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Accuracy of airway ultrasound parameters to predict difficult airway using the LEMON criteria as a reference: A cross-sectional diagnostic accuracy study

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Abstract:

OBJECTIVES: Ultrasound (US) airway indexes were frequently compared with other scoring systems such as Mallampati score and Cormack – Lehane classification system, but to the best of our knowledge never with LEMON. Here, in this study, we evaluated the accuracy of some recommended airway US parameters in terms of screening difficult airway using the LEMON criteria as a reference.

METHODS: This was a cross-sectional diagnostic accuracy study in which people with at least 18 years old coming to the emergency departments for any reason who had consent for participation, were enrolled with the simple random sampling method. Hyo-mental distance (HMD), skin to epiglottis distance (EP), and peri-epiglottic space to epiglottis to vocal cord ratio (PEP/E. VC) were the US indexes that were calculated in all participants. Using a preprepared checklist, measured US parameters were recorded. For each participant, the LEMON score variables were also assessed and recorded, and the cutoff point for considering as a difficult airway case, based on LEMON score, was 2. Demographic characteristics of the participants were also registered.

RESULTS: A total of 299 cases with a mean age of 41.1 years (95% confidence interval [CI]: 39.3–42.9), were participated. Based on LEMON score ≥2, 20 participants (6.7%) were categorized in difficult airway group. Comparison of the PEP/E. VC ($P = 0.007$) and EP distance ($P = 0.049$) of the participants based on LEMON score showed a statistically significant difference; but comparison of the means of HMD in the two groups was not statistically significant ($P = 0.144$). The median of EP of the participants was 7.70 mm (interquartile range [IQR]: 6.70–9.40). The best cutoff point of EP distance for evaluating a difficult airway was 12.27 mm and more with the sensitivity of 35% and the specificity of 86.96% (accuracy = 0.614; 95% CI: 0.492–0.736). The median of PEP/E. VC was 1.01(IQR: 0.79–1.23). The best cutoff point of PEP/E. VC for evaluating a difficult airway was 0.88 and less with the sensitivity of 70% and the specificity of 67.38% (accuracy = 0.701; 95% CI: 0.583–0.818).

CONCLUSION: As per our results, PEP/E. VC and EP distance measured with sonography can be used in distinguishing the difficult airway, using the LEMON criteria as the reference. However, further studies are needed to use PEP/E. VC and EP distance as a part of reliable indexes.

Keywords:

Airway management, difficult airway, intratracheal intubation, LEMON score, prediction, ultrasonography

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Box-ED

What is already known on the study topic?

- About 10% of the cases requiring intubation are considered as difficult cases.
- Ultrasound (US) airway indexes were frequently compared with other scoring systems such as Mallampati score and Cormack – Lehane classification system.

What is the conflict on the issue? Has it importance for readers?

- It is likely that, ultrasound airway indexes have never been compared with LEMON as a predictive clinical tool for difficult airway.

How is this study structured?

- This was a prospective diagnostic accuracy study includes data from approximately 300 cases.

What does this study tell us?

- It seems that hyo-mental distance and skin to epiglottis distance cannot differ difficult and nondifficult airway cases based on LEMON criteria; but peri-epiglottic space to epiglottis to vocal cord ratio could do. However, further studies are still needed before generalizing the results.

Introduction

Airway management is a common and pivotal skill in the emergency departments (ED), intensive care units, and even prehospital setting. Although it does not usually encounter with a significant problem, about 10% of the cases requiring intubation are considered as difficult cases.[1] It is important to assess and predict potentially difficult airway for choosing appropriate equipment and management strategy, and failure can lead to a catastrophic outcome.[1,2]

LEMON criteria is the most common noninvasive clinical difficult airway prediction rule; however, its use in the ED may be limited due to uncooperative patients or cervical spine immobilization.[1,3] Therefore, the search to find another simple and noninvasive method for airway assessment is still going on.[4] In recent years, the anterior cervical soft-tissue ultrasound (US) is being used to forecast difficult intubations.[2,5] Given that sometimes calculating the LEMON score is not completely possible because of the patient's poor condition and cooperation in the ED, airway US may be a good alternative, even with higher accuracy, considering its practicality and the physician's skills.[6]

US airway indexes were frequently compared with other scoring systems such as Mallampati score and Cormack – Lehane classification system, but to the best of our knowledge never with LEMON. Here, in this study, we evaluated the accuracy of some recommended airway US parameters in terms of screening difficult airway using the LEMON criteria as a reference.

Methods

This cross-sectional diagnostic accuracy study was performed in EDs of Sina hospital and Imam Khomeini hospital affiliated to Tehran University of Medical Sciences (TUMS), from September 2019 to July 2020 with the approval of the ethics committee of TUMS (IR.TUMS.MEDICINE.REC.1399.025). Conducting this study did not impose any additional cost, neither to the participants nor to the health system. All participants were enrolled after receiving a signed informed consent.

Considering the main goal of this study, which was the evaluation of the relationship between airway US parameters and LEMON score as the reference tool for screening difficult airway, the most important item for calculating sample size was difficult airway prevalence. Therefore, assuming an 8% prevalence of difficult airway[7] and with the 3% error in prevalence estimation with 95% confidence interval (CI), the smallest calculated sample size was 290. People who were at least 18 years old coming to the ED for any reason who had given consent for participation in the study were enrolled with simple random sampling method using a software generated table set. Refusing the participation from completing the sonography, presence of unstable vital sign, or interference with other diagnostic process were consider as exclusion criteria.

Out of more than 45 defined US parameters in the literature, three parameters among those with higher accuracy were chosen in this study.[2] Those variables were hyo-mental distance (HMD), skin to epiglottis distance (EP), and peri-epiglottic space to epiglottis to vocal cord ratio (PEP/E. VC). The method of performing the procedure can be easily found in this regard in various website. The airway sonography was performed by a PGY-3 emergency medicine resident who underwent a 1-month training course in this regard, and after performing 20 fully correct sonographies under direct supervision of an emergency medicine attending physician, started the data gathering process of this study. Airway ultrasonography was performed using the Linear probe 6–13 MHZ and the US device SONOACE X8 SAMSUNG.

Sampling was performed prospectively. At first, using a preprepared checklist, demographic characteristics of the participants were also registered. Thereafter, for each participant, the LEMON score variables were assessed and recorded one by one. Instantly after the completion of this examination, airway sonography was performed, and measured US parameters were also recorded.

The LEMON score has five different items with the total score of 10, and the cutoff point for considering as a difficult airway case, based on LEMON score, was ≥2.

The categorical data are expressed as frequency with percentage. The continuous data are presented as mean with 95% CI and nonparametric variable are reported as median with interquartile range (IQR). We used of Kolmogorov – Smirnov test and graphical approach, Q-Q plot, to assess the normality assumption of the variables; so according to the establishment of assumptions parametric or nonparametric test was done. Qualitative variables were analyzed using the Chi-square test. For considering quantitative variables, independent *t*-test has been used for comparing the means of two groups and analysis of variance for comparing the means of three groups. Furthermore, the nonnormal distributed variable, we used of Kruskal–Wallis H and Mann–Whitney *U* test.

A receiver operating characteristic (ROC) area under the curve (AUC) analysis was used for considering the accuracy of the proposed criterion. A ROC curve analysis with 95% CI was calculated for considering the differentiation of US criteria. J-Youden index was used to obtain US criteria cutoff points. Furthermore, we calculated sensitivity, specificity, positive likelihood ratio and negative likelihood ratio, and positive predictive value and negative predictive value of USG image variables (HMD, EP, and PEP/E. VC) for difficult airway by LEMON score in the best cutoff point. All analyses were performed using the STATA statistical software, version 16 (StataCorp 2019, College Station, TX, USA).

Results

Baseline characteristics

A total of 299 cases with a mean age of 41.1 years (95% CI: 39.3–42.9) were enrolled; there was not a single case who dropped out or excluded from the study after enrolment. The baseline characteristics of the study participants are reported in Table 1. The mean body mass index (BMI) of the participants was 25.4 kg/m^2 (95% CI: 24.8–25.9). Based on the LEMON criteria, 20 participants (6.7%) were categorized in difficult airway group.

Participants with higher LEMON score were significantly older but did not differ in terms of their gender (7.8% of men vs. 4.7% of women; P = 0.312). The mean age of the participants with LEMON score = 0 was 38.7 years (95% CI: 36.8–40.7), the mean age of the participants with LEMON score = 1 was 45.4 years (95% CI: 41.2–49.6), and the mean age of the participants with LEMON score >1 was 51.9 years (95% CI: 43.3–60.5) (P < 0.001).

Table 1: The baseline characteristics of the study population (*n*=299)

Variable	*n* (%)
Sex	
Male	193 (64.5)
Female	106 (35.5)
BMI	
<18.5	13 (4.3)
18.5-24.9 (normal range)	137 (45.8)
25-29.9	111 (37.1)
>30	38 (12.7)
LEMON score	
0	212 (79.9)
1	67 (22.4)
2	18 (6.0)
3	2 (0.7)

BMI: Body mass index

The older participants also had significantly higher BMI. The mean BMI of the participants with LEMON score = 0 was 24.9 kg/m^2 (95% CI: 24.3–25.6), the mean BMI of the participants with LEMON score = 1 was 25.7 kg/m^2 (95% CI: 24.7–26.8), and the mean BMI of the participants with LEMON score >1 was 28.4 kg/m^2 (95% CI: 25.6–31.2) (P = 0.005).

Ultrasonography findings

The mean of HMD of the participants was 57.6 mm (95% CI: 56.6–58.6). The HMD distance in participants in difficult airway group (LEMON score ≥2) was lower than that of the participants with lower LEMON score. The comparison of the means of HMD in the participants with different LEMON scores was not statistically significant (P = 0.144). The mean HMD of the participants with LEMON score = 0 was 58.0 mm (95% CI: 57.0–59.1), and in the participants with LEMON score >1, it was 58.9 mm (95% CI: 54.7–63.2) [Table 2].

The median of EP distance of the participants was 7.70 mm (IQR: 6.70–9.40), varied between 3.43 mm to 25.3 mm. The EP distance was higher in participants in difficult airway group (LEMON score 2–3) than the participants with lower LEMON score (0–1). The comparison of the EP distance showed a statistically significant difference between the groups (P = 0.049). The median EP distance in the participants with LEMON score = 0 was 7.60 mm (IQR: 6.50–9.06) and in the participants with higher LEMON score, it was 8.10 mm (IQR: 7.13–13.6) [Table 2].

The median of PEP/E. VC was 1.01 (IQR: 0.79–1.23), varied between 0.42 and 2.57. The PEP/E. VC in participants with difficult airway (LEMON score = 2–3) was lower than the participants with lower LEMON score (0–1). The comparison of the PEP/E. VC of participants based on LEMON score showed a statistically significant difference (P = 0.007) and the median of PEP/E. VC in

participants with zero LEMON score was 1.02 (IQR: 0.81–1.23) and in participants with higher LEMON score was 0.80 (IQR: 0.66–1.00) [Table 2].

The accuracy of determining HMD as a diagnostic test for predicting difficult airway based on AUC of ROC was 0.554 (95% CI: 0.420–0.689) [Figure 1]. The best cutoff point of HMD for evaluating a difficult airway was 60.5 mm and more with the sensitivity of 55% and specificity of 62.72% [Table 3].

The accuracy of determining EP distance as a diagnostic test for predicting difficult airway based on AUC of ROC was 0.614 (95% CI: 0.492–0.736) [Figure 1]. The best cutoff point of EP distance for evaluating a difficult airway was 12.27 mm and more with the sensitivity of 35% and the specificity of 86.96% [Table 3].

The accuracy of determining PEP/E. VC as a diagnostic test for difficult airway screening based on AUC of ROC was 0.701 (95% CI: 0.583–0.818) [Figure 1]. The best cutoff point of PEP/E. VC for evaluating a difficult airway was 0.88 and less with the sensitivity of 70% and the specificity of 67.38% [Table 3].

The accuracy of determining PEP/E. VC as a diagnostic test for evaluating a difficult airway was higher than HMD and EP distance [Figure 1]. Although, there was no statistically significant difference between them, maybe due to small sample size ($P = 0.182$).

Out of all participants, 149 (49.8%) had a 25 or more BMI. The difficult airway prevalence among them was 8.7% (13 participants). The prevalence of difficult airway in participants with BMI lower than 25 was 4.7% and had no statistically significant difference ($P = 0.160$).

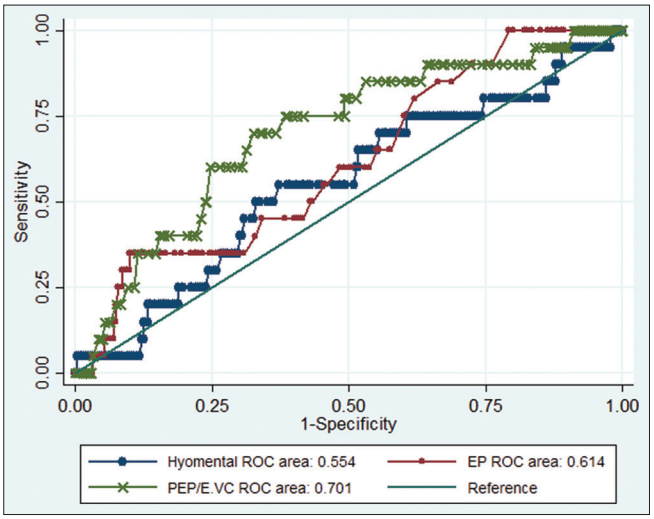

Figure 1: Comparing ROC curves of Hyo-mental distance (HMD), EP distance and PEP/E.VC for evaluating difficult intubation (LEMON score ≥2)

Table 2: The distribution of age, body mass index and ultrasound parameters of patients by their LEMON score

Variable	LEMON score, mean (95% CI)/median (IQR)			*P*	LEMON score, mean (95% CI)/median (IQR)		*P*
	0	1	>1		<2	≥2	
Age (years)	38.7 (36.8-40.7)	45.4 (41.2-49.6)	51.9 (43.3-60.5)	<0.001	40.3 (38.5-42.1)	51.9 (43.3-60.5)	0.002
BMI	24.9 (24.3-25.6)	25.7 (24.7-26.8)	28.4 (25.6-31.2)	0.005	25.1 (24.6-25.7)	28.4 (25.6 31.2)	0.003
HMD (mm)	58 (57.0-59.1)	55.8 (53.1-58.5)	58.9 (54.7-63.2)	0.144	57.5 (56.5-58.5)	58.9 (54.9-62.9)	0.487
EP (mm)	7.60 (6.50-9.06)	8.36 (6.80-10.40)	8.10 (7.13-13.6)	0.049*	7.70 (6.60-9.37)	8.10 (7.13-9.37)	0.089*
PEP/E.VC	1.02 (0.81-1.23)	1.08 (0.82-1.29)	0.80 (0.66-1.00)	0.007*	1.05 (0.82-1.24)	0.80 (0.66-1.00)	0.003*

*The *P* value based-on nonparametric test, Kruskal-Wallis *H* and Mann-Whitney *U*-test. The median with IQR reported for nonnormal distributed variable (EP and PEP/E.VC). CI: Confidence interval, IQR: Interquartile range, BMI: Body mass index, HMD: Hyo-mental distance, EP: Skin to epiglottis distance, PEP/E.VC: Peri-epiglottic space to epiglottis to vocal cord ratio

Table 3: The cross-tabulation and diagnostic test evaluation between the ultrasonography images variables (hyo-mental distance, skin to epiglottis distance and peri-epiglottic space to epiglottis to vocal cord ratio) and difficult airway by LEMON Score

Variable in best cut-off	LEMON score		AUC (95% CI)	Sesitivity (95% CI)	Spesificity (95% CI)	PLR (95% CI)	NLR (95% CI)	PPV (95% CI)	NPV (95%CI)
	<2 (*n*=279), *n* (%)	≥2 (*n*=20), *n* (%)							
HMD >60.50 mm									
No	175 (62.7)	9 (45.0)	0.554	55.0	62.7	1.48	0.72	9.6	95.1
Yes	104 (37.3)	11 (55.0)	(0.420-0.689)	(31.5-76.9)	(56.8-68.4)	(1.0-2.3)	(0.4-1.2)	(4.9-16.5)	(90.9-97.7)
EP >12.27 mm									
No	251 (90.0)	13 (65.0)	0.614	35.0	90.0	3.5	0.72	20.0	95.1
Yes	28 (10.0)	7 (35.0)	(0.492-0.736)	(15.4-59.2)	(85.8-93.2)	(1.7-7.0)	(0.5-1.0)	(8.4-36.9)	(91.7-97.4)
PEP/E.VC ≤0.88									
No	188 (67.4)	6 (30.0)	0.701	70.0	67.4	2.2	0.45	13.3	96.9
Yes	91 (32.6)	14 (70.0)	(0.583-0.818)	(45.7-88.1)	(61.5-72.9)	(1.5-3.0)	(0.2-0.9)	(7.5-21.4)	(93.4-98.9)

CI: Confidence interval, AUC: Area under an receiver operating characteristic curve, PLR: Positive likelihood ratio, NLR: Negative likelihood ratio, PPV: Positive predictive values, NPV: Negative predictive values, HMD: Hyo-mental distance, EP: Skin to epiglottis distance, PEP/E.VC: Peri-epiglottic space to epiglottis to vocal cord ratio

The mean EP distance and PEP/E. VC in the participants with the BMI more than 25 was higher than the participants with lower BMI. The difference between the median EP distance in the two groups was 1.0 mm ($P < 0.001$) and the difference between PEP/E. VC in the two groups was 0.07 and marginally significant ($P = 0.053$) [Table 4].

The accuracy of determining HMD and PEP/E. VC as a diagnostic test for evaluating a difficult airway in participants with a BMI >25 was higher than participants with lower BMI. The accuracy of determining EP distance as a diagnostic test for evaluating a difficult airway was higher in participants with normal or lower BMI [Table 5].

Discussion

The findings of this study showed that PEP/E. VC and EP distance could properly differ the difficult and nondifficult airway cases using the LEMON criteria as the reference; but, HMD could not. Ultrasonography has recently gained more attention in terms of differentiating difficult airway, difficult direct laryngoscopy, and also difficult intubation and several studies were conducted in this era. It should be mentioned that such studies mainly conducted in operating room rather than ED and mainly focused on difficult direct laryngoscopy; however, there it is still a considerable heterogeneity in the literature, that prevents to reach a definitive conclusion.[8]

Table 4: The distribution of hyo-mental distance, skin to epiglottis distance and peri-epiglottic space to epiglottis to vocal cord ratio of the study patients by their body mass index

Variable	BMI, mean (95% CI)/median (IQR)		*P*
	<25 (*n*=149)	≥25 (*n*=150)	
HMD (mm)	57.25 (55.9 -58.6)	57.95 (56.5 -59.4)	0.494
EP (mm)	7.20 (6.30 -9.14)	8.20 (7.00 -9.55)	<0.001*
PEP/E.VC	1.00 (0.77 -1.19)	1.07 (0.80 -1.29)	0.053*

*The *P* value based-on nonparametric test, Mann-Whitney *U*-test. The median with IQR reported for nonnormal distributed variable (EP and PEP/E.VC). CI: Confidence interval, IQR: Interquartile range, BMI: Body mass index, HMD: Hyo-mental distance, EP: Skin to epiglottis distance, PEP/E.VC: Peri-epiglottic space to epiglottis to vocal cord ratio

Table 5: The area under the receiver operating characteristic curve (95% confidence interval) of hyo-mental distance, skin to epiglottis distance and peri-epiglottic space to epiglottis to vocal cord ratio of patients for evaluating difficult intubation (LEMON score ≥2) by their body mass index

Variable	BMI, AUC (95% CI)	
	<25 (*n*=149)	≥25 (*n*=150)
HMD (mm)	0.474 (0.259-0.689)	0.590 (0.431-0.748)
EP (mm)	0.725 (0.544-0.906)	0.509 (0.347-0.671)
PEP/E.VC	0.695 (0.474-0.917)	0.726 (0.599-0.852)

AUC: Area under an receiver operating characteristic curve, CI: Confidence interval, BMI: Body mass index, HMD: Hyo-mental distance; EP: Skin to epiglottis distance; PEP/E.VC: Peri-epiglottic space to epiglottis to vocal cord ratio

In the current study, comparison of the means of PEP/E. VC and EP distance of the participants based on their LEMON score had a statistically significant difference. In line with our findings, Koundal *et al*. reported that PEP/E. VC has the potential to become a reliable airway sonography index for preoperative airway assessment in terms of predicting difficult laryngoscopy.[9] The same results also reported by Gupta *et al*. that showed PEP/E. VC has a significant correlation with Cormack – Lehane criteria, similar to our study.[10] While, in another study, Soltani Mohammadi *et al*. were found no significant correlation between PEP/E. VC and Cormack-Lehane which is different with the result of our study, probably due to smaller sample size of that study.[11] When it comes to EP distance, there are also various studies in which its accuracy in terms of predicting the difficult intubation has been confirmed.[4,12,13]

HMD, also was not shown to be a proper index for predicting difficult airway in this study, but was previously reported to be good predictors of difficult intubation.[4,12-14] Such results may be due to the fact that most of previous studies were conducted in the preoperative setting and also compare the findings with a better and more reliable standard, than the LEMON criteria which was used in the current study. Indeed, accuracy of LEMON criteria by itself in terms of predicting difficult airway is under debate and it was even tried to make some modifications on it;[15,16] Although, as the score of the patients increased, the likelihood of difficult laryngoscopy also increased. As an example, the analysis of demographic characteristics of the participants showed a correlation between higher age or higher BMI and higher LEMON score but, in the previous study by Ezri *et al*., higher BMI does not correlate with higher LEMON score.[17] In a study by Petrisor *et al*. found a correlation between HMD and Cormack-Lehane in obese patients and that correlation was even more prominent in neck hyper-extension position which is different with the result of the current study probably due to the difference between two study groups' BMI.[18]

Limitations

The rate of difficult airway prevalence in ED is different from what was reported in previous studies that mostly performed in the operating room. Therefore, there may be a need for more accurate estimation of difficult airway prevalence to better sample size calculation, as low sample size would alter the generalizability of the results. Furthermore, considering the method of sampling in the current study, there could be potential selection bias. Importantly, the patients who were met

with truly difficult intubation were not considered in this study; so this point should be considered for designing further studies.

Conclusion

As per our results, PEP/E. VC and EP distance measured with sonography can be used in distinguishing the difficult airway, using the LEMON criteria as the reference. However, further studies are needed to use PEP/E. VC and EP distance as a part of reliable indexes. For further studies, it can be underlined that these USG parameters can be used in combination with current criteria to create a novel scoring system to assess patients with difficult airway.

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Author contributions statement
The conception and design of the work by MS, NA, AA and AB; Data acquisition by NA and RB; Analysis and interpretation of data by MS, RB and AB; Drafting the work by NA and RB; Revising it critically for important intellectual content by MS, AA, and AB; all the authors approved the final version to be published; AND agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work.

Conflicts of interest
None declared.

Consent to participate
All participants were enrolled after receiving a signed informed consent.

Ethical approval
The study proposal was approved by the ethical committee of Tehran University of Medical Sciences (code: IR.TUMS.MEDICINE.REC.1399.025) at 2019-12-14 (available via the URL: https://ethics.research.ac.ir/form/349olwq9j6mjlhe0.pdf). Conducting this study did not impose any additional cost, neither to the participants nor to the health system.

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