

Reliability of ultrasound in confirming endotracheal tube placement as a new and fast tool

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Background Chest ultrasound has been an important tool for the diagnosis of many chest diseases, and, recently, it became an important tool for confirmation of the site of endotracheal tube placement. In our study, we used the ultrasound for this confirmation and compared this with capnography and clinical examination as gold standards and also with chest radiograph.

Patients and methods This is a cross-sectional study conducted in our chest ICU from January 2019 to August 2019. We included 30 chronic obstructive pulmonary disease patients with acute respiratory failure who needed endotracheal intubation according to the protocols. Ultrasound was used to identify and confirm endotracheal tube placement simultaneously with a quantitative waveform capnography (end-tidal carbon dioxide), clinical methods, and chest radiograph. Confirmation of tube placement and time taken for the confirmation were noted by our staff.

Results Of the 30 intubation attempts, six (20%) had esophageal intubations. The sensitivity and specificity of diagnosis using ultrasonography were 95.8 and 93.3%, respectively. This was statistically comparable with the other

three modalities. The time taken to confirm tube placement with ultrasonography was 7.7 ± 1.6 s compared with waveform capnography, clinical examination, and chest radiograph, which were 18.8 ± 2.6 , 26.1 ± 3.4 , and 73.6 ± 7.7 s, respectively. The time taken by ultrasonography was significantly less.

Conclusion Sonar-confirmed endotracheal intubation saves time and life, particularly in patients with low pulmonary blood flow in comparison with other traditional methods of confirmation.

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Introduction

Chest ultrasound has become widely used and easy with high diagnostic yield in many critical care areas and chest departments. The European Resuscitation Council 2010 in the scope of the International Liaison Committee on Resuscitation Consensus on Science and Treatment Recommendations recognized the value of chest ultrasound as an adjuvant for the diagnosis and treatment of the possible reversible causes of cardiac arrest [1,2]. Using ultrasonography to confirm the positioning of the endotracheal tube (ETT) is advisable owing to many causes, as it is portable, bedside and can be repeated many times, cost-effective, noninvasive and painless method. Direct tracheal ultrasound demonstrates larynx anatomy and tracheal anatomy independent of patient physiology and is not influenced by other variables such as decreased pulmonary blood flow. Tracheal ultrasound also can detect intubation into the esophagus before starting the patient's mechanical ventilation, and this, in turn, prevents further forced ventilation that introduces a big amount of air into the stomach and subsequently involves undesirable complications [3].

Confirmation of the ETT site may be challenging for the majority of ICU physicians [4,5]. Sometimes, it may be so difficult to see the glottis, especially when there is difficult intubation [6]. Physical examination,

pulse oximetry, and chest radiography are not definite methods to detect the ETT position [7]. Esophageal detection device is not available in many locations and can be misinterpreted [8]. Capnography is recommended as a reliable tool for confirming ETT placement [9]. In contrast, capnography may not be widely available, and it has many constraints [10,11]. At least six breaths are required for the stomach to be completely cleared of CO₂ [12]. On the contrary, fiberoptic bronchoscopy is expensive and invasive [13].

Chest ultrasound is a simple, real-time, and less invasive diagnostic method that is commonly used in the chest ICU for many other causes [14].

At the moment of original intubation, ETT site confirmation should be completed in all patients. Continuous and nonwaveform capnography may be less precise for patients in cardiac arrest and for those with significantly reduced tissue perfusion. In such situations, if capnography is inconclusive, other confirmation methods such as an esophageal detector device, ultrasound, or bronchoscopy should

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be used. Ultrasound imaging can be used to reliably verify the positioning of the ETT. However, this should be performed by someone who is experienced in this technique [15]. The ultrasound machine is portable, noninvasive, and the pictures are readily reproducible [16]. Several studies demonstrated that ultrasound is a method to confirm ETT's right placement. In our study, we aimed to find the effectiveness of tracheal ultrasonography to confirm ETT placement with the existing methods.

Patients and methods

This study was carried out in the ICU of our Chest Department from January 2019 to August 2019, and -35 consecutive patients with acute exacerbation of chronic obstructive pulmonary disease (COPD) who presented to the ICU with an indication for endotracheal intubation were recruited for the study. Patients with significant neck pathologies that would affect the study methods were excluded from the study (five patients). Tracheal sonography was performed using a SonoScape ultrasound machine (SonoScape SSI-4000; SonoScape Medical Corp., Guangdong, China; EC REP SonoScape Europe S. R.L, Rome, Italy). Intubation was carried out as per the standard hospital protocol, which includes confirmation by quantitative waveform capnography by using Philips M-20 monitor (Philips, Dublin, Ireland), clinical examination and chest radiograph. If a typical square waveform capnography was noted along with carbon dioxide detection of more than 4 mmHg after six breaths, the tube was considered endotracheal.

Inclusion criteria

The study included COPD patients who underwent endotracheal intubation as a result of acute respiratory failure. The patients were included during the times when at least two of the investigators were on duty.

Exclusion criteria

The exclusion criteria were as follows: (a) neck trauma, (b) neck malignancy, (c) neck surgery or tracheostomy.

We identify and confirm the placement of tube as tracheal or esophageal (by ultrasound) as follows:

Tracheal intubation when there is only one air-mucosal interface and reverberation artifact with posterior shadowing.

Esophageal intubation when 'double tract' sign appears.

Time zero was the moment when intubation completion was approved by the individual who performed the intubation. Subsequently, the tube placement was concurrently confirmed by four distinct health care employees, and the time taken by each technique was observed using a stopwatch. The final time observed was the moment when tube placement was verified by individual health care employees with their modality. The sensitivity and specificity of ultrasonography were performed to verify endotracheal intubation against the other three techniques. Time was taken to verify the positioning of the tube in an emergency environment for each technique.

Ethical statement

The study was approved by Faculty of Medicine, Zagazig University Ethics Committee. A written informed consent was obtained from all participants.

Statistical analysis

Data were collected throughout history taking, basic clinical examination, laboratory investigations, and outcome measures and were coded, entered, and analyzed using Microsoft Excel software. Data were then imported into statistical package for the social sciences (SPSS, version 20.0; 2013; Minitab Inc., State College, PA, USA) software for analysis. According to the type of data, qualitative data were represented as number and percentage, quantitative continuous data were represented by mean±SD, and the following tests were used to test differences for significance: difference and association of qualitative variables by χ^2 test, Kappa for agreement, and differences between multiple quantitative data by analysis of variance. *P* value was set at less than 0.05 for significant results and less than 0.001 for a highly significant result.

Results

Among the 30 patients who underwent intubation, 16 were male individuals and 14 were female individuals. The mean±SD was 62.0±7.88 years, with a BMI of 24.9±3.95 and neck circumference of 31.2±2.9. All patients were suffering from COPD with acute respiratory failure. The relation between ultrasound accuracy and BMI and neck circumference showed no statistically significant difference. This is presented in Table 1. Of the 30 patients who underwent intubation, we found significant association and agreement between clinical findings as gold standard and ultrasound findings, with sensitivity of 95.8% and specificity of 83.3%, wherein we correctly detected five of the esophageal

intubations but misinterpreted one of tracheal intubations as esophageal (Table 2). We found significant association and agreement between capnogram as gold standard and ultrasound finding with sensitivity of 95.7% and specificity of 57.1%. Tracheal ultrasonography correctly detected four of esophageal intubations but misinterpreted one of tracheal intubations as esophageal (Table 3). We use clinical examination and capnography as the gold standards, because they are the most applicable methods and most professional in our chest ICU. We also assessed the time consumed for each method, and the ultrasound was found to consume the least amount of time; this is shown in Fig. 1.

Discussion

The aim of this study was to identify the accuracy and timeliness of tracheal ultrasonography to confirm the ETT positioning in respiratory and ICU patients. As demonstrated by the 2018 guidelines for advanced cardiac life support, the position of the ETT requires to be clinically verified and also verified after intubation in order to prevent the catastrophic effects of esophageal intubation [17]. For each confirmatory method, however, there are some

constraints. Even when conducted by qualified doctors, the clinical evaluation of the ETT situation remains unreliable [10]. The most prevalent clinical technique to confirm endotracheal intubation is stethoscopic auscultation of the chest and detection of motion and extension of the chest wall.

However, these methods may interfere with chest compressions during cardiopulmonary resuscitation. Quantitative waveform capnography has been regarded as the gold standard to verify endotracheal intubation. However, waveform capnography requires good ventilation and adequate pulmonary blood flow to produce reliable results. It can give false-positive (e.g. a nonfasting patient producing gastric CO₂) [18] and false-negative outcomes (e.g. low flow of pulmonary circulation, using epinephrine drugs, technical error, or obstruction of the airways), during the resuscitation of the cardiopulmonary system [10,11].

In the latest National Emergency Airway Registry Series studies, one third of doctors used continuous quantitative capnogram in their clinics despite the availability of colorimetric end-tidal CO₂ samples in 77% of them [19]. With extremely effective and more accurate outcomes, fiberoptic bronchoscopy can be used to verify the tube's position, but the bronchoscope is more costly with liability to be broken. It is also not commonly accessible to use bronchoscopy for routine tube position confirmation [20].

It is, therefore, advisable to use other confirmatory methods during cardiopulmonary resuscitation without disruption of thorax compression. The curved probe was used in this research, which is more frequently used through the suprasternal notch window. This window

Table 1 Relation between accurate ultrasound and BMI and neck circumference

	US	N	Mean	SD	t	P
BMI	Accurate	28	24.8571	4.07308	0.287	0.832
	Not	2	25.5000	2.12132		
NC	Accurate	28	31.3929	2.99802	0.874	0.236
	Not	2	29.5000	0.70711		

NC, neck circumference; t, independent sample t test; US, ultrasound.

Table 2 The sensitivity and specificity of ultrasonography with regard to the clinical method as gold standard

	Clinical [n (%)]		Total	χ^2	P	Kappa agreement	Sensitivity (%)	Specificity (%)
	Esophageal	Tracheal						
US								
Esophageal	5 (83.3)	1 (4.2)	6 (16.7)	17.5	0.00**	0.75	95.8	83.3
Tracheal	1 (16.7)	23 (95.8)	24 (83.3)					
Total	6 (100.0)	24 (100.0)	30 (100.0)					

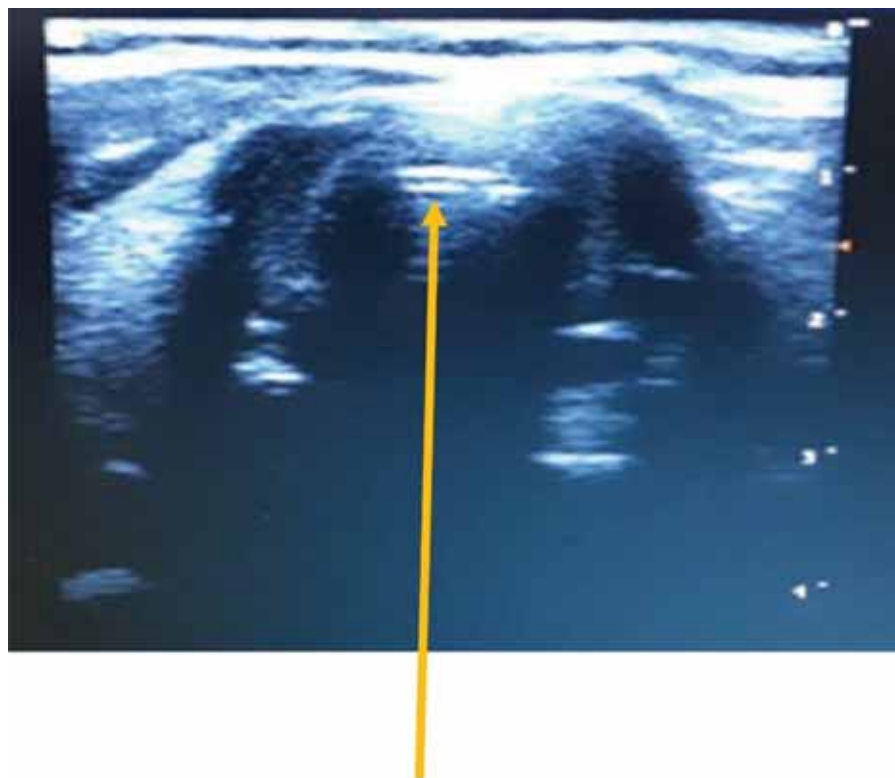
US, ultrasound. **Highly significant.

Table 3 The sensitivity and specificity of ultrasonography with regard to capnography as gold standard

	Capnogram [n (%)]		Total	χ^2	P	Kappa agreement	Sensitivity (%)	Specificity (%)
	Esophageal	Tracheal						
US								
Esophageal	4 (57.1)	1 (4.3)	5 (16.7)	10.7	0.001**	0.62	95.7	57.1
Tracheal	3 (42.9)	22 (95.7)	25 (83.3)					
Total	7 (100.0)	23 (100.0)	30 (100.0)					

**Highly significant.

Figure 1



Tracheal ultrasound using high-frequency probe with transverse position showing one air–mucosal (A–M) interface and reverberation artifact with posterior shadowing.

has been used because it is more precise to visualize the trachea and the esophagus and hence the ETT position [21]. We also used dynamic real-time evaluation during the intubation phase, which may appear more precise and faster.

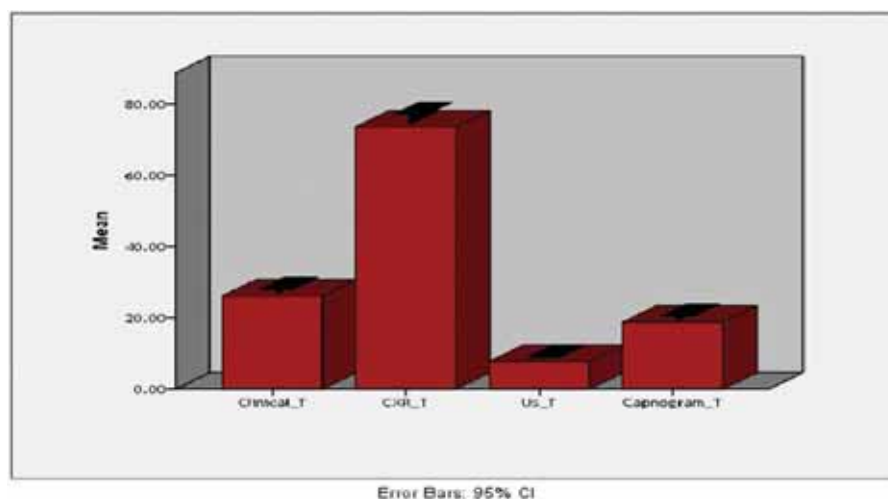
If the ETT was wrongly inserted into the esophagus, another hyperechoic air–mucosal interface artifact with posterolateral shadowing to the trachea appeared in this technique [17]. In this research, as regards clinical technique as a gold standard, real-time tracheal ultrasound has a high sensitivity (95.8%) and specificity (83.3%) to confirm the location of the ETT during patient intubation in the pulmonary ICU (Table 2). As regards capnography as a gold standard, real-time tracheal ultrasound has a high sensitivity (95.7%) and specificity (57.1%) (Table 3). The relatively low specificity of ultrasound with regard to the capnogram is due to the low pulmonary blood flow, which affects the efficacy of the waveform capnogram. Two prospective studies by Werner *et al.* [21] and Milling [22] agree with these outcomes. They discovered that, under optimal settings in the procedure room, tracheal ultrasound reached 100% sensitivity and specificity. It also coincides with the results of Karacabey *et al.* [23] who demonstrated that

real-time tracheal ultrasound has greater sensitivity and specificity to confirm the location of the ETT and has quicker outcomes than capnography. However, in order to prevent one-lung ventilation with bronchial intubation, they added ultrasonographic lung sliding sign to the procedure.

The elevated efficacy of ultrasonography in the diagnosis of esophageal intubation was found by a latest systematic review and meta-analysis [24]. It can also be used as additional proof with elevated sensitivity and specificity in airway evaluation, particularly in many units where capnometry is inaccessible and may be unreliable if available. Our research showed that tracheal ultrasound consumes less time (7.7 ± 1.6 s) than capnography, clinical techniques, and radiograph in the neck (Fig. 2).

Kabila *et al.* [3] also had demonstrated that tracheal ultrasound is less time consuming than bronchoscopy in confirming the position of the ETT. This is a very important issue during airway management as a lifesaving procedure. In agreement with our results, Karacabey *et al.* [23] reported that ultrasonography took significantly less time than capnography in confirming ETT placement.

Figure 2



The time (s) of each method.

This study concluded that the quality of detection of ETT by ultrasound is not affected by BMI or NC.

Zamani *et al.* [25] concluded that the patients who were studied for detection of accuracy of intubation by ultrasound had high BMI and less thyromental distance.

Moreover, Zamudio-Burbano and Casas-Arroyabe [26], used some parameters measured by ultrasound and high BMI and neck circumference as predictors of a difficult laryngoscopy, and this points out that the ultrasound is not affected significantly by BMI and neck circumference.

Conclusion

Sonar-confirmed endotracheal intubation saves time and life, particularly in patients with low pulmonary blood flow in comparison with other traditional methods of confirmation.

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Conflicts of interest

There are no conflicts of interest.

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