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OPEN ACCESS JOURNAL ISSN: 2148-6832

MSD Medical Science and Discovery
2019; 6(12):321-6

Research Article Doi: 10.36472/msd.v6i12.329

The Evaluation of Upper Airway: Point of Care Ultrasound vs. Traditional Tests

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Abstract

Objective: The ultrasound-guided interventions have gained widespread popularity in several aspects of anesthesia practice. In this study, we aimed to compare the preoperative evaluation tests and sonographic measurements of the upper airway for the prediction of a potentially difficult airway.

Material and Methods: In this prospective observational study, we enrolled 136 adult patients undergoing elective surgery under general anesthesia. The Modified Mallampati classification, thyromental distance, sternomental distance, and Cormack-Lehane scores were recorded. Sonographic measurements included pre-epiglottic space (PES), the distance between the midpoints of vocal cords and epiglottis (EVC). The ratio was interpreted. Main outcome is to determine the sensitivity and specificity of the upper airway ultrasound for the prediction of a potentially difficult airway.

Results: There was no statistically significant relationship between body mass index value and thyromental distance, Thyromental/Sternomental Ratio and PES/EVC ratio, Cormack-Lehane, Mallampati classification and thyromental/sternomental distance ratio ($p>0.05$). The sonographic measurements of airway have no significance to predict the difficult intubation and the comparison between PES, EVC and the PES/EVC ratio and assessment tests (Cormack-Lehane, Mallampati classification, thyromental and sternomental distances) was insignificant. The sternomental distance measurement was predictive for the difficult airway only in patients having body mass index more than 31.6 kg m-2.

Conclusion: Ultrasound is a useful tool for identifying the upper airway prior to anesthesia but the validity for the prediction of difficult airway is not clear. By increasing the clinical experiences and further investigations, a greater insight into its use will be gained.

Keywords: airway management; endotracheal intubation; laryngoscopy; ultrasonography

Introduction

The prediction of difficult airway remains the major troublesome of anesthesiology practice. Many bedside airway assessment tests are available in clinical practice but the sensitivity and specificity of these tests are not strong enough to predict the difficult airway (1). The difficult airway was defined as the experience of difficulty with face mask ventilation, difficulty with tracheal intubation, or both by a conventionally trained anesthesiologist (2). However, it's subjective to determine the degree of difficulty. For this purpose, an intubation difficulty scale has been introduced to categorize the difficulty as easy, slightly and very difficult intubation in 1997 (3).

Recently, point of care ultrasound has gained rapid popularity to visualize the airway structures (4-6). Sonographic measurements at the level of hyoid bone and thyrohyoid membrane levels demonstrated as a predictor for the distinction of difficult laryngoscopy (7). Mallampati score is widely used pre-anesthesia evaluation of airway difficulty in daily practice but this screening tool shows considerable inter-observer variation and is influenced by gagging, phonation and posture of the patient (8,9). Thyromental and sternomental distance are the anthropometric measurements to predict the difficult intubation but they were found to be poor single predictors of airway difficulty (10). Cormack-Lehane (grade1-4) classification was based on the direct laryngoscopic view of the anatomic features and strongly associated with the prediction of difficult intubation (grade3-4) (11).

Received 20-11-2019 **Accepted** 23-12-2019 **Available Online** 25-12-2019 **Published** 30-12-2019

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http://dx.doi.org/10.36472/msd.v6i12.329

Rana et al. (12) demonstrated that the assessment of the pre-epiglottic space and the distance from the epiglottis to the midpoint of the distance between the vocal cords is a better predictor of Cormack-Lehane grading as compared to hyomental distance ratio. On the other hand, in another study it was concluded that the measurements do not correlate with Body Mass Index although they correlate with Mallampati score (13) .

This present study was undertaken to compare the utility of sonographic measurements of pre-epiglottic space and the distance from the mid-point of the vocal cords to epiglottis to predict the difficult intubation comparing with Modified Mallampati classification, thyromental distance, sternomental distance, and Cormack-Lehane classification.

Material and Methods

This prospective observational study was conducted after approval of the Institutional Ethics Committee (Decision no: 2017/514/105/3) and written informed consent of all the participants, according to the Good Clinical Practice guidelines and the principles of the Declaration of Helsinki.

We enrolled 136 patients over 18 years of age with American Society of Anesthesiology (ASA) physical status I-III who were scheduled to undergo elective surgery under general anesthesia conducted with endotracheal intubation in a tertiary training hospital. The patients were selected randomly from the operation lists of each operating room in a sequential order among the patients requiring the general endotracheal anesthesia. If the ordered patient refused to enroll in the study, following patient in the list was offered to participate.

Exclusion criteria: Emergency surgery, patients with limited mouth, head and neck movement, patients with temporomandibular joint impairment, the history of previous head and neck surgery, fracture or tumors of maxillofacial region, patients requiring awake intubation, uncooperative patients, any cervical spine deformity, patients with severe arthritis, patients with prominent teeth deformities or lost and pregnant patients were excluded from study.

According to institution protocol, an anesthesiologist conducted the preoperative assessment for ASA risk stratification by evaluation of laboratory findings, chest X-ray and electrocardiography. All preoperative assessments have been performed by the anesthesiologists having at least 5 years experienceyears' experience in anesthesia who were participated in this study.

Airway assessment tests: The Modified Mallampati score (MMS) was specified in a sitting position with the patient's head in a neutral position. The patient was asked to open her/his mouth as widely as possible, protrude the tongue out of her/his mouth as much as possible. The observer provided a score of I-IV according to the visibility of the soft palate, uvula and faucial pillars. The thyromental distance (TMD) was measured from the mental prominence to the thyroid cartilage while the patient's neck was fully extended in a supine position. The sternomental distance (SMD) was measured from the suprasternal notch to mentum with the neck fully extended in the supine position.

Ultrasound measurements: Ultrasound measurements were performed by the primary investigator and obtained by using a Sonoline Adara, Siemens ultrasound system. All measurements have been conducted in the supine position with the maximal head and neck extension. The ultrasound probe was placed in the submandibular area and rotated in the transverse plane from cephalad to caudad direction without changing the probe position. Epiglottis and posterior part of the vocal folds with arytenoids was visualized in one 2-dimensional view. Epiglottis visualized as hypoechoic curvilinear structure and its anterior border demonstrated a hyperechoic structure named pre-epiglottic space (PES). Vocal cords appeared as hyperechoic lateral V-shaped structure identified by the movement of two linear structures during breathing or phonation. The distance between the midpoints of vocal cords and epiglottis (E-VC) was measured. The ratio of PES to E-VC was estimated.

After all measurements were completed, patients were premedicated with 0.05 mg kg-1 midazolam intravenously and transferred to the operating room. Standard monitoring recommended in ASA guideline has been employed to the patients and 100% oxygen has been administered before induction for a minimum of 3 minutes. Anesthesia was induced with 0.5 µg kg-1 fentanyl and 2-3 mg kg-1 propofol intravenously. After checking the loss of consciousness and adequate mask ventilation, 0.6 mg kg-1 rocuronium has been administered intravenously to facilitate the endotracheal intubation. For laryngoscopy, a re-usable metal Macintosh blade 3-4 was used depending on the patient's body structure and patients were intubated by another anesthesiologist with more than 5 years of anesthesia experience blinded to the preoperative airway assessments. This anesthesiologist noted the Cormack-Lehane classification according to the position of vocal cords without compressing the larynx. After insertion of the appropriate size of an endotracheal tube, the maintenance of anesthesia was provided depending on the clinical condition of the patient. Guide-wire was not attached to the endotracheal tubes to achieve standardization. If the intubation process was difficult, guide-wire was inserted into the endotracheal tube to facilitate the procedure.

Data collection: Demographic characteristics of the patients including age, gender, height, weight, body mass index (BMI) and ASA physical status were recorded. Thyromental and sternomental distance were recorded for each patient. The ratio of thyromental to sternomental distance was estimated. Modified Mallampati score is graded from I to IV as follows; Grade I: faucial pillars, uvula, soft and hard palate visible; Grade II: uvula, soft and hard palate visible; Grade III: Only base of uvula visible; Grade IV: Only hard palate visible. Grade III and IV are predicted as difficult intubation. The patients with a thyromental distance less than 6-6.5 cm and sternomental distance $\leqslant$12.5 cm are pre-diagnosed as intubation difficulty. Cormack-Lehane classification including four grades (Grade I: full view of the glottis, Grade II: supraglottis not seen, Grade III: visible epiglottis, not the glottis, Grade IV: neither glottis nor epiglottis visible). Grade III and IV imply airway difficulty. Ultrasonographic

measurements of PES, E-VC, the calculation of PES E-VC ratio and the airway assessment test results were recorded in a sheet prepared for each patient. The primary outcome of this study was to determine the sensitivity and specificity of the upper airway ultrasound for the prediction of a potentially difficult airway.

Statistical analysis: For statistical analysis, IBM SPSS Statistics (Version 22.0) was used. Continuous data were expressed as means ± standard deviation (SD); categorical data were expressed as numbers of occurrences (percents). Student-t test was used in the 2-group comparisons of the normally distributed parametric values. Mann-Whitney U test was used to decide the significance between 2-group comparisons not showing normal distribution. Correlation analysis was performed using the Pearson test in normally distributed data. Spearman rank correlation test was used to analyze the correlation between data not showing normal distribution. The level of statistical significance was $p<0.05$.

In the sample size analysis based on 80% power and 95% confidence interval, the minimum sample size to be reached was 78 participants to detect a reasonable change in sensitivity and specificity. The sensitivity and specificity values for calculation were based on a previous study by Reddy et al. (14).

Results

The data of 136 patients were evaluated. None of the patients were excluded. Patient demographics are listed in Table 1. Ninety-two patients (67.6%) had short thyromental distance (⩽ 6 cm). Forty-two patients (30.9%) have a sternomental distance of ⩽12.5 cm. According to Mallampati classification, 107 patients had a score of 1-2 (78.7%) and 29 had a score of 3-4 (21.3%). Cormack-Lehane scores varied between 3-4 for 26 patients (19.1%) and 1-2 for 110 patients (80.9%). All study parameters were shown in Table 2.

Based on the Cormack-Lehane scoring, the sensitivity (D) of detecting difficult intubation of thyromental distance test was 76.9%, specificity (S) was 34.5%, positive predictive value (PPD) was 21.7% with a negative predictive value (NPD) of 86.4%. Sternomental distance test identified the sensitivity (D) of 42.3%, the specificity (S) of 71.8%, the positive predictive value (PPD) of 26.2% and the negative predictive value (NPD) of 84%. There was no statistically significant relationship between Cormack-Lehane and Mallampati classification and TMM / SMM ratio ($p>0.05$). The Mallampati classification was able to detect difficult intubation in 7 of 26 difficult intubation cases, and difficult intubation in 22 of 110 easy intubations comparing to Cormack-Lehane scoring. The statistical sensitivity (D) of the Mallampati classification was 26.9%, the specificity (S) was 80%, the positive predictive value (PPD) was 24.1% and the negative predictive value (NPD) was 82.2% (Table 3).

There was an inverse, moderate (40.4%) and statistically significant relationship between BMI level and sternomental distance ($p<0.0001$). There was a similar, weak (29.2%) statistically significant relationship between BMI and Mallampati classification ($p=0.001$). There was a statistically significant relationship between BMI and Cormack-Lehane (20.7%, $p=0.016$). There was no statistically significant relationship between BMI value and thyromental distance, thyromental/sternomental ratio and PES/E-VC ratio ($p>0.05$) (Table 4). However, the mean BMI of Mallampati class 1-2 patients was 28.42 kg m-2 and 32.42 kg m-2 for subjects with Mallampati class 3-4(p=0,001). The BMI of the patients (31.6 kg m-2) with the sternomental distance of 12.5 cm or less was significantly higher than the BMI (28.02kg m-2) of 12.5 cm ($p = 0.001$).

According to US measurements, there was no statistically significant difference between PES/EVC ratio and Cormack-Lehane, Mallampati classification, thyromental and sternomental distances (Table 5).

Table 1: Patients' characteristics

Variables	Results
[1]**Age (years)**	49.71±13.61
[1]**Height (cm)**	164.78±9.25
[1]**Weight (kg)**	78.89±16.34
[1]**BMI (kg m^{-2})**	29.13±6.04
[2]**Gender Male/Female**	59 (43.4)/77 (56.6)
[2]**Comorbidity Yes/No**	50(36.8)/86 (63.2)

BMI: Body Mass Index . Data were expressed as [1] Mean±SD or [2] numbers (percentage)

Table 2. The study parameters

	Minimum	Maximum	Mean±SD
Thyromental Distance (cm)	4	12	6.19±1.55
SternomentalDistance (cm)	9	18	13.54±1.81
Thyromental/Sternomental ratio	0.31	0.74	0.45±0.1
MallampatiScore	1	4	1.94±0.72
Cormack-Lehane	1	4	1.78±0.82
Perepiglottic Space (PES) (mm)	4	20	10.19±3.53
Epiglottis-Vocal Cord Distance (E-VC) (mm)	3	19	9.17±2.55
PES/E-VC	0.33	28	1.39±2.35

http://dx.doi.org/10.36472/msd.v6i12.329

Table 3. The correlations between Cormack-Lehane score and preoperative airway assessement tests

Thyromental Distance (cm)	r	-0.252
	p	0.003*
Sternomental Distance (cm)	r	-0.245
	p	0.004*
Mallampati Classification	r	0.157
	p	0.068
Thyromental/Sternomental Ratio	r	-0.109
	p	0.205

Spearman's rho correlation test, *p<0.05; statistically significant

Table 4. The correlation between BMI and study parameters

ThyromentalDistance	r	-0.063
	p	0.467
SternomentalDistance	r	-0.404
	p	0.000*
Thyromental/Sternomental Ratio	r	0.161
	p	0.061
MallampatiClassification	r	0.292
	p	0.001*
PES/E-VC	r	-0.024
	p	0.779
Cormack-Lehane	r	0.207
	p	0.016*

BMI: Body Mass Index, PES/E-VC: Perepiglottic Space/ Epiglottis-Vocal Cord Distance *Pearson correlation coefficient *p<0.05; statistically significant*

Table 5. The correlations between PES/E-VC and airway assessment tests

		PES/E-VC
Cormack-Lehane	r	-0.006
	p	0.948
Mallampati Classification	r	-0.012
	p	0.891
Thyromental Distance	r	0.034
	p	0.697
Sternomental Distance	r	0.035
	p	0.690
Thyromental/Sternomental ratio	r	0.003
	p	0.971

PES/E-VC: Perepiglottic Space/ Epiglottis-Vocal Cord Distance, *Spearman's rho correlation test*

Discussion

In this study, we compared the role of ultrasonographic assessment of upper airway with the traditional three preoperative airway assessment tests including Modified Mallampati classification, thyromental distance, and sternomental distance. Our results showed that the sonographic evaluation of airway for the prediction of difficult intubation was not supportive of traditional assessment tests. Moreover, the Cormack-Lehane classification indicated no correlation with the sonographic measurements. The comparison between preoperative bed-side assessment tests revealed that the sternomental distance predicted the difficult airway significantly in patients having body mass index over 31.6 kg m-2.

The prediction of difficult airway is a challenging issue and the expectations from the assessment tests are to be highly sensitive and specific with minimal false positive and negative results (15). The reliability of these tests depends on the correct measurements and the optimization of inter-observer variability. Seo at al. (16) studied 7 airway assessment test and estimated a total airway score (TAS) with the sum of all scores. They suggested that the TAS>6 was a better method than using only one score for the prediction of difficult intubation.

Thyromental distance (TMD) is a frequently used preoperative assessment test for the prediction of the difficult airway. However, the discussion about its sensitivity and specificity has been going on.

The accepted cut-off value is 6.5 cm but there are many contradictions about this value. Baker et al. (17) suggested that the cut off value of TMD ranged between 6 and 8 cm. In a similar study new score estimated by the ratio of the height of the patient to TMD showed better accuracy for the prediction of airway difficulty (18). Selvi et al (19) indicated that TMD measurement was not being the alone tool to predict the difficulty in intubation with the cut off value of 6.5 cm. The sensitivity of TMD has been found %10.5 in a large case study and the value of the positive and negative predictive values were 20% and 92% respectively (20).

The sensitivity of TMD was 76.9%, specificity was 34.5%, the positive predicting value was 21.7% and the negative predicting value was 86.4% in our study. This result indicated that the TMD alone is not sensitive and specific for the prediction of the difficult airway with the cut of the value of 6.5 cm.

Since it's introduced to clinical practice, the Mallampati score has been widely used preoperative assessment test. However, its accuracy has been discussed in a previous meta-analysis due to large variation among studies (21). Controversially, a large meta-analysis had been indicated that bedside airway examination tests should be used with caution due to challenges in the literature but the Mallampati test had the highest sensitivity among all the screening tests (22).

Acer et al. (23) suggested that the Mallampati itself was not sufficient to predict the difficult intubation so; conjunction with measurement of neck circumference should be used. Sternomental and thyromental distances together with neck length found more useful in preoperative assessment tests. In our study, the sensitivity of the Mallampati test was 26.9%. The specificity was 80%, the positive predicting value was 24.1% and the negative predicting value was 82.2% in our study. This indicated that the sensitivity and specificity of the Mallampati test were not strong enough to predict the airway difficulty.

Sternomental distance (SMD) provides a rapid, simple and objective test to identify the difficult airway. The validity of this test increases when combined with the other bed-side assessment tests (24). Our results indicated that the sensitivity of 42.3%, the specificity of 71.8%, the positive predicting value of 26.2% and negative predicting value of 84% in SMD assessments in our patient population for the prediction of the difficult intubation.

Cormack-Lehane (C-L) classification is an invasive assessment test so, it's not be used as a prediction method. The accuracy of this test is still a challenging issue. Selvi et al. (19) reported that 28 of 37 patients who were accepted as difficult intubation had been graded C-L classification 3 and 4. The sensitivity and the specificity of C-L classification have been reported as 96.43 and 97.64% respectively. In our study, the number of the patient having C-L grade III and IV was 23 and 3 respectively. The correlation between preoperative screening tests and C-L classification revealed no significance.

Due to non-invasive characteristics, the use of ultrasound (US) in operating rooms has been increasing. The usage of US for the assessment of airway structures gains popularity during the last years. The measurement of anterior neck soft tissue (ANS) thickness at the hyoid bone, thyrohyoid membrane, and anterior commissure levels were found as independent predictors of difficult laryngoscopy (6). Ultrasonographic measurement of ANS- vocal cords was found a potential predictor of difficult intubation. A value of 0.23 mm was shown to be more sensitive than the preoperative screening tests (MMS, TMD, SMD) (14).

Gupta et al. (25) measured the distance from the epiglottis to the midpoint of the distance between vocal cords (E-VC), the depth of the pre-epiglottic space (PES) and compared with C-L grade of the patient. They found a weak correlation with 87% sensitivity and 30% specificity to predict the airway difficulty. In a similar study, the ratio of PES to E-VC showed a weak correlation with the C-L grade (26). We measured the PES, E-VC distance and estimated the PES to E-VC ratio by ultrasound. The results showed a weak correlation with the preoperative assessment tests and C-L classification. Our results indicated that ultrasonographic measurements of airway were not an accurate tool for the prediction of difficult intubation before anesthesia.

Limitations: The study group is not homogenous so the further comprehensive studies based on gender, age, body mass index, ASA physical status may give more revealing results. The evaluation of the presence of co-existing disease, the anatomical differences between patients in respect of head, neck and dental status may change the measurements. The number of patients C-L grade III and IV was limited in our study. The more patients having high graded C-L classification may change the statistical results.

Conclusion

The prediction of difficult airway is still one of the main topics of anesthesia practice and the researches to find the most accurate assessment tool has been going on. The evaluation of upper airway with US is a promising issue and the further investigations on this area will encourage the clinicians to use US in daily anesthesia practice for the prediction of difficult airway.

Acknowledgements: None

Conflict of Interest: The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author's Contributions: BY, BÇ, YK, OS, KTS; Research concept and design, Research the literature, preparation of the article, Revision of the article.

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