Original Article

Diagnostic Value of Epigastric Ultrasound and Suprasternal Notch Ultrasound in Comparison with Standard Capnography in Confirmation of Endotracheal Tube Placement after Intubation

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Abstract

Background: Endotracheal intubation is the basic method of providing a safe cross-sectional airway area and the incorrect placement can be dangerous and causes complications. So this study aimed to access the diagnostic value of color Doppler epigastric ultrasound and linear probe suprasternal notch ultrasound in comparison with standard capnography in confirmation of endotracheal tube (ETT) placement after intubation.

Materials and Methods: This diagnostic value study was conducted on 104 patients requiring intubation who were referred to the Emergency Department. After the intubation, color Doppler epigastric ultrasound and suprasternal notch ultrasound as well as the standard capnography were used to confirm the placement ETT.

Results: The sensitivity and specificity of color Doppler epigastric ultrasound were 97.96% and 100%, for suprasternal notch ultrasound were 98.98% and 66.67%, and for combination of the both methods were 96.94% and 100% respectively that showed the significant diagnostic value in the confirmation of ETT placement ($P < 0.001$). The mean of elapsed time to confirm the ETT placement by the standard capnography method (17.95 ± 2.45 s) was significantly more than the two methods of epigastric ultrasound (10.38 ± 4.65 s) and suprasternal notch ultrasound (5.08 ± 4.45 s) as well as the combined method with the mean of 15.46 ± 8.31 s ($P < 0.001$).

Conclusion: The results of this study showed that although ultrasound is a potentially accurate, fast, and reliable method to confirm the endotracheal tube placement, but suprasternal notch ultrasound is considered to be a more appropriate diagnostic technique due to its higher sensitivity and less detection time compared to epigastric ultrasound and combined method.

Keywords: Endotracheal, epigastric, intubation, suprasternal notch, ultrasonography

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Introduction

Intubation is a highly-sensitive method for management of critically ill patients and the most important priority is confirming the placement of the endotracheal tube (ETT) after intubation as in previous studies the results supported that ETT is inappropriately placed in 6%–25% of cases.[1,2] The initial physical examination involves chest assessment which has bilaterally and symmetrically dilated and listening to the epigastric area (the sound of blowing air into the stomach should not be heard) and bilateral hearing of the lungs (breath sounds should be adequate and symmetrical). It is therefore necessary to use a secondary method to confirm the placement of ETT intubation. Although no confirmation technique alone is completely reliable, in addition to clinical evaluation, the continuous waveform capnography for the

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end-tidal CO2 (ETCO2) detection is recommended as the most reliable method of confirming and monitoring correct ETT placement.[3] However, due to the false-positive or false-negative cases in the ETCO2 detection, if CO2 is not detected, the direct observation of ETT placement is recommended to confirm the esophageal intubation.[4] The methods to distinguish endotracheal from esophageal intubation have been compared in numerous studies. There are some modalities that are currently used in practice such as visual confirmation during laryngoscopy, expansion of the chest wall during ventilation, auscultatory method, capnography, and chest X-ray that are vary in the degree of accuracy.[5-7]

More recently, a limited number of studies have been performed to confirm the endotracheal intubation (ETI) by ultrasound that via this method the placement can be indirectly assessed by observing the pleura or diaphragm movement.[8-10]

Methods used to confirm ETT must have a sensitivity of 100% in order to properly identify the esophageal intubation. Physicians should learn these methods and apply them easily in order to not only reduce the duration of hypoxia by the early detection of a tube in the esophagus, but also to prevent esophageal ventilation and its complications, such as vomiting and aspiration.[10] Ultrasound does not have these limitations and can be used to assess the ETT through observing the pleura or diaphragm movement (indirect).[11,12] Nowadays, ultrasound devices are available in many emergency departments, and if the accuracy of ultrasound in the ETT is confirmed, it can be used in emergency wards or intensive care units (ICU) where the incidence of failed intubation is common.[11]

According to previous studies, ultrasound is used to confirm the ETT placement in adults and children, but it is emphasized that physicians require experience and expertise in ultrasound when using this method.[13,14]

Most previous studies were performed under controlled conditions, such as the operating room and ICU, had a small sample size, or the study population consisted of children. However, the present study was conducted on patients aged 18 years or older who were admitted to the emergency department. In addition, the results of recent studies have shown the high sensitivity of ultrasound in confirming ETT placement and also reported the utility of color Doppler ultrasound (CDU) to confirm ETT placement compared to conventional (black-and-white) ultrasound.[9,15,16]

Many studies have focused on the identification of correct ETT place by conventional ultrasound, but only two studies have investigated CDU to assess ETT placement and no study has so far considered the diagnostic value of combination of the CDU and linear probe ultrasound on the accuracy of ETT intubation. Given that CDU may be a safe and does not impose additional costs on the patients; therefore, this method can be used in hospitals located near cities and do not need more complicated and expensive equipment like capnograph. There are no known risks to do CDU and it is also considered safe during pregnancy. Using CDU the elapsed time for diagnosis would be much shorter than the other conventional methods. Therefore, the aim of this study was to evaluate the diagnostic value of color Doppler epigastric ultrasound and the linear probe suprasternal notch ultrasound in comparison with the standard capnography and the combination of these methods in the confirmation of ETT placement after intubation.

Materials and Methods

The present cross-sectional study was the diagnostic value study. This study was conducted on all patients requiring intubation who were referred to the Emergency Department in Al-Zahra and Ayatolah-Kashani hospitals of Isfahan, Iran, during 2019–2020. Of the study population, a total of 104 patients were selected by nonrandomly convenience sampling at the 95% confidence level, power of 80%, and considering the sensitivity of 93% for ETT placement regarding the previous studies, adaptation ratio of 0.94[17] and error level of 0.2%. The study inclusion criteria were: (1) those undergoing rapid sequence intubation in the Emergency Department, (2) age of 18 years or older, (3) not requiring intubation for cardiopulmonary resuscitation and (4) having no chest and abdominal trauma. The patients were excluded from the study if they had respiratory distress, hemodynamic changes, inability to sleep in the supine position and withdrawing from the study.

The study protocol was approved by the Ethics committee of Isfahan University of Medical Sciences with the code of IR.MUI.MED.REC.1398.246. After obtaining written informed consent from subjects, their demographic and clinical information including age and sex were recorded.

The intubation was then performed by an emergency medicine specialist, and immediately the epigastric ultrasound was performed by the research assistant using the Esaote-Technus MP CDU machine with 2.5–5 MHz multi-frequency convex 40 R transducer. After placing the probe in the epigastric region, if air entered the stomach, it appeared red, and when the air exit, it appeared blue. It means that the ETT was inserted into the esophagus instead of the trachea, indicating the incorrect placement of ETT, and when red and blue were not seen, indicating that the ETT was inserted into trachea and its placement was correct.

Also, in the conventional ultrasound, the linear prop was transversely placed in front of the neck at the top of the suprasternal notch. The position of the trachea could be determined by a hyperechoic air-mucosa (A-M) interface with reverberation artifact posteriorly (comet-tail artifact). Position of ETT, when it is placed in trachea, is defined as observable contour between A-M and comet-tail artifact. If the second contour is appeared, it would be similar to the second airway which is called double-tract sign. If position of the esophagus is suspected of being exactly behind the trachea, operator can determine the placement of the esophagus by moving the probe

to the left and right during scan. The results of the combined methods would be considered positive if both of them reached the positive result and confirm the ETT placement.

It should be noted that at the beginning of intubation, a sonographer who was not involved in the process of intubation, and selection of technique or drugs, turned on the ultrasound device and by holding the probe, stranded on the right side of the patient's bed prepared to perform the ultrasound. Immediately after intubation by placing the probe in the defined position, the ETT placement was evaluated by the mentioned two methods.

The time taken to perform ultrasound was calculated and recorded by one of the nurses from the time of probe was placed in the epigastric region and the suprasternal notch until the correct placement of ETT was confirmed or not. Capnography was performed to confirm ETT placement and the time taken to confirm the ETT placement was also recorded.

Statistical analysis was done by SPSS software (version 25; SPSS Inc., Chicago, Ill., USA) and data were reported as *n* (%) or mean ± standard deviation. Receiver operating curve (ROC) analysis was used to evaluate the diagnostic value of epigastric ultrasound and suprasternal notch ultrasound and their combination compared to capnography and area under curve (AUC), sensitivity and specificity, positive predictive value (PPV) and negative predictive value (NPV) were reported. Independent *t*-test was also used to compare the elapsed time of confirming the ETT placement. $P < 0.05$ were considered as statistically significant.

Results

Out of 104 patients, there were 73 (70.2%) males and 31 (29.8%) females. The patients had the mean age of 52.13 ± 22.15 years. According to capnography (the gold standard method), the ETT placement was confirmed in 98 (94.2%) cases that it was 92.3% and 95.2%, for epigastric ultrasound and suprasternal notch ultrasound, respectively [Table 1].

The sensitivity and specificity of epigastric ultrasound were 97.96% and 100%, respectively with PPV of 100% and NPV of 75% (AUC = 0.990, $P < 0.001$). The sensitivity and specificity of suprasternal notch ultrasound were 98.98% and 66.67%, respectively with PPV of 98% and NPV of 80% (AUC = 0.828, $P < 0.001$).

Table 1: Demographic and clinical characteristics of the participants

Characteristics	*n* or mean	Percentage or SD
Age (years)	52.13	22.15
Sex		
Male	73	70.2
Female	31	29.8
Confirm with epigastric ultrasound	96	92.3
Confirm with suprasternal notch ultrasound	99	95.2
Confirm with capnography	98	94.2

SD: Standard deviation

Also, the combined results of the two methods of epigastric ultrasound and suprasternal notch ultrasound in detecting the accuracy of intubation has sensitivity and specificity of 96.94% and 100%, respectively with the PPV of 100% and NPV of 66.7% (area under the ROC curve = 0.985, $P < 0.001$) [Table 2]. The correct placement of intubation was confirmed if the result of the both methods were positive. In addition, two by two comparison of the results of these ultrasound methods and their combination, found no significant difference between the area under the curve ($P > 0.05$) [Figure 1].

The elapsed time to confirm the ETT placement by epigastric ultrasound with the mean of 10.38 ± 4.65 s and with suprasternal notch ultrasound with the mean of 5.08 ± 4.45 s was significantly less than capnography with the mean of 17.95 ± 2.45 s ($P < 0.001$). In addition, the total of elapsed time by the two ultrasound methods with the mean of 15.46 ± 8.31 s was still significantly less than the capnography with the mean of 17.95 ± 2.45 s ($P < 0.001$) [Table 3].

Discussion

In the present study, the success rate of correct ETT placement for the patients was 94.2%, and was confirmed by capnography as a gold standard method. Both methods (epigastric ultrasound, and suprasternal notch ultrasound) showed the significant diagnostic value in the confirmation of ETT placement. The sensitivity of both methods was more than 97% and the specificity of epigastric ultrasound was 100%, while for suprasternal notch ultrasound it was 66.67%. It should be noted that in the combination of the results of these two methods to confirm the ETT placement, the sensitivity and specificity

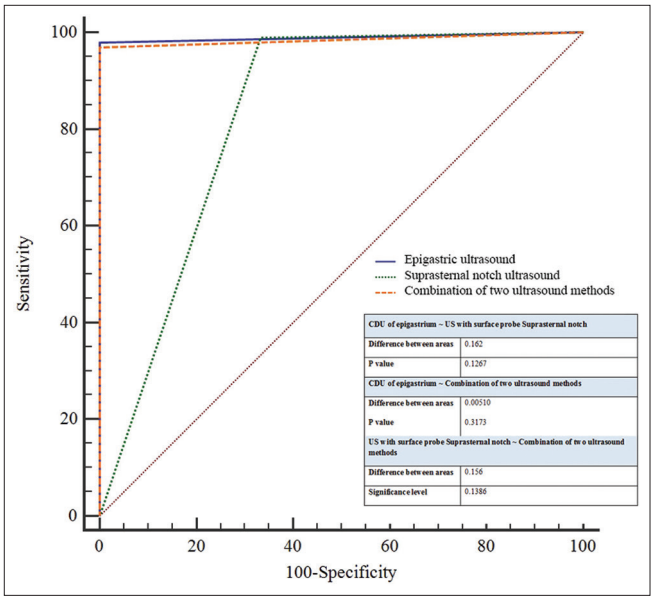

Figure 1: Receiver operating curve in confirmation of endotracheal tube placement using different methods

Table 2: Diagnostic value of epigastric ultrasound, and suprasternal notch ultrasound in the confirmation of endotracheal tube placement

Intubation results	Capnography	
	Positive (n=98)	Negative (n=6)
Epigastric ultrasound		
Positive (n=96)	96	0
Negative (n=8)	2	6
Suprasternal notch ultrasound		
Positive (n=99)	97	2
Negative (n=5)	1	4
Combined methods		
Positive (n=95)	95	0
Negative (n=9)	3	6

Parameters of ROC analysis	Epigastric ultrasound	Suprasternal notch ultrasound	Combination of two ultrasound methods
AUC (95% CI)	0.990 (0.97-1.00)	0.828 (0.62-1.00)	0.985 (0.96-1.00)
P	<0.001	0.002	<0.001
Sensitivity (95% CI)	97.96 (92.8-99.8)	98.98 (94.4-100.0)	96.94 (91.3-99.4)
Specificity (95% CI)	100.00 (54.1-100.0)	66.67 (22.3-95.7)	100.00 (54.1-100.0)
PPV (95% CI)	100.0 (96.2-100.0)	98.0 (92.9-99.8)	100.0 (96.2-100.0)
NPV (95% CI)	75.0 (34.9-96.8)	80.0 (28.4-99.5)	66.7 (29.9-92.5)

AUC: Area under curve, PPV: Positive predictive value, NPV: Negative predictive value, ROC: Receiver operating curve, CI: Confidence interval

Table 3: Operating time of different methods

Time (s)	Minimum-maximum	Mean±SD
Elapsed time for epigastric ultrasound to diagnose (T1)	5.52-27.15	10.38±4.65
Elapsed time for suprasternal notch ultrasound to diagnose (T2)	1.89-14.85	5.08±4.45
Elapsed time for combined methods to diagnose (T3)	7.41-42.00	15.46±8.31
Elapsed time for capnography to diagnose (T4)	10.27-24.66	17.95±2.45
Comparison	**Difference**	***P***
T1-T4	7.57	<0.001
T2-T4	12.87	<0.001
T3-T4	2.49	0.006
T1-T2	5.30	<0.001
T1-T3	5.08	<0.001
T2-T3	10.38	<0.001

SD: Standard deviation

were 96.94% and 100%, respectively, and this method had the largest AUC compared to each of the ultrasound method.

In consistent with our results, Zamani *et al*. showed that ultrasound sensitivity in diagnosis of intubation accuracy was 97.9% with 83.3% specificity. PPV and NPV were 98.9% and 71.4% respectively.[18]

Also, Gottlieb *et al*. conducted a study to confirm the ETT placement by CDU and the black-and-white suprasternal notch ultrasound and the results demonstrated that color flow imaging was the more reliable method to confirm ETT placement.[9] Thomas *et al*. conducted a study to evaluate the reliability of ultrasound in confirming ETT placement in an emergency setting and the results showed that using ultrasound the sensitivity and specificity of diagnosis were 97.89% and 100%, respectively, which was consistent with our results.[2]

In addition, another study found that the use of ultrasound imaging of diaphragm motion is a useful, quick, noninvasive, portable and direct anatomic method for assessment of ETT placement with the sensitivity and specificity of 100%.[12]

In their study Ahmadi *et al*.[19] demonstrated that 97% of cases had correct ETT placement in comparison with direct visualization by a glydoscope and no cases of incorrect ETT placement in the esophagus was detected by ultrasound. In our study, suprasternal notch ultrasound failed to identify the correct ETT placement (two cases), but no cases of incorrect placement were detected by epigastric ultrasound.

Wong *et al*. conducted a study using color flow detection of air insufflation to improve accuracy in verifying nasogastric tube position and the results showed that the sensitivity, specificity, PPV and NPV of 2D USG were 11.1%, 100%,

100%, and 11.1%, respectively. For color flow Doppler USG, the sensitivity, specificity, PPV and NPV were 90%, 80%, 97.6%, and 47.1%, respectively. In general, the accuracy of this Doppler ultrasound was 89%, which was much more than USG with 20% accuracy.[16] In the present study, the accuracy and predictive value of epigastric ultrasound were more than suprasternal notch ultrasound, but the sensitivity and speed of suprasternal notch ultrasound was higher in detecting the correct place of ETT. In addition, no significant difference was found between the results of the two methods of epigastric ultrasound and suprasternal notch ultrasound alone and in combination with each other. In fact, it can be said that although the combination of these two methods can provide a more definite and reliable result to diagnose the accuracy of intubation, but statistically there is no significant difference between the use of each method or in combination.

The elapsed time for confirmation of ETT placement by epigastric ultrasound was significantly more than the suprasternal notch ultrasound. On the other hand, the elapsed time in each of these ultrasounds was significantly less than the capnography method. Even if the related time of the two ultrasound methods were added, the standard method (capnography) still has the most time in determining the accuracy of intubation. The specificity (or accuracy) of epigastric ultrasound was higher than the suprasternal notch ultrasound, but the sensitivity of the suprasternal notch ultrasound was higher which is important to search for the method with the highest sensitivity. Therefore, it may be said that supernatural notch ultrasound is preferred to epigastric ultrasound due to its higher sensitivity and shorter diagnostic time, although no statistically significant difference was found between the two methods. In addition, by combining the results of the two ultrasound methods, no significant change was found in the diagnostic value of ETT placement accuracy and only the elapsed time had increase. Therefore, it can be said that the diagnostic value of any of these ultrasound methods can be the same as their combinations and it is not necessary to use the combined methods.

In consistent with our results, Chun *et al*. showed that visceral-parietal pleural interface could be well-imaged for all of the patients using the power Doppler. In general, thoracic sonography may be another tool that could be employed to confirm proper ETT placement after intubation; however, this technique requires further scientific evaluation.[15] Another study showed that the elapsed time to confirm tube placement with ultrasonography was significantly less in comparison with waveform capnography and clinical methods.[2] In their study, Gottlieb *et al*. found that transtracheal sonography is fast to perform, with an acceptable degree of sensitivity and specificity for the confirmation of ETI.[9]

It should be noted that sonography can be performed with different accuracy and speed due to its dependence on the skill of the technician and therefore this method has some limitations. In addition, the type and accuracy of the ultrasound device and the location of performing the sonography are among the other limitations of this method as well as the small sample size. However, the comparison between the two ultrasound methods is one of the advantages of this study. Therefore, it is recommended to do future studies considering the clinical signs of patients along with ultrasound results simultaneously in the confirmation of ETT placement in order to increase the sensitivity of ultrasound methods and able to generalize the results.

Conclusion

According to the results of the present study, both epigastric ultrasound and suprasternal notch ultrasound were potentially reliable methods to confirm the ETT placement alone and in combination. Although the latter had higher sensitivity and the former had higher specificity and their combination had no significant increase in sensitivity and specificity of diagnostic value. In addition, the time needed to detect the ETT placement with suprasternal notch ultrasound was significantly more than the two other methods of epigastric ultrasound and capnography. It should also be noted that if a combination of both ultrasounds was used, the elapsed time would still be less than the capnography. Therefore, it can be said that in cases that use of one of the ultrasound methods is not very reliable due to the specific conditions of the patient, it can be used a combination of the two ultrasound methods and decide about the accuracy of ETT placement; because it still saves time compared to ultrasound. But in general, it seems that suprasternal notch ultrasound is associated with more appropriate diagnostic value due to higher sensitivity and less diagnosis time than epigastric ultrasound.

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Conflicts of interest

There are no conflicts of interest.

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