

The Role of Ultrasonography in Confirming Position of Endotracheal Tube when Interpreted by Emergency Medicine Residents

Phuriphong Songarj, M.D.*, Sithichai Veeranachai, M.D.***, Arunotai Siriussawakul, M.D.*

*Department of Anesthesiology, **Department of Emergency Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

ABSTRACT

Background: Delays in the detection of endotracheal tube (ETT) misplacement increase morbidity and mortality. Although numerous methods have been suggested to verify ETT position, each method has its limitations in terms of its reliability and applicability. Recently, ultrasonography (US) has emerged to assess the ETT position.

Objective: This observation study was designed to assess the role of using ultrasonography for examining the ETT position among intubated patients who were admitted to the emergency department (ED).

Methods: The study was conducted in patients at the ED of a university-based hospital from September 2010 to November 2010. The ultrasound was performed after confirmation by a clinical assessment and a portable chest radiograph (CXR) conducted by a second- or third-year, emergency-medicine resident on-call at ED.

Results: Eighty patients were enrolled. The average time of US usage (time from turning the US machine on to finishing the confirmation of the ETT position and depth) was 149.9 ± 91.7 seconds. The average time of CXR evaluation, which was the gold standard, was 30 ± 10 minutes. Improper position of ETT was detected by CXR in 11 cases and by US in one case.

Conclusion: Ultrasonography could be used as the first line non-invasive ETT position instead of using CXR in ED.

Keywords: Ultrasound, airway, confirmation, emergency

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INTRODUCTION

Rapid and accurate ETT placement is an extremely important factor affecting patient survival in many critical settings. While delayed detection in ETT misplacement such as endobronchial (one lung) or esophageal intubation are uncommon, once they have occurred, they may lead to higher morbidity and mor-

tality in critical cases.^{1,2} Geisser et al., showed that ETT malposition was still a major problem. The incidence of misplacement in emergency patients both in- and out-of-hospital settings was around 18.2%.³ Numerous methods have been suggested to verify ETT placement, namely, direct visualization of ETT passing through the vocal cord or videoscope endotracheal intubation, bilateral equal breath sound with equal chest wall rising, gastric auscultation, capnography and CXR, but still no single technique is applicable to all situations, and none has 100% sensitivity or specificity in detecting esophageal intubation.^{4,5,6} Fiber-optic laryngoscope is a good tool to detect the depth of

Correspondence to: Arunotai Siriussawakul
E-mail: arunotai.sir@mahidol.ac.th

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ETT. Nevertheless, its use in an emergency setting is limited due to its many limitations, such as its high cost, the need for skilled training, and the limitation of visualization in situations in which sputum, blood, or secretion is present in the airway.⁷

CXR has been used as a standard method in confirming correct ETT position and depth in all hospitals. CXR should be done to document the correct placement after ETT intubation in all patients.¹¹ Therefore, whenever the ETT depth is re-adjusted or the patient's neck is manipulated, especially during the transferring process, a repeat portable CXR has to be performed. This increases the avoidable risk of radiation exposure and consumes more time while waiting for the results. Lately, newer equipment and technique, capnography, has been developed to reduce the above-mentioned problems and, with its ease of use, it has become a standard for ETT-placement confirmation. However, a limitation still exists in that its usage in patients with unstable vital signs or in cardiac arrest is unreliable.⁶

Recently, US has been introduced to identify and visualize airway anatomy and confirm ETT position. It is a good alternative as a third generation esophageal detector device.⁸ Gene et al., and Sandra et al., conducted randomized controlled trials by using bedside US to confirm correct ETT placement in human cadavers and live humans, respectively. The results showed high sensitivity (97% (95% confidence interval (CI), 85.1-99.9)) and specificity (100% (95% CI, 77-100)) in identifying esophageal intubation.^{9,10} However, both studies had limitations, because the patients were not in a critical situation in either study, and in the case of the second study, the sample size (n=33) was small since it was only a pilot study.

Few studies have applied the US as a tool for identifying ETT placement in critical patients in emergency setting. We conducted this study in the emergency department (ED) at Siriraj Hospital. The aim of this study was to evaluate the applicability of using US in confirming proper position of ETT placement at ED by second- or third-year ED residents.

MATERIALS AND METHODS

This prospective observational study was conducted in the ED, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. The study was approved by Siriraj Institute Review Board (IRB) Si no.493/2010, and all data was collected from September 2010 to November 2010. All consecutive patients aged over 18 years who were intubated with either an oral endotracheal or nasotracheal tube and who had no obvious malformation of airway anatomy were enrolled. Those patients who had a history of neck radiation, cervical spine immobility/instability or unstable vital signs, or who refused informed consent, were excluded.

Routine methods to confirm ETT placement in the trachea were direct visualization that the ETT had passed through the glottis, auscultation of bilateral breath sound and the presence of waveform capnography. The proper position of the ETT was then confirmed by a portable CXR. The distal tip of a properly positioned ETT would be located roughly 4 ± 1 cm above the bifurcation of the carina.¹² According to Conrardy PA, et al., alteration of ETT with head position occurs, so upon CXR interpretation, 1.9 cm was added on flexion and subtracted on extension, and 0.7 cm was subtracted in the extensive lateral rotation position.¹³ In the case of improper position, ETT possibly placed too deep or too shallow, the position must be corrected immediately.

US assessment of ETT position was performed after clinical assessment and portable CXR by a second- or third-year emergency-medicine resident, who had finished a one week training course on US in general practice. All performers had at least one-year's experience in using US at ED. Patients were placed in a neutral position while performing US. The portable ultrasonography (Sonosite MICROMAXXTM) with a linear probe at L38e/10-5 MHz was used to examine the position of ETT in all patients. A transcricothyroid membrane view was chosen to confirm the ETT position and measure its depth.¹⁴ Various glottic structures such as true vocal cord (TVC), false vocal cord (FVC), and arytenoid cartilage could be visualized under this view. The identified

ETT position was defined as a double-thin, hyper-echoic line with acoustic shadow, and the line resembles the air interface at both the inner and outer layer of the tube (Fig 1). As for the depth of ETT measured by US, the Pythagoras rule was used to find the distance from the vocal cord (VC) to the proximal end of the balloon cuff (BC) using the following steps. Firstly, the US probe was placed transversely through the vocal cord level, and a measurement was made of the distance (distance a) from the probe (skin) to the anterior surface of the ETT. Secondly, the US probe was rotated caudally until the posterior air column changed in diameter and shape (from a round to a bullet shape), which indicated the balloon-cuff level. The distance (distance c) from the US probe (skin) to the proximal end of balloon cuff was then measured. Finally, the distance from the vocal cord to the balloon cuff (distance b) was calculated by applying the Pythagoras formula (Fig 2). According to basic knowledge, the tip of the endotracheal tube is advanced into the trachea until the cuff just disappears completely beyond the vocal cords. This can imply that the distance b should not be long.²³

The following essential data was recorded: age, sex, weight, height, body mass index (BMI), clinical parameters for ETT confirmation, CXR and sonographic assessment of ETT depth, total

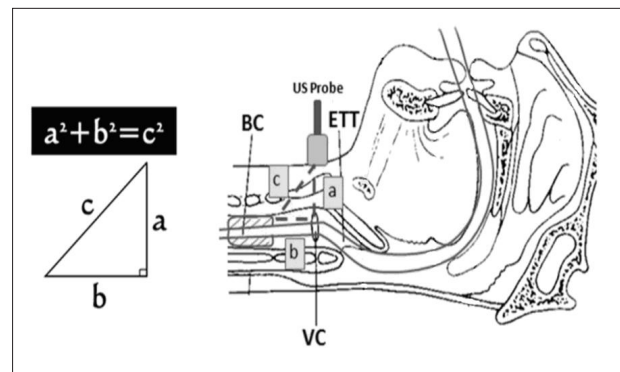


Fig 2. Diagram showing the application of the Pythagoras formula.

time for clinical evaluation, CXR and US evaluation (from operating the machine until the ETT position and depth were confirmed), and any complications.

RESULTS

Fifty men (62.5%) and thirty women (37.5%) were enrolled in the study. Their average BMI was $22.6 \pm 3.6 \text{ kg/m}^2$. The frequencies of system-based diagnosis were as follows: respiratory disease: 36.25%, neurologic disease: 26.25%, cardiovascular disease: 21.25%, malignancy: 5.00%, infectious disease: 5.00%, gastrointestinal disease: 3.75%, and nephrology: 2.50%. These values have been shown in Table 1.

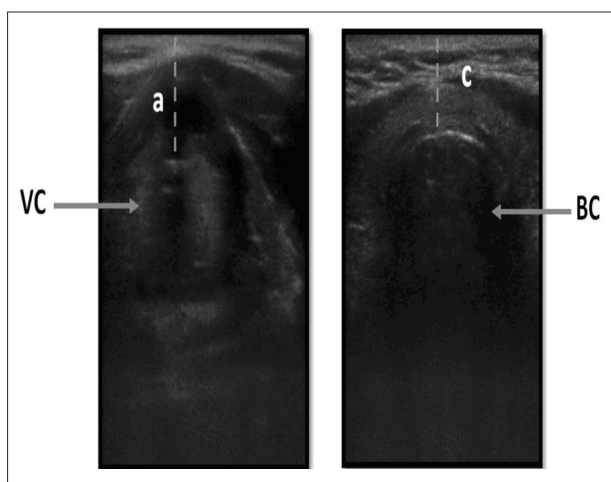


Fig 1. Transcricothyroid membrane view, a = distance from skin to endotracheal tube, VC = vocal cord, c = distance from skin to proximal end of balloon cuff, BC = balloon cuff

TABLE 1. Demographic data of intubated patients.

Variables	Mean \pm S.D. or number (%) (n= 80)
Age (years)	67.1 \pm 13.8
Male gender	50 (62.5)
Weight (kg)	58.7 \pm 10.8
Height (cm)	160.5 \pm 7.0
Body mass index (kg/m ²)	22.6 \pm 3.6
Diagnosis (Systemic based)	
Respiratory	29 (36.25)
Neurologic	21 (26.25)
CVS	17 (21.25)
Malignancy	4 (5.00)
Infectious	4 (5.00)
GI	3 (3.75)
Nephrology	2 (2.50)

TABLE 2. Results of different methods to confirm ETT position.

	Clinical assessment	Chest radiograph	Ultrasonography
Number of patients	80	80	79
Time until appropriate ETT position is confirmed (mean \pm S.D.)	25 \pm 12 seconds	30 \pm 10 minutes	149.9 \pm 91.7 seconds
Complications from tests	Nil	Nil	Nil
Performer	Treating physician, Emergency physician	Routine portable man	Treating physician, Emergency physician
Interpreters	Treating physician, Emergency physician	Treating physician, Emergency physician	Treating physician, Emergency physician
Number of patients with improper ETT position	Nil	11	1

Table 2 shows the data on assessment of ETT depth by various methods. Seventy nine patients were measured by US method, with a mean distance from VC to BC of 0.7 ± 0.9 cm, while eighty cases were measured by the CXR method, with a mean ETT tip-carina distance of 4.0 ± 1.9 cm. US could not measure the depth of ETT in one patient because the BC was not visualized even at sternal angle level, so the sonographer interpreted that the position of the ETT was too deep. The result was similar to CXR: the ETT tip was located 1.93 cm above the carina. Assessment of the ETT depth from CXR showed 69 patients with proper ETT placement and 11 patients with improper ETT placement. Among those improperly placed, 4 were too shallow and 7 were too deep.

The average time for US usage (the time from turning the US machine on to finishing the confirmation of the ETT position and depth) was 149.9 ± 91.7 seconds. The average time for the clinical assessment was 25 ± 12 seconds, and the average time for the CXR evaluation, which was the gold standard, was 30 ± 10 minutes. No complications were detected in any patient.

DISCUSSION

This study has shown the ease of use of US, with only a one-hour briefing before initiating the data collection process. Unfortunately, this study could not show the effectiveness of US for detecting the ETT position because US is now not

the standard or routine method for proving ETT position in emergency patients.

Assessment of the ETT depth by US has the distance from VC to BC in a range of -0.2 to 1.6 cm. Seventy nine cases were measured by using the US method, but the depth of the ETT in one case could not be measured because the BC was not visualized even at sternal angle level, which the sonographer interpreted as the ETT being placed too deep. The result was similar to the CXR, with the ETT tip located 1.93 cm above the carina. The total US time ranged from 58 seconds to 4 minutes, which was significantly faster than that for CXR. Galicinao et al. demonstrated a similar finding: that US was much quicker than CXR in a pediatric population. However, in his study, the fastest CXR result was 20 minutes from ordering to obtaining a result while the fastest US result was obtained in 50 seconds from initiation to obtaining the image. In this study, timing of US was longer than Galicinao et al. due to the time spent obtaining the US machine from storage and then operating the US machine. The common diagnoses of indication for intubation in ED are respiratory, neurology, and cardiovascular system, respectively. These seem to have no direct effect on US evaluation or contraindication.

CXR revealed the majority of cases 69 (86.25%) had a proper ETT placement while a further 11 cases (13.75%) had improper ETT placements, 7 of which (63.60%) involved the ETT being placed too deep. The rate of improper ETT placement in this study was lower than that

in the report from Geisser W, et al., (20.5%) who studied the radiologic validation of ETT placement in an emergency setting in Germany in trauma patients. However, our rate was similar to several other reports, for example, Brunel W, et al., Roberts JR, et al., and Schwartz DE, et al., whose rates varied from 9.6% to 15.5%.²⁰⁻²²

In this study, we have demonstrated the optimal usefulness of US by trying to assess the ETT depth (by the application of the basic mathematical Pythagoras theory) and evaluate how easy this technique was. One-week training course was performed before this study, for residents who were involved in this study, which revealed the ability of residents in learning new techniques and operating the equipment and how easy it was to use US. US itself is a non-invasive tool for investigating patients, which has been demonstrated to probably not be harmful to patients. It is possible to use US as an investigating tool in ED. However, we recommended the intensive course or workshop for the usage of US for the greatest benefit.

The limitation of this study was the use of unblinded interpreters and performers because of the patient-safety issue. All interpreters and performers could use US to evaluate the ETT position after the ETT position was checked and was thought to possibly be in an adequate position. The interpreters and performers could have bias in their interpretation that the ETT position might be adequate. In the future, we need more diagnostic studies or cost effectiveness studies to confirm the ability of US to detect ETT position in ED.

Both the US and clinical assessment in this study compared with CXR as the reference standard; thus, the results may not be an accurate prediction of the ETT placement as CXR itself may not reflect the real clinical impact on a patient. Therefore, to accurately assess the clinical impact of the ETT placement, the patient should be observed until clinical consequence of the ETT malposition occurs. However, US for detection of the ETT in the airway showed easy performance, and it could be used in a pre-hospital setting where CXR was not available, or in the ED after intubation when CXR was not immediately provided,

and also used as an adjunct tool in a hospital setting where CXR was time-consuming and costly.

CONCLUSION

Ultrasonography can be used as an adjunct tool to confirm the ETT position. Physicians can perform this technique easily after a briefing or short-course training. They also can interpret the results by themselves fast and easily. Nevertheless, further study is needed to confirm the diagnostic performance of US compared to CXR.

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