Ultrasound as an Assessment Method in Predicting Difficult Intubation: A Prospective Clinical Study

Simin Abraham¹ · J. Himarani¹ · S. Mary Nancy¹ · S. Shanmugasundaram¹ · V. B. Krishnakumar Raja¹

Received: 18 September 2017 / Accepted: 22 January 2018 / Published online: 8 March 2018
© The Association of Oral and Maxillofacial Surgeons of India 2018

Abstract

Objective Aim of the study is to predict the difficulty in intubation preoperatively using ultrasonography.

Methods One hundred and thirty-seven patients underwent ultrasound followed by surgery under general anesthesia. A experienced radiologist examined the airway and performed measurements of specific airway parameters: visualization of hyoid bone, visualization of vocal cords through thyroid cartilage, visualization of epiglottis, distance from base of tongue to hyoid bone, distance of hyomental region distance of thyrohyoid region, distance between skin and fat pad thickness to thyroid cartilage, thickness of submental region, distance from epiglottis to skin (above hyoid), and visualization of cricothyroid membrane. After performing ultrasound, patient was presented for surgery. An experienced anesthesiologist who is associated with this study did all the laryngoscopy and intubation.

Results We were able to visualize all relevant anatomical structures in all the participants using ultrasound. The receiver operating characteristic curve analysis results showed that hyomental is ≤ 1.09 (P value < 0.01) to classify difficult in intubation.

Conclusion The study shows that ultrasound can reliably image all the airway structures. This study suggests that hyomental distance is a more valid criterion in predicting difficult intubation. Further, case control study is needed for assessing the ease of intubation.

Keywords Airway · Intubation · Ultrasonography · Laryngoscopy

Introduction

Airway assessment is an essential component for anesthesiologist and also for primary trauma care. A secure airway is essential to maintain adequate oxygenation and ventilation. Failure to do so can be life threatening even for a short period of time. The major responsibility of physician and surgeon in managing critically ill patient with life-threatening condition often necessitates airway management.

Mismanagement of airway can lead to devastating consequences for patients and providers. During a preoperative period of an anticipated difficult airway, the management is determined by airway structure, architecture, and its movement. Clinical evaluation can be done by Mallampati classification, upper lip bite test, jaw movement, thyromental distance, and sternomental distance. Sternomental distance had an increased sensitivity and specificity for predicting subsequent difficult laryngoscopy [1].

Inadequate ventilation, esophageal intubation, and difficult tracheal intubation are the most common mechanisms of respiratory-related adverse outcomes in the clinical practice of anesthesiology [2]. Due to many concerns in the present scenario, we are in a situation to find a highly sensitive and specific method of assessing airway as an adjuvant to the routine clinical methods. Ultrasound imaging is a technology of extraordinary images, specialized system, and innovative solution in the field of anesthesia to track the region of interest. Modern ultrasound machine is more compact and portable with better resolution and enhanced tissue penetration.

✉ Simin Abraham
Siminabraham77@gmail.com

¹ Department of Oral and Maxillofacial Surgery, SRM Dental College, Ramapuram, Chennai 600089, India

Principles of Ultrasonography

Ultrasound is a high-frequency sound wave. These waves are inaudible to humans. These waves have the power to penetrate different tissues of body at different speed. Ultrasound pulses must be spaced with enough time between the them, to permit the sound to travel the depth of interest and return before the next pulse is sent [3].

Reflection of sound is marked at interfaces between tissues of different acoustic impedance. These reflected sound signals are reproduced visually in a grayscale. The pattern of sound waves generated by the probe and processing of reflected signals are controlled by software, to generate optimal images. Ultrasound is a safe, easily accessible point of care imaging modality that is being increasingly adopted in modern anesthesiology practice [4].

Different Modes of Ultrasound

1. *A-mode* A single transducer scans a line through the body with the echoes plotted on screen as a function of depth.
2. *B-mode* A linear array of transducers simultaneously scans a plane through the body that can be viewed as a two-dimensional image on screen.
3. *Real time* This mode displays motion by showing the images of the part of the body under transducer as it is being scanned.

Endotracheal intubation is a routine procedure for anesthesiologist in oral and maxillofacial surgeries, but sometimes there will be some difficulty in managing the airway. Hence ultrasonography, a quick, portable, inexpensive, non-radiating, repeatable, and noninvasive tool, can be used in airway assessment. However, there are limited data on assessing the airway by ultrasonography.

Aim and Objectives

The prospective study of ultrasound as an assessment method for predicting difficult intubation was carried out in our institution.

Aim

To find whether ultrasound can predict difficult airway.

Objective

- a. To find the sensitivity of the test with qualitative analysis comparing to other methods.

- b. To choose the correct method of intubation under general anesthesia.

Materials and Method

This study was conducted after obtaining institutional review board approval. One hundred and thirty-seven patients, scheduled for various surgical procedures under general anesthesia, were included in the study after obtaining informed consent. Patients who were not undergoing surgery were excluded from the study.

First, a single investigator performed preoperative clinical assessment. The patient's information (name, age, gender) were recorded, and the following information was obtained in standard fashion: mouth opening (cm), thyromental distance (cm), neck mobility (flexion/extension degrees from midline), Mallampati classification, sternomental distance (cm), jaw movement, neck movement, receding mandible, prominent incisor, upper lip bite test, etc.

Preoperative ultrasonographic airway assessment was performed for all patients in the study using ultrasonography. These patients were positioned in supine. Patients were explained about the procedure before starting the study. A small-footprint, high-frequency curved-array probe was used for measuring various parameters like hyoid bone, thyrohyoid distance, hyomental distance normal and extended, distance from base of tongue to hyoid bone, thickness of submental region, distance from epiglottis to hyoid bone, distance from skin fat pad thickness to thyroid cartilage, and vocal cords, and they were recorded.

On the day of surgery, laryngoscopy was performed by anesthesiologist who was associated with this study. The glottic view obtained on first attempt of direct laryngoscopy was graded according to the Cormack–Lehane classification [5].

Grade I If most of the glottis is visible, then there is no difficulty.

Grade II If only the posterior extremity of the glottis is visible, then there may be slight difficulty.

Grade III If no part of the glottis can be seen but only the epiglottis, then there may be fairly severe difficulty.

Grade IV If not even the epiglottis can be exposed, then intubation is impossible except by special methods.

The grade of view obtained on direct laryngoscopy was regarded as a surrogate for intubation difficulty, with grades II, III, and IV classified as “difficult” (Figs. 1, 2).

Fig. 1 Hyomental distance in normal position

Fig. 2 Hyomental distance in extended position

Results

One hundred and thirty-seven patients who have consented for the study were enrolled. In all patients, ultrasound probe was placed in accurate position in the neck without sedation or anesthesia. The same radiologist did the ultrasound imaging with due instructions. The attending anesthesiologist with experience of more than 15 years performed laryngoscopy in all patients. Out of 137 patients, 127 were found not to have difficult airway as per ultrasonographic airway assessment and correlated to have easy tracheal intubation with Cormack–Lehane classification grade I. Remaining 10 patients were expected difficulty in tracheal intubation according to preoperative clinical and ultrasound assessment. They were opted for fiber-optic

intubation and were successfully intubated. These 10 patients had grade II–IV laryngoscopic view according to the Cormack–Lehane scale. In 10 patients with difficult airway, some of them had bilateral TMJ ankylosis, Papillon–Lefevre syndrome, obstructive sleep apnea syndrome, oral submucous fibrosis (2 patients), carcinoma of tongue, post-reconstruction of mandibular defect following resection, bilateral condylar fracture (2 patients), or zygomatic maxillary complex fracture. The normality tests Kolmogorov–Smirnov and Shapiro–Wilk test results reveal that the variables follow normal distribution. Therefore, to analyze the data parametric methods are applied. The association between different variables (age, thickness of submental, epiglottis to hyoid bone, thyrohyoid distance, skin to fat pad thickness to thyroid cartilage, hyomental

distance) and difficulty in intubation was evaluated using independent-samples *t* test to compare mean values, and the results are tabulated (Table 1).

Significance level is fixed as 1% ($\alpha = 0.01$). The following parameters are listed in Table 1. ROC curve analysis was performed to find the best cutoff values to classify difficult intubation for hyomental distance (Fig. 3), and the sensitivity and specificity were measured. Hyomental distance was significant, and at ≤ 1.09 cm, we may conclude that the intubation will be difficult (Tables 2 and 3).

Discussion

Airway assessment constitutes a very important stage in determining the ease of intubation. Routinely, the preoperative assessment has been done by clinical examination. Other imaging modalities available are conventional radiograph, ultrasonography, and computed tomography. These studies have employed only a single modality in grading the airway and are associated with some limitations. Our study has combined the use of clinical and ultrasonographic airway assessment in an objective manner for better predictability. It has confirmed its validity with the actual difficulty during intubation.

This study demonstrates that ultrasonography is a potential and convenient tool for airway assessment. We were able to successfully visualize all the relevant anatomical structures of the upper airway by ultrasonography in this study. Our result suggested that ultrasonography is a safe and noninvasive method. It is well tolerated by the patients without risk of radiation and is an efficient tool for preoperative airway assessment. Clinical tests like Mallampati grading, inter-incisor distance, upper lip bite test, thyromental distance, sternomental distance, weight, skeletal analysis, neck movement, tongue size were also analyzed. As a renaissance, ultrasonography is an effective

Fig. 3 ROC curve analysis

tool which is used as a modality and a valuable adjunct for assessing airway.

Current and potential applications of ultrasonography include prediction of difficult airway, confirmation of proper endotracheal tube placement, ventilation, evaluation of airway pathologies that may affect the choice of airway management (e.g., subglottic hemangiomas and stenosis), mandating urgent securing airway (e.g., Epiglottitis), prediction of size of endotracheal, endobronchial and tracheostomy tubes, and assessment of vocal cord movements [4]. Restricted extension of head, decreased mento-hyoid distance, and poor Mallampati class can lead to difficult intubation [6]. Pennsylvania patient safety authority has assessed certain criteria for potential difficult intubation which include measurement of thyromental, sternomental,

Table 1 Independent-samples *t* test to compare mean values

Variables	Intubation	N	Mean	SD	<i>t</i> value	<i>P</i> value
Age (years)	Easy	127	29.11	10.525	0.863	0.390
	Difficult	10	32.10	10.878		
Thickness of submental region (cm)	Easy	127	1.11	0.32074	1.916	0.057
	Difficult	10	1.31	0.26758		
Epiglottis to hyoid bone distance (cm)	Easy	127	1.80	0.54191	0.393	0.695
	Difficult	10	1.87	0.36555		
Thyrohyoid distance (cm)	Easy	127	1.71	0.62377	0.594	0.563
	Difficult	10	1.62	0.43982		
Skin pad thickness to thyroid cartilage (cm)	Easy	127	1.08	0.48931	1.315	0.191
	Difficult	10	1.29	0.47799		
Hyomental distance (cm)	Easy	127	1.14	0.08807	4.270	< 0.001
	Difficult	10	1.02	0.06960		

Table 2 Area under the curve

Area	SE	<i>P</i> value	95% CI	
			LL	UL
<i>Area under the curve = 0.934</i>				
0.934	0.036	< 0.001	0.863	1.000
		Intubation		Total
		Difficult	Easy	
Sensitivity and specificity analysis				
Hyomental				
Difficult (≤ 1.09)		9	15	24
Easy (> 1.09)		1	112	113
Total		10	127	137

Table 3 Hyomental

Parameters	Estimate (%)	95% CIs
Sensitivity	90	(59.58, 98.21)
Specificity	88.19	(81.43, 92.71)
Positive predictive value	37.5	(21.16, 57.29)
Negative predictive value	99.12	(95.16, 99.84)
Diagnostic accuracy	88.32	(81.87, 92.68)

hyomental, and inter-incisor distances [7]. Ultrasonography was able to visualize all major airway structures like hyoid, epiglottis, vocal cords, base of tongue to hyoid bone, cricothyroid membrane, hyomental distance, thyrohyoid distance, thickness of submental region, skin fat pad thickness to thyroid cartilage, and distance between epiglottis to hyoid bone in our study.

Ultrasonography was helpful in predicting difficult intubation, especially in obese patients and those with obstructive sleep apnea [8]. Difficulty in endotracheal intubation can lead to morbidity and mortality. This unexpected difficulty in intubation is the result of lack in accurate predictive tests and inadequate preoperative assessment of the airway.

There are certain preoperative risk which will alert the anesthesiologist so that alternative methods of securing the airway can be used or additional expertise sought before hand [9]. To prevent or decrease the morbidity and mortality, we thought ultrasonography can be an ideal alternative method to find difficulty in intubation preoperatively.

Computed tomography and ultrasonography were compared, and they found that the major airway structures

shown on computed tomography can also be visualized with ultrasonography [10]. Visualization of epiglottis and laryngeal inlet were difficult with the intraoral approach because of the acoustic shadowing cast by the hyoid bone and the intra-luminal air [11].

In our study, we could visualize epiglottis in all the patients with proper neck extension while taking ultrasonography. Thicker the submental region, the difficulty level is increased for laryngoscopy [10]. We found that submental thickness ≥ 1.29 cm may conclude as difficult intubation, but the *P* value (< 0.05) is insignificant. This parameter is important because tongue can get displaced during laryngoscopy, and hence it may cause difficult laryngoscopy in patients' with thick submental region. Epiglottis was visualized by placing the linear transducer probe at the level just above the thyroid cartilage [12]. With a little tilting of the probe or asking the patient to extend his neck slightly, the standard view can be located. Computed tomography does not eliminate the possibility of intubation being difficult but substantially reduces it [13, 14]. Cricothyroid membrane was well visualized by ultrasonography in difficult cases too which is insignificant.

The hyomental distance was clinically and radiographically studied correlated with difficult intubation [15]. Likewise, thyromental distance has been shown to predict difficulty in intubation by multiple studies and predictive models [16]. Hyoid is the only bony structure of the larynx which is readily identifiable on sublingual ultrasound as a distinct hyper echoic structure and helped in predicting difficult intubation [17]. We found out that in all our patients we were able to visualize hyoid bone using ultrasonography and was not a good predictor in finding difficult intubation.

Limitations of Hui et al. [17] says that they did not compare between airway assessment methods. Different physician's performed subjective airway assessment using traditional methods and also graded the laryngoscopy view. They did sublingual ultrasound without conductive gel. In our study, anesthesiologist did traditional clinical method and Cormack–Lehane grading and sonography by the same radiologist. Thyrohyoid distance can indicate difficulty during intubation. The hyoid and thyroid cartilages were well visualized by ultrasonography. Thyrohyoid distance was insignificant (*P* value 0.56) in our study.

Certain factors causing difficult airway includes [18, 19].

- Tumors which may bleed easily.
- Obstructing lesions.
- Post-radiotherapeutic patients.
- Obesity.
- Obstructive sleep apnea.

Laryngoscopy was difficult in patient with radiation therapy due to fibrosis and edema which can result in trismus and restriction of mouth opening. Radiation induces a variety of changes in the airway which can potentially lead to difficult intubation [20].

The hyomental distance is the distance between the upper border of the hyoid bone and the lower border of the mentum. The hyomental distance ratio (defined as distance measured with the head in the neutral position to the head hyper extended) ultrasonographically measured can be used to distinguish patients with easy versus difficult laryngoscopy (Cormack–Lehane grades 3 or 4).

In a pilot series by Kristensen et al. [21] which included obese and morbidly obese patients, all patients with a hyomental distance greater than 1.1 had easy laryngoscopy and those below 1.1 had difficult laryngoscopy. Similarly, in our study, we found that hyomental distance below 1.09 cm had difficult intubation and (P value < 0.01) is a significant parameter. Disadvantage of fiber-optic bronchoscope and similar devices such as optical stylets is the visualization performed through an optical channel within the device can cause encroachment of airway soft tissue on the device which will result in a loss of the view [22].

Dr. Mallampati published an important letter to an editor of Canadian journal of Anaesthesia saying ultrasound imaging is a safe, simple, and noninvasive modality through which soft tissues can be visualized and identified when combined with a thorough knowledge of regional anatomy [23].

Higher the frequency, the better is the resolution [14]. However, the depth of penetration decreases. Ultrasound (US) imaging technique has emerged as a novel, simple, portable, non-radiating, and noninvasive tool which is helpful for airway assessment and management. Sound knowledge of the sono-anatomy of the upper airway can help the anesthesiologist to use sonography in airway-related conditions [24].

Conclusion

Oral and maxillofacial surgeries are well known for posing difficulty in airway management. Unanticipated difficulty in intubation can occur anytime. Hence, a proper preoperative airway assessment can avoid mishaps. Clinical and ultrasonological assessment of airway will significantly reduce morbidity and mortality ensuring a safe perioperative period.

We conclude that if hyomental distance is ≤ 1.09 cm, then intubation will be difficult. We believe that ultrasound can be one of the sensory organ for the anesthesiologist to help in managing difficult airway. Not only for the anesthesiologist but also for the maxillofacial surgeon,

ultrasonography plays a pivotal role in finding an unanticipated difficult laryngoscopy in intubation.

Acknowledgements I am extremely thankful to Dr. Santhosh Pasupleti, Radiologist, for helping, guiding and teaching me about ultrasound. I would like to thank my colleagues in the department for all their support, help, and constructive criticism and in making this an invaluable and enjoyable experience.

Compliance with Ethical Standards

Ethical Approval Ethical clearance certificate obtained from institutional review board. All procedures performed in studies involving human participants were in accordance with ethical standards of institutional research committee and with 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed Consent Informed consent obtained from the involved human participants.

References

1. Ramadhani SAL, Mohammed LA, Rocke DA et al (1996) Sternomental distance as the sole predictor of difficult laryngoscopy in obstetric anaesthesia. *Br J Anaesth* 77:312–316
2. Wilson WC, Benumof JL (1998) Respiration in anesthesia pathophysiology and clinical update: pathophysiology, evaluation and treatment of the difficult airway. *Anesthesiol Clin N Am* 16:29–75
3. Gupta PK, Gupta K, Dwivedi AND, Jain M (2011) Potential role of ultrasound in anaesthesia and intensive care. *Anaesth Essays Res* 5(1):11–19
4. Terkawi AS, Karakitsos D, Elbarbary M, Blaivas M, Durieux ME (2013) Ultrasound for the anaesthesiologists: present and future. *Sci World J* 2013. <https://doi.org/10.1155/2013/683685>
5. Cormack RS, Lehane J (1984) Difficult tracheal intubation in obstetrics. *Anaesthesia* 39:1105–1111
6. Vasudevan A, AB Adhe (2008) Predictors of difficult intubation—a simple approach. *Internet J Anesthesiol* 20(2):2
7. Management of Unanticipated Difficult Intubation (2010) [Blog] Pennsylvania Patient Safety Advisory. Available at: http://patientsafety.pa.gov/ADVISORIES/documents/201012_home.pdf
8. Sustic A et al (2007) Role of ultrasound in the airway management of critically ill patients. *Crit Care Med* 35:173–177
9. Gupta AK, Mohamad O, Showkat N, Imtiyaz N, Anjali M (2010) Predictors of difficult intubation: study in Kashmiri population. *Br J Med Practitioners* 3(1):307
10. Prasad A et al (2011) Comparison of sonography and computed tomography as imaging tool for assessment of airway structures. *J Ultrasound Med* 30:965–972
11. Singh M, Chan VWS, Prasad GA (2010) Use of sonography for airway assessment an observational study. *J Ultrasound Med* 29:79–85
12. Chau CW, Chan HH, Wong CP, Wong TW, Lau CC (2010) Sonographic measurement of the epiglottis in normal Chinese adults. *Hong Kong J Emerg Med* 17(5):429–434
13. Dastidar P, Heinonen T, Numminen J, Rautiainen M, Laasonen E (1999) Semi-automatic segmentation of computed tomographic images in volumetric estimation of nasal airway. *Eur Arch Otorhinolaryngol* 256:192–198
14. Bakker NH, Lohuis PJ, Menger DJ, Trenité GJN, Fokkens WJ, Grimbergen CA (2005) Objective computerized determination of

- the minimum cross-sectional area of the nasal passage on computed tomography. *Laryngoscope* 115:1809–1812
15. Chou HC W (1993) Mandibulohyoid distance in difficult laryngoscopy. *Br J Anaesth* 71:335–339
 16. Naguib M, Scamman FL, O'Sullivan C et al (2006) Predictive performance of three multivariate difficult tracheal intubation models: a double-blind, case-controlled study. *Anaesth Analg* 102:818–824
 17. Hui CM, Tsui BC (2014) Sublingual ultrasound as an assessment method for predicting difficult intubation: a pilot study. *Anaesthesia* 69:314–319
 18. Law JA, Broemling N, Cooper RM, Drolet P, Duggan LV, Griesdale DE, Hung OR, Jones PM, Kovacs G, Massey S, Morris IR, Mullen T, Murphy MF, Preston R, Naik VN, Scott J, Stacey S, Turkstra TP, Wong DT (2013) The difficult airway with recommendations for management—part 2—the anticipated difficult airway. *Can J Anaesth* 60:1119–1138
 19. Laura F, Cavallone MD, Vannucci A (2013) Extubation of the difficult airway and extubation failure. *Int Anaesth Res Soc* 116(2):368–383
 20. Balakrishnan M, Kuriakose R, Koshy RC (2004) Radiation induced changes in the airway—anaesthetic implications. *South Afr J Anaesth Analg* 10:19–21
 21. Kristensen MS, Teoh WH, Graumann O, Laursen CB (2014) Ultrasonography for clinical decision-making and intervention in airway management: from the mouth to the lungs and pleurae. *Insights Imaging* 5:253–279
 22. Fiadjoe JE, Stricker P, Gurnaney H, Nishisaki A, Rabinowitz A, Gurwitz A, McCloskey JJ, Ganesh A (2012) Ultrasound-guided tracheal intubation—a novel intubation technique. *Anesthesiology* 117(6):1389–1391
 23. Tsui BCH et al (2008) Sublingual airway ultrasound imaging. *Can J Anaesth* 55(11):790–791
 24. Kundra P, Mishra SK, Ramesh A (2011) Ultrasound of the airway. *Indian J Anaesth* 55:456–462