Original Article

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Pre-epiglottic Space and Epiglottis to Vocal Cord Ratio in Order to Predict Difficult Intubation in Adults: A Multivariate Analysis

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Abstract:

Objective: We aimed to enhance the prediction of difficult intubation by using ultrasonographic parameters (pre-epiglottic space (Pre-E), distance between epiglottis to middle part of vocal cord (E-VC) and Pre-E/E-VC) adjusting for traditional airway assessments.

Material and Methods: This prospective cohort study was conducted at a super-tertiary care hospital in Thailand. Participants aged 18-65 years with ASA classification I-III and who required general anesthesia with endotracheal intubation were included. Preoperative traditional and ultrasonographic airway assessments were performed by two investigators. The outcome was difficult intubations as diagnosed by laryngoscopic view grade 3 or 4. Multivariate logistic regression was used to identify predictors for difficult intubation presented by adjusted odds ratio (OR) and 95% confidence interval (CI).

Results: A total of 94 patients were recruited. The incidence of difficult intubation was 15%. The median Pre-E/E-VC ratio among this group was 0.8 compared with 1.0 in the control group (p-value 0.124). The cut-off point of <1.0 of Pre-E/E-VC was not associated with difficult intubation after adjusting for sex and other traditional parameters (p-value 0.11). Predictors of difficult intubation were female sex (OR [95% CI]: 13.8 [2.8, 68.3]), sternomental distance ≤175 mm (OR [95% CI]: 11.6 [1.9, 71.4]) and interincisor gap <4 cm (OR [95% CI]: 19.8 [1.1, 373.8]) with the area under the receiver operating characteristic curve at 0.88 and a specificity of 90.0%.

Conclusion: There was no association between the Pre-E/E-VC in predicting difficult intubation in low-risk patients. The ultrasonographic measurements of Pre-E/E-VC were not helpful in predicting difficult intubations in our setting. Trial registration: thaiclinicaltrials.org: TCTR20180115002, Registered 9 January 2018 - Prospectively registered, https://www.thaiclinicaltrials.org/#

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Keywords: airway ultrasonography, difficult intubation, distance between epiglottis to vocal cord, Pre-E/E-VC ratio, pre-epiglottic space

Introduction

The incidence of difficult intubation ranges from 1-18% in perioperative airway management, depending on the criteria and setting[1-4]. Traditional airway assessments include the Mallampati test, thyromental distance, sternomental distance, and interincisor gap, and have low to moderate sensitivity (20-62%) and moderate to fair specificity (82-97%) to detect difficult intubation. Combinations of those tests can increase diagnostic value[2]. Airway ultrasonography, including the ratio of pre-epiglottic space (Pre-E) and distance from the epiglottis to the midpoint of the vocal folds (E-VC) has also been used to predict airway difficulty[5]. However, the association between Pre-E and E-VC ratio and difficult intubation remains controversial in predetermined low-risk patients[6-8]. Soltani et al.[7] reported a weak correlation between Pre-E and E-VC ratio and the Cormack-Lehane grade. Moreover, most studies reported a correlation between the Pre-E and E-VC ratio and the airway difficulty using high grade Cormack-Lehane classifications by univariate analysis[5-8]. We hypothesized that the Pre-E and E-VC ratio would be associated with difficult intubation in the multivariate analysis. Therefore, we aimed to examine if the Pre-E and E-VC ratio was associated with difficult intubation by multivariate analysis after adjusting for other airway assessments.

Material and Methods

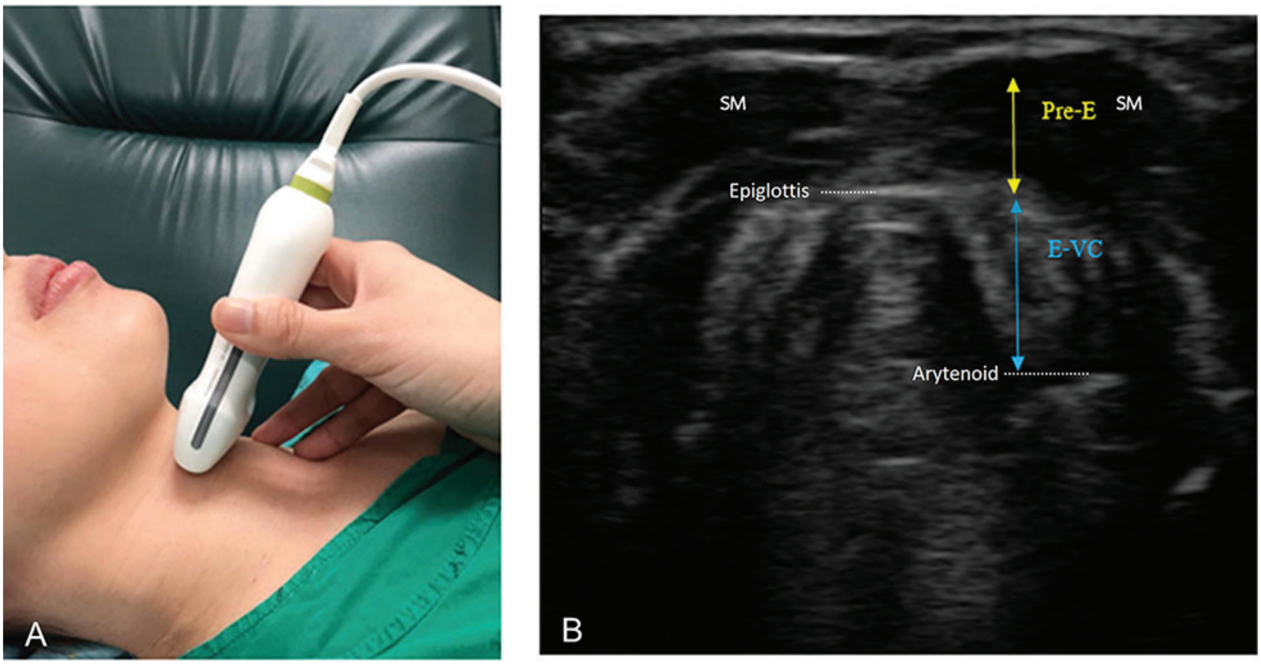
This study design was approved by the Ethics Committee of the Faculty of Medicine, Prince of Songkla University, Thailand (REC. 60-183-08-1) on 11 October 2017, and registered with thaiclinicaltrials.org: TCTR20180115002 on 9 January 2018. The data collection was performed at a super-tertiary care university hospital in southern Thailand, where 14,000 anesthetic procedures with 9,000 endotracheal intubations were annually conducted. As it is a university hospital, a conventional blade is first performed by a resident. An anesthesiologist staff member will take over if difficult intubation is encountered and then video laryngoscopy will be considered. Patients aged 18-65 years old with the American Society of Anesthesiologists (ASA) classification I-III and who required general anesthesia with endotracheal intubation between January and April 2018 were included in the study. We excluded patients who had a risk of aspiration and required a rapid-sequence induction technique. Written informed consent was obtained from all patients one day before their day of surgery. Preoperative traditional airway assessment was performed by one investigator (AT) who was a chief resident, while airway assessments by ultrasonography were performed by two investigators (NK and AT), one of whom was an attending anesthesiologist (board certified anesthesiologists).

The study protocol

On the day of surgery, after standard monitoring was applied, patients were pre-oxygenated with 100% oxygen via an anesthetic face mask for five minutes. Anesthesia was induced by propofol (2 mg/kg) and fentanyl (1-3 mcg/kg) intravenously. Orotracheal intubation was performed after 5 minutes of 0.15 mg/kg intravenous cisatracurium administration with the conventional laryngoscope (MacIntosh laryngoscope with No. 3 blade) by the attending nurse anesthetists or anesthesia residents who had at least 1-year experience in performing tracheal intubation and were blinded from preoperative airway assessments.

Main exposure variables

The main exposure variables were the preoperative airway ultrasonography of Pre-E and the distance between the epiglottis to the middle part of the vocal cord (E-VC). The Philips lumify (handheld) linear ultrasound probe was used for airway ultrasound performance. In order to standardize the image, the image was enhanced at the area of interest (Pre-E and E-VC) occupying two-thirds of the image view. The patient was placed in the supine position with an active maximal head tilt-chin lift. The ultrasound probe was placed in a horizontal view between the hyoid and thyroid cartilage in the midline. The probe was rotated in the transverse plane from the cephalad to the caudal direction until an oblique transverse view identifying the bilateral strap muscles (SM) and then bisecting the epiglottis and the middle of the vocal folds was obtained. The depth of the pre-E was measured from the anterior border of the hyperechoic epiglottic space to the epiglottis, which was a bright linear air mucosal interface (the yellow arrow). The E-VC was measured from the epiglottis to the middle of the vocal folds identified by the anterior border of the arytenoid (the blue arrow) (Figure 1). The Pre-E and E-VC ratios were then calculated accordingly. For the reliability assessment, both ultrasound performers spent two days at a hands-on workshop practicing the technique for obtaining the proper ultrasound image before initiating the pilot study. The pilot study, which consisted of 10 patients, was done to assess the intra-rater and the inter-rater reliabilities among the two ultrasound performers. The average of the two measurements of the depth of the Pre-E and E-VC by the two performers was used.



SM=strap muscles

Figure 1 The probe position (A) and the ultrasound view of the depth of the pre-epiglottic space (Pre-E) and distance between epiglottis to the midpoint of the vocal folds (E-VC) (B).

Covariates

Covariates included patient demographic data and the traditional airway assessment. The preoperative traditional airway assessments consisted of Mallampati test, thyromental distance, sternomental distance[9], interincisor gap, atlanto occipital joint extension, upper lip bite test[10], and neck circumference[11].

Study outcome

The outcome of the study was difficult intubation, which we defined as a Cormack–Lehane classification scale of grade 3 or 4[4,6], or if the number of intubation attempts exceeded 3, or if the duration of intubation exceeded 10 minutes[1-2]. If difficult intubation occurred, the patient's management was governed by the Difficult airway algorithms[12]. The laryngoscopic view using the Cormack–Lehane classification scale, number of intubation attempts, and duration of intubation was recorded by nurse anesthetists, who were blinded from preoperative airway assessments.

The cut point for traditional airway assessment and ultrasound airway parameter

The cut point for difficult intubation for traditional airway assessments, including the Mallampati classification, were 3 or 4, the thyromental distance was less than 6.5 cm, the interincisor gap was less than 4 cm, and the upper lip bite test grade 3 were performed based on a study by Gupta[5]. The new cut point for other traditional airway assessments, including the sternomental distance, the neck extension, and the neck circumference, were performed by optimal cut point of the Receiver Operating Characteristic (ROC) curve for predicting difficult intubation.

Statistical analysis

Student's t-test was used to compare continuous variables and Pearson's chi-square test was used to compare categorical variables. Mean and standard deviation were calculated to describe normally distributed data while the median and interquartile range were calculated to describe non-normally distributed data. The association between the main exposure (Pre-E/E-VC) and the outcome (difficult intubation) was analysed using a multivariate logistic regression model. Multivariate logistic regression using a stepwise backward elimination method to select the lowest Akaike information criterion for the best fit was used to identify risk factors for the difficult intubation presented by adjusted odds ratio (OR) and 95% confidence interval (CI)[13]. Since we used a cut-off point of the parameter that was associated with difficult intubation, those parameters were included in the initial multivariate logistic regression model. The model discrimination performance was examined using the area under the ROC curve providing sensitivity and specificity based on the optimal cut-point to predict difficult intubation.

Sample size determination

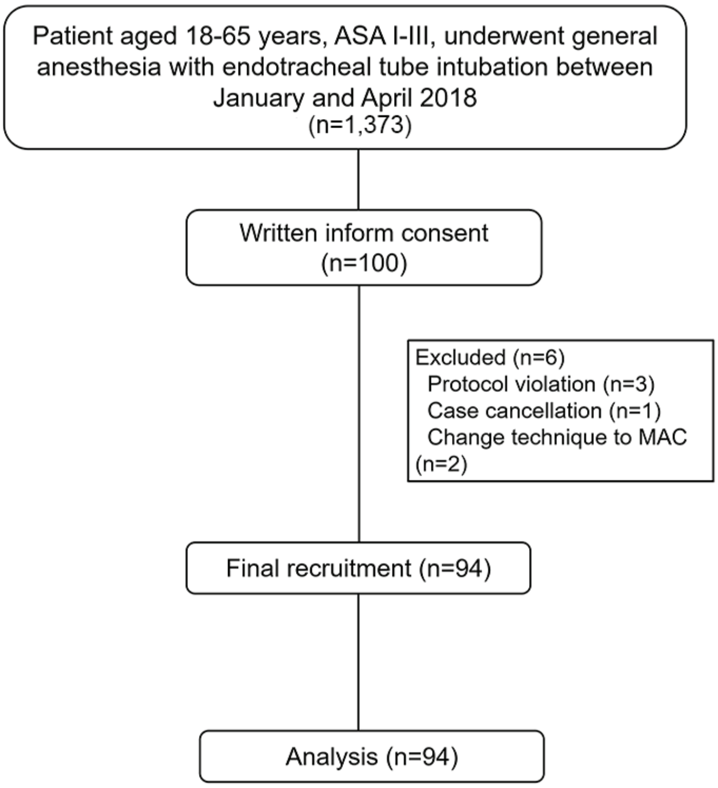
We estimated that the incidence of difficult intubation in our hospital was 15%[14]. We assumed that 30% of patients with a Pre-E/E-VC ratio >1.0 would have difficult intubation. Using the formula for comparing two independent proportions with a ratio of unexposed to exposed variables of 2:1 under a significance level of 0.05 and a power of 90% resulted in a minimum sample size of 27 patients with Pre-E/E-VC >1 and 54 patients with Pre-E/E-VC <1. The total sample size was increased to 97 cases to compensate for an expected 10% dropout rate. Therefore, the number of patients with difficult intubation would be expected to be at least 14 cases.

Results

A total of 94 out of 100 patients were recruited (Figure 2). Six patients were excluded due to protocol violation (n=3) cancellation (n=1) and change of technique (n=2). The criteria for difficult intubation are presented in Table 1. There were 14 patients that had laryngoscopic view grade 3 of which 1 patient also required more than 3 intubation attempts. Therefore, the incidence of difficult intubation was 14.9% (14/94).

Table 1 Parameters to diagnose difficult airway

Parameter	Number (%)
Laryngoscopic view	
Grade 1	50 (53.2)
Grade 2	30 (31.9)
Grade 3	14 (14.9)
Grade 4	0 (0.0)
Intubation attempts	
≤3	93 (98.9)
>3	1 (1.1)
Intubation time (minutes)	
≤10	94 (100.0)
>10	0 (0.0)



ASA=American Society of Anesthesiologists classification, MAC=monitor anesthetic care

Figure 2 Flowchart of the study

Patient demographic data and ultrasound parameters as well as traditional airway assessments are presented in Table 2. Seventy-one percent of females were in the difficult intubation group (p-value 0.01). The mean age was 51.1 ±14.5 years. The pre-epiglottis distance (Pre-E) among those with a difficult airway was 5.2 mm compared with 6.0 mm among those with a non-difficult airway (p-value 0.134), the epiglottis to vocal cord distance (E-VC) among those with a difficult airway was 6.3 mm compared with 6.1 mm among those with a non-difficult airway (p-value 0.633). The Pre-E/E-VC ratio in the difficult group was 0.8 compared with 1.0 in the non-difficult group (p-value 0.124).

The sternomental distance ≤17.5 cm was the optimal cut-off point and showed a moderate to high discriminative power (sensitivity=86.0%, specificity=50.0%) for predicting difficult intubations in both the univariate and the multivariate analysis (Table 3). A cut-off point of >1 for the Pre-E/E-VC ratio was not associated with difficult intubation (p-value 0.306) as well as in the multivariate analysis after adjusting for sex and other parameters (p-value 0.11). Table 3 shows the predictors of difficult intubation by multivariate analysis.

Table 2 Patient characteristics, ultrasound parameters and traditional airway assessments for prediction of difficult intubation

Parameter	Difficult intubation (n=14)	Non-difficult intubation (n=80)	p-value
Female	10 (71.4)	25 (31.2)	0.010
Age (years), mean (S.D.)	52.4 (10.7)	50.9 (15.1)	0.723
Body mass index (kg/m^2), mean (S.D.)	23.2 (4.4)	24.2 (4.0)	0.366
Pre-epiglottis distance (mm), median (IQR)	5.2 (4.7,6.2)	6 (5.3,7.0)	0.134
Epiglottis-VC distance (mm), mean (S.D.)	6.3 (1.3)	6.1 (1.5)	0.633
Pre E and E-VC ratio, median (IQR)	0.8 (0.7, 1.1)	1 (0.8, 1.3)	0.124
Pre E and E-VC ratio >1	4 (29.6)	38 (47.5)	0.306
Mallampati classification 3 or 4	1 (7.1)	13 (16.2)	0.685
Thyromental distance ≤6.5 cm	2 (14.3)	9 (11.2)	0.666
Sternomental distance ≤17.5 cm	12 (85.7)	40 (50.0)	0.029
Interincisor gap <4 cm	2 (14.4)	3 (3.8)	0.159
Upper lip bite test grade 3	1 (7.1)	2 (2.5)	0.387
Neck extension <25 degrees	8 (57.1)	28 (35.0)	0.203
Neck circumference ≥38 cm	5 (35.7)	20 (25.0)	0.512

S.D.=standard deviation, cm=centimetre, IQR= interquartile range, Pre-E=pre-epiglottis distance, E-VC=epiglottis to middle part of vocal cord

Table 3 Predictors of difficult intubation by multivariate logistic regression

Predictors	Crude OR (95% CI)	Adjusted OR (95% CI)	p-value
Female	5.5 (1.57, 19.24)	13.75 (2.77, 68.25)	<0.001
Sternomental distance ≤17.5 cm	6.0 (1.26, 28.54)	11.63 (1.89, 71.41)	0.002
Mallampati classification 3 or 4	0.4 (0.05, 3.30)	0.13 (0.01, 1.33)	0.085
Interincisor gap <4 cm	4.28 (0.65, 28.31)	19.77 (1.05, 373.81)	0.045
Pre-E and E-VC ratio >1	0.44 (0.13, 1.54)	0.25 (0.04, 1.53)	0.110

cm=centimetre, OR=odds ratio, CI=confidence interval, Pre-E=pre-epiglottis distance, E-VC=epiglottis to middle part of vocal cord

Risk factors of difficult intubation were female sex (OR [95% CI]: 13.8 [2.8, 68.3]), sternomental distance ≤175 mm (OR [95% CI]: 11.6 [1.9, 71.4]) and interincisor gap <4 cm (OR [95% CI]: 19.8 [1.1, 373.8]). The final model for predicting difficult intubation resulted in an AUC of 0.88 with sensitivity of 64.0% and a specificity of 90.0% (Figure 3).

Discussion

The incidence of difficult intubation in our study was 14%. We used the combination of high grade Cormack–Lehane classification[4,6], which corresponded to difficult laryngoscopy in children[15] and criteria of difficult intubation in adults[1,2] to establish the criteria of difficult intubation. According to previous airway ultrasound studies, researchers used high grade CL (2b up) to represent difficult laryngoscopy and difficult intubation[16]. Our study found that the ultrasonographic measurement of the Pre-E, the distance between the epiglottic to the middle part of vocal cord (E-VC), and the Pre-E/E-VC ratio were not sufficiently helpful to predict difficult intubation in Thai patients. Some studies reported the Pre-E/E-VC ratio could provide a more objective airway assessment compared with a standardized procedure for predicting difficult intubation at a cut-off point for the ratio between Pre-E and EVC >2 in US patients[5], a ratio >1.79 in Indian patients[17], and a ratio >1 in Chinese patients[18]. These previous studies suggest that a higher ratio (broad Pre-E, narrow E-VC) results in a higher risk of difficult intubation. In contrast, our study found the opposite result; the Pre-E distance was smaller in those with a difficult airway and the E-VC distance was larger. The Pre-E and E-VC ratios trended to be smaller among those with a difficult airway, but the difference was not statistically significant. Our contrasting result with the US study might be due to the difference in ethnicity[5] and, for the other studies, the difference in measurement of E-VC[17,18]. We measured the E-VC distance from the epiglottis to the middle part of the vocal cord identified by the anterior border of the arytenoid described by Koundal[17] and Chan[18]. However, the position of our airway ultrasound probe was slightly lower (toward the caudad direction) compared to

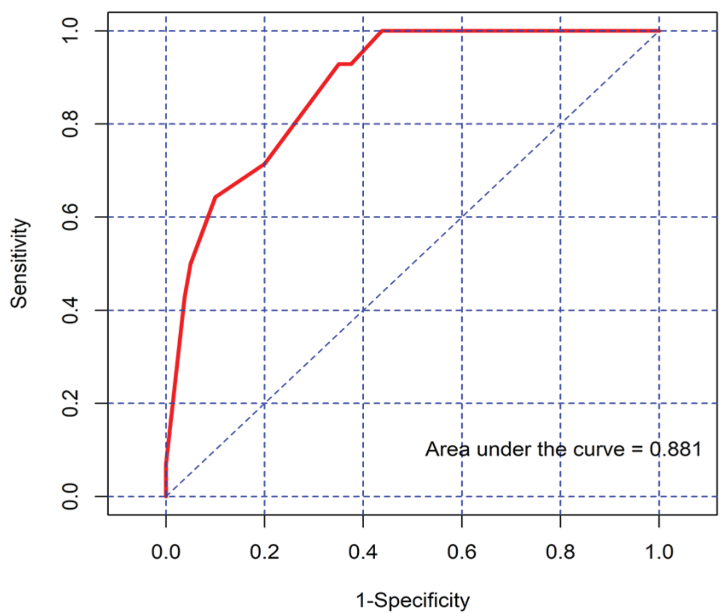


Figure 3 The final model of the Receiver Operating Characteristic (ROC) curve for predicting difficult intubation

studies by Reddy[6] and Chan[18]. This might be the reason why our result was difficult compared to the others. In fact, other studies showed a weak association between Pre-E and E-VC ratio and Cormack-Lehane grade.[7, 19] Yadav et al.[19] reported that anterior neck soft-tissue thickness at the level of the vocal cord had high sensitivity (87.5%) and high area under the curve (0.887) to predict difficult laryngoscopy whereas the pre-E and E-VC ratio had much lower validity profiles. Falcetta et al.[16] reported that only the pre-epiglottic area, measured at the thyrohyoid membrane (>5 cm), was the best predictor of a Cormack-Lehane grade of at least 2b on direct laryngoscopy and of difficult intubation but not at the vocal cord level (E-VC). Abraham et al.[20] also reported a hyomental distance ≤1.09 cm measured by ultrasound, which was strongly correlated with difficult intubation. Systematic reviews and meta-analyses revealed that the Pre-E/E-VC ratio had a low to moderate association with DI/Cormack-Lehane classification but most results came from univariate analyses[21-23]. Our final model showed that the Pre-E/E-VC ratio was not a significant predictor for difficult intubation after adjusting for the female sex, sternal distance, and the interincisor gap <4 cm.

We compared the correlation of several traditional airway assessments with difficult intubation. Overall, our study found a significant difference between the sternomental distance in those patients with difficult intubation. A sternomental distance of ≤17.5 cm had the best discriminative power for detecting difficult intubation in our study. Savva[24] and Ramadhani, et al.[25] reported a similar result in UK populations reporting that the sternomental distance was the most sensitive and specific determinant of difficult intubation but at a cut-off point of ≤12.0 cm and ≤13.5 cm, respectively. Our study showed, among the traditional airway parameters, that only the interincisor gap <4 cm was strongly correlated with difficult intubation. The other airway parameters such as thyromental distance ≤6.5 cm, Mallampati classification 3 or 4 and upper lip bite test grade 3 were not associated with difficult intubation, in contrast to the previous studies[4,26-29]. This difference might be due to the small number of difficult intubation cases, in which the sample size calculation was only confined to the main exposure (Pre-E and E-VC ratio). Yadav et al.[19] found that the combination of traditional clinical and ultrasound parameters can improve the diagnostic validity profile.

Study implications and clinical use

We found no significant association between the Pre-E/E-VC ratio >1 and difficult intubation. The sternomental distance ≤17.5 cm or interincisor gap <4 cm were specific parameters that may be used to diagnose difficult intubation with a low false positive rate (10.0%). The preoperative traditional airway assessments including Mallampati test, thyromental distance, interincisor gap, atlantooccipital joint extension, and upper lip bite test, are routinely utilised among anesthesia personnel in our hospital. However, the sternomental distance is not routinely measured unless difficult airway cases are suspected. Airway ultrasound is still a novel procedure in our practice for all residents, and attending anesthesiologists. However, we found no association between Pre-E/E-VC ratio >1 and difficult intubation. Airway ultrasound, which provides accurate dimensions of the Pre-E, is still used to predict difficult laryngoscopy in morbidly obese patients in our setting[30], but new staff need to practice regularly so that they gain more experience. Future studies with larger sample sizes should be conducted to better assess the association between Pre-E/E-VC and difficult intubation.

Strengths and limitations

The strengths of our study were as follows. First, the two ultrasonographers (NK and AT) were trained to ensure standardization before the data collection to reduce performance bias. Second, there was no missing data in the study. The limitations of our study were as follows. First, although we found 3 significant predictors, the confidence intervals for the odds ratios were fairly wide due to the low number of cases with difficult intubation. The number of events per variable was less than 10, thus the regression coefficients may have been biased toward the negative direction. Second, since we included only patients with no previous airway abnormality, the generalizability of our results to all patients with probable difficult intubation is limited.

Conclusion

We found no association between the Pre-E and E-VC ratio to predict probably difficult intubation in our predetermined low-risk patients. The utility of ultrasonographic measurements of Pre-E, E-VC or Pre-E/E-VC was not sufficiently helpful to predict difficult intubation after adjusting for patient and traditional clinical airway parameters.

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Conflict of interest

The authors have no conflicts of interest to declare.

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