(1):32-7. [PubMed | Full Text | DOI]

12. 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 Jun;12(2):292-6. [PubMed | Full Text | DOI]

13. Gupta D, Srirajakalidindi A, Ittiara B, Apple L, Toshniwal G, Haber H. Ultrasonographic modification of Cormack Lehane classification for preanaesthetic airway assessment. Middle East J Anaesthesiol. 2012 Oct;21(6):835-42. [Full Text]

14. Sotoodehnia M, Rafiemanesh H, Mirfazaelian H, Safaie A, Baratloo A. Ultrasonography indicators for predicting difficult intubation: A systematic review and meta-analysis. BMC Emerg Med. 2021 03;21(1):76. [PubMed | Full Text | DOI]

15. Koundal V, Rana S, Thakur R, Chauhan V, Ekke S, Kumar M. The usefulness of point of care ultrasound (POCUS) in preanaesthetic airway assessment. Indian J Anaesth. 2019 Dec;63(12):1022-8. [PubMed | Full Text | DOI]

16. Falcetta S, Cavallo S, Gabbanelli V, Pelaia P, Sorbello M, Zdravkovic I, et al. Evaluation of two neck ultrasound measurements as predictors of difficult direct laryngoscopy: A prospective observational study. Eur J Anaesthesiol. 2018;35(8):605-12. [PubMed | Full Text | DOI]

17. Fulkerson JS, Moore HM, Lowe RF, Anderson TS, Lucas LL, Reed JW. Airway sonography fails to detect difficult laryngoscopy in an adult veteran surgical population. Trends Anaesth Crit Care. 2019 Dec;29:26-34. [Full Text]

18. Martínez-García A, Guerrero-Orriach JL, Pino-Gálvez MA. Ultrasonography for predicting a difficult laryngoscopy. Getting closer. J Clin Monit Comput. 2021 Apr;35(2):269-77. [PubMed | Full Text | DOI]