STUDY TO EVALUATE THE ACCURACY OF ULTRASONOGRAPHY IN CONFIRMING ENDOTRACHEAL TUBE PLACEMENT IN EMERGENCY DEPARTMENT

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Abstracts: **Background & Objective:** To assess the diagnostic accuracy of using tracheal ultrasound to examine endotracheal tube placement during emergency intubation, to assess sensitivity, specificity and time taken of airway ultrasounds in confirming endotracheal tube placement against traditional clinical methods.**Methods:** Patients who needs emergency intubation were evaluated. Endotracheal intubations were confirmed by ultrasound findings, direct visualization, condensation of endotracheal tube, five point auscultation and pulse oxymetry method ,findings and time taken for that were recorded, sensitivity, specificity, PPV, NPV,CI and Likelihood ratio were calculated for each method. **Results:** A total 250 patients were evaluated. The overall accuracy of ultrasonography method was 98.80% (95% confidence interval (CI) 96.53% to 99.75%) The Sensitivity, Specificity, Positive predictive value and Negative predictive value of ultrasonography method for tracheal intubation confirmation were 98.72% (95% CI 96.30% to 99.73%), 100% (95% CI 79.41% to 100%),100 % and 84.21% (95%CI 63.41% to 94.26%) respectively. The likelyhood ratio of a positive test was Infinite and the likelyhood ratio of a negative test was 0.01(95% CI 0.00 to 0.04). Mean duration for confirmation of esophageal and tracheal intubation was 7.45 sec with ultrasonography method. **Conclusion:** Present study demonstrated that transtracheal sonography has an acceptable degree of sensitivity and specificity for the confirmation of endotracheal intubation.

Key Words: Emergency Intubation, Emergency medicine, Confirmation of Endotracheal tube placement , Ultrasound.

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INTRODUCTION:

Securing the airway by endotracheal intubation is a fundamental skill in emergency medicine for definitive airway management. Unrecognized intubation of the esophagus is a significant source of morbidity and mortality.[1] Many traditional methods can be employed to confirm endotracheal tube placement, including direct visualization of the vocal cords, observation of chest movement, chest and gastric auscultation, condensation of water vapor,cyanosis and pulse oximetry, chest radiography etc. Each of these methods has limitations, and is not entirely reliable in the emergency setting.[2, 3] Studies found that quantitative capnography is the most sensitive tool for confirming tracheal intubation but this method has some limitations, particularly in cardiac arrest patients, such as the need for epinephrine use, low pulmonary flow and low cardiac output.[4, 5, 6] However, capnography is still not widely available in some emergency departments (EDs) and intensive care units (ICUs). Ultrasound is a common examination tool in many EDs and ICUs. To assist with airway management in critically ill patients, ultrasound is very useful due to its low-cost and portable capability.

Study Objectives:

1. To assess the diagnostic accuracy of using tracheal ultrasound to examine endotracheal tube placement during emergency intubation.
2. To assess sensitivity and specificity of airway ultrasounds in confirming endotracheal tube placement against traditional clinical methods.

3. To assess the time taken for each method to confirm tube placement in an emergency setting.

MATERIAL AND METHODS:

This study was a prospective observational study conducted over a period of 2 years and 3 months on 250 adult patients who underwent emergency intubation because of impending respiratory failure, cardiac arrest, or severe trauma, coming to Emergency medicine department.

Inclusion criteria: Cases included in our study fulfilled the following: -

1. Adult patients, aged more than 18 yrs.
2. Eligible study subjects were all adult patients who underwent emergency intubation because of impending respiratory failure, cardiac arrest, or severe trauma.
3. Patients who had given positive consent for this study.

Exclusion criteria:

1. Patients aged less than 18 years.
2. Patients with severe neck trauma.
3. Patients with neck tumors.
4. A history of neck operation or tracheostomy.
5. Patients who had given negative consent for this study.

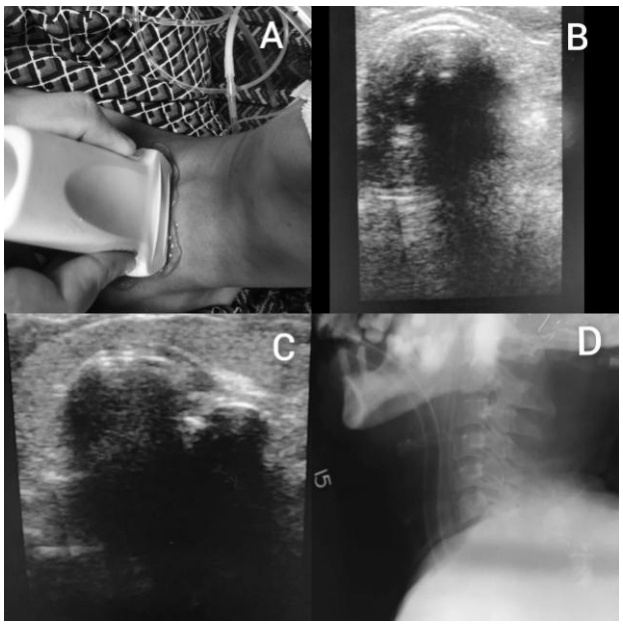
As per inclusion and exclusion criteria patients were recruited into the study. Total five persons from emergency medicine department (1 Emergency medicine department faculty, 2 senior residents and 2 residents) were involved in this study. One Emergency physician for ultrasonographic confirmation, one senior resident for intubation and direct visualization, second senior resident for 5 point auscultation, one emergency medicine resident to look for rise in oxygen saturation by pulse oxymetry and second to see condensation in the endotracheal tube. Everyone had recorded their findings and time using a stopwatch.All patients were examined in supine position. All methods of endotracheal tube placement confirmation were performed in emergency department by same emergency physician. Micromax ultrasound system, sonosite was used to evaluate the patients. High frequency (5–10 MHz) linear probe was used to get best possible findings.

The operating time required for intubation and ultrasound confirmation was recorded. The intubation time was defined as the time from preoxygenation with a bag-valve-mask to completion of endotracheal tube insertion. The ultrasound operating time was defined as the time from completion of endotracheal tube insertion to when the sonographer had interpreted the sonographic results. Simultaneously by pulse oxymetry (rise in oxygen saturation) , visualization of condensation in endotracheal tube, and 5 point auscultation were done and separate time and findings were recorded. Time for direct visualization defined as the time from stopping of bag-valve-mask preoxygention to successful placement of endotracheal tube under direct visualization. Portable lateral X-ray of the neck was done after repositioning of endotracheal tube whenever it was found in oesophagus by other confirmatory methods. The time spent in the radiograph spanned from the time it was requested to the time it was read in the unit.

Post-intubation confirmation of endotracheal tube placement was cross-checked by direct visualization, auscultation, pulse oximetry and bedside portable lateral neck X-ray and it was used as the criterion standard for tracheal intubation confirmation.

Ethical Committee approval was taken.

Figure 1: Method of ultrasonographic confirmation:



The probe was placed transversely on the anterior neck just superior to the suprasternal notch (Fig. 1A). Tracheal intubation if only one air–mucosa A–M interface with comettail artifact and posterior shadowing was observed (Fig. 1B). Esophageal intubation if two A–M interfaces with comet-tail artifacts and posterior shadowing were noted, which we called a "double tract sign" (Fig. 1C). Fig.1D Bedside portable lateral neck X-ray showing ET tube in situ.

RESULT:

Total 250 patients with requirement of emergency intubation were evaluated with mean age of 51.12±17.51 years. 172 patients were male, and 78 patients were female. All patients included in the study ranged between the age group 18-90 yrs. The mean age was 51.12 yrs.

Figure 2: Intubation indication in patients with emergency presentation (n=250)

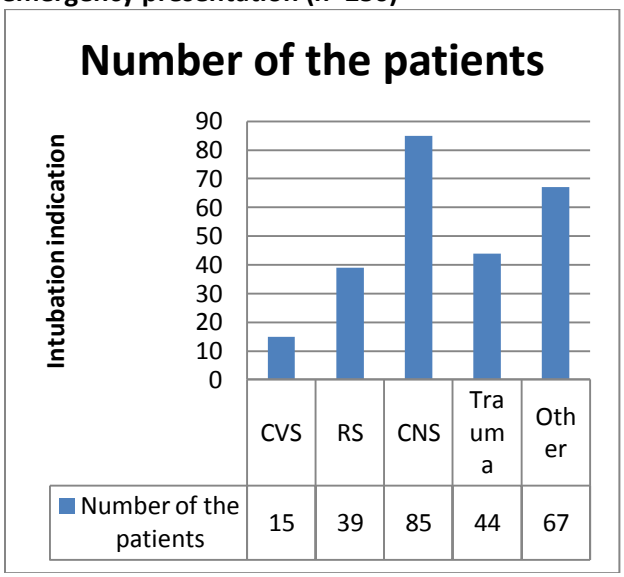


Figure 2 shows that majority of the study patients (34%) who required intubation had central nervous system disease, 27% patients classified in other category which includes hepatic encephalopathy patients, Chronic kidney disease patients and poisoning patients. 17% , 15% and 7% patients had trauma, respiratory disease and cardiovascular disease respectively.

Airway examination shows 85% patients had normal airway while 8% patients had difficult airway and 7% patients had crash airway. Majority (46%) patients had given Etomidate as an inducing agent. 7% patient had crash airway and did not required any inducing agent. 9% subjects required use of neuromuscular blocking agent in difficult airway. 83 patients were received etomidate and midazolam both. 87% patients were intubated in the first attempt while rest of the patients required more than 1 attempts. Most of the Male patients 79% were intubated with 8.5 number endotracheal tube and most of female patients 96% were intubated with 7.5 number endotracheal tube. In difficult intubations smaller number of the tubes 6, 6.5 and 7 were required in 1, 5 and 9 patients respectively. 77% patients were intubated in 6 to 12 minutes. Mean intubation time for all study subject was 6.94±2.34 min.

Direct visualization method detected 85% of tracheal intubation and 5% of esophageal intubation. In 10% of the patients direct visualization was not possible.

According to condensation in Endotracheal tube method 83% intubations were tracheal intubation and 5% intubations were esophageal intubation.

According to five point auscultation method 85% intubations were tracheal intubation and 15% intubations were esophageal intubation.

Pulse oximetry method detected 77% of tracheal intubation and 18% of esophageal intubation. In 5% of the patients pulse oximetry method was not able to record the results.

Ultrasonography detected 92% tracheal intubation and 8% esophageal intubation.

Portable lateral X-rays of neck was done after repositioning of endotracheal tube whenever it was found in oesophagus by any of the above methods.

The mean time taken for confirmation of ETT by Direct visualization method was 37.13 sec with a standard deviation of 7.064 sec. The shortest time taken was 23.15 sec and longest time taken was 68.32 sec. In 24 patients direct visualization was not possible.

The mean time taken for confirmation of ETT by observing condensation in endotracheal tube method was 6.39 sec with a standard deviation of 1.89 sec. The shortest time taken was 2.1 sec and longest time taken was 14.25 sec.

The mean time taken for confirmation of ETT by five point auscultation method was 35.68 sec with a

standard deviation of 9.88 sec. The shortest time taken was 18.46 sec and longest time taken was 67.41 sec.

The mean time taken for confirmation of ETT by Pulse oximetry method was 7.08 sec with a standard deviation of 2.63 sec. The shortest time taken was 2.21 sec and longest time taken was 18.32 sec. In 12 patients pulse oximetry was not able to record the reading.

The mean time taken for confirmation of ETT by Ultrasonograpy method was 7.45 sec with a standard deviation of 1.50 sec. The shortest time taken was 4.89 sec and longest time taken was 18.31 sec.

The mean time taken for confirmation of ETT by Portable lateral X-rays of neck method was 26.20 min with a standard deviation of 5.73 min. The shortest time taken was 14 min and longest time taken was 51 min.

Figure 3: Comparison of different methods of confirmation of esophageal and tracheal intubation.

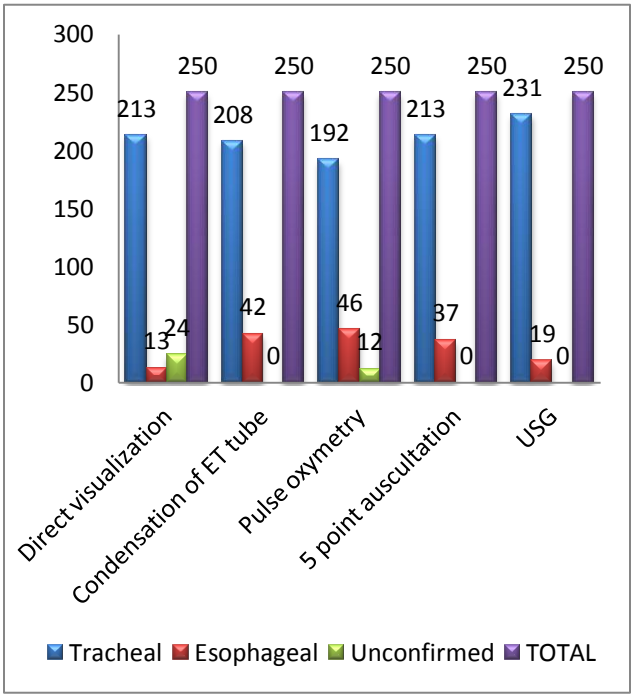


Table 1: Comparison of mean duration of different methods for confirmation of esophageal and tracheal intubation.

Method of confirmation	N	Mean ± SD	Minimum, Maximum (in sec)
Direct visualization	226	37.13±7.064	23.15, 68.32
Condensation of ET tube	250	6.39±1.89	2.1, 14.25
Pulse oximetry	238	7.088±2.63	1.21, 18.32
5 point auscultation	250	35.68±9.88	18.46,67.41
USG	250	7.45±1.50	4.89, 18.31

The overall accuracy of direct visualization method was 98.24% (95% confidence interval (CI) 95.55% to 99.52%). The Sensitivity, Specificity, Positive predictive value and Negative predictive value of direct visualization method for tracheal intubation confirmation were 99.06% (95% CI 96.65% to 99.89%), 84.62% (95% CI 54.55% to 98.08%), 99.06% (95% CI 96.72% to 99.74%) and 84.62% (95%CI 57.59% to 95.70%) respectively. The likelyhood ratio of a positive test was 6.44 (95% CI 1.80 to 23.04) and the likelyhood ratio of a negative test was 0.01 (95% CI 0.00 to 0.04).

The overall accuracy of observing condensation of endotracheal tube method was 81.16% (95% confidence interval (CI) 76.04% to 85.60%). The Sensitivity, Specificity, Positive predictive value and Negative predictive value of observing condensation of endotracheal tube method for tracheal intubation confirmation were 88.89% (95% CI 84.14% to 92.61%), 38.10% (95% CI 23.57% to 54.36%), 88.89% (95% CI 86.27% to 91.06%) and 38.10% (95%CI 26.61% to 51.09%) respectively. The likelyhood ratio of a positive test was 1.44 (95% CI 1.13 to 1.83) and the likelyhood ratio of a negative test was 0.29 (95% CI 0.17 to 0.50).

The overall accuracy of pulse oximetry method was 77.24% (95% confidence interval (CI) 71.75% to 82.12%). The Sensitivity, Specificity, Positive

predictive value and Negative predictive value of pulse oximetry method for tracheal intubation confirmation were 86.49% (95% CI 81.27% to 90.69%), 32.61% (95% CI 19.53% to 48.02%), 86.10% (95% CI 83.42% to 88.40%) and 33.33% (95%CI 22.70% to 45.99%) respectively. The likelyhood ratio of a positive test was 1.28 (95% CI 1.04 to 1.58) and the likelyhood ratio of a negative test was 0.41 (95% CI 0.24 to 0.71).

The overall accuracy of five point auscultation method was 84.50% (95% confidence interval (CI) 79.63% to 88.60%). The Sensitivity, Specificity, Positive predictive value and Negative predictive value of five point auscultation method for tracheal intubation confirmation were 91.03% (95% CI 86.61% to 94.36%), 43.24% (95% CI 27.10% to 60.51%), 91.03% (95% CI 88.42% to 93.09%) and 43.24% (95%CI 30.53% to 56.91%) respectively. The likelyhood ratio of a positive test was 1.60 (95% CI 1.21 to 2.13) and the likelyhood ratio of a negative test was 0.21 (95% CI 0.12 to 0.36).

The overall accuracy of ultrasonography method was 98.80% (95% confidence interval (CI) 96.53% to 99.75%). The Sensitivity, Specificity, Positive predictive value and Negative predictive value of ultrasonography method for tracheal intubation confirmation were 98.72% (95% CI 96.30% to 99.73%), 100% (95% CI 79.41% to 100%),100 % and 84.21% (95%CI 63.41% to 94.26%) respectively. The likelyhood ratio of a positive test was Infinite and the likelyhood ratio of a negative test was 0.01(95% CI 0.00 to 0.04).

Table 2: Comparison of Sensitivity, Specificity, Positive predictive value, Negative predictive value and accuracy of different methods for confirmation of esophageal and tracheal intubation.

Method of confirmation	Sensitivity	Specificity	PPV	NPV	Accuracy
Direct visualization	99.06 %	84.62 %	99.06%	84.62%	98.24 %
Condensation of ET tube	88.89 %	38.10 %	88.89%	38.10%	81.16 %
Pulse oximetry	86.49 %	32.61 %	86.10%	33.33%	77.24 %
5 point auscultation	91.03 %	43.24 %	91.03%	43.24%	84.50 %
USG	98.72 %	100%	100 %	84.21%	98.80 %

Discussion:

This prospective study aimed to assess accuracy and timeliness of tracheal ultrasound for determining endotracheal tube placement during emergency intubation. In this study, tracheal ultrasound achieved high sensitivity and specificity for confirming endotracheal tube placement. Therefore, ultrasound can serve as a good diagnostic tool for confirming tracheal intubation during resuscitation. However, each confirmation technique has its own limitations. Capnography is the currently accepted criterion standard for tracheal intubation confirmation. According to the new ACLS guidelines, quantitative waveform capnography is recommended as the most reliable method for confirming endotracheal tube placement. Nevertheless, quantitative capnography is neither widely available nor consistently applied in some of EDs. In a survey of the National Emergency Airway Registry Series, a total of 77% of physicians reported that colorimetric end-tidal CO2 detectors were available in their hospitals, but only 25% of respondents used continuous quantitative capnography.[7] Base on these results, the EDs and ICUs should be appropriately equipped with capnography. Besides that, another confirmation technique with high accuracy is desirable if capnography is not available.

Ultrasound is a common and useful diagnostic tool in many EDs and critical care areas. The use of ultrasound to confirm endotracheal tube placement is attractive due to the following reasons. First, ultrasound is portable, repeatable, and widely available in many EDs, critical care areas, and even outside of the hospital. If ultrasound is as sensitive and specific as the waveform capnography, it can be used instead if waveform capnography is not available. Second, ultrasonographic images are not affected by low pulmonary flow, as compared to capnography. Third, tracheal ultrasound can detect esophageal intubation even before ventilating the patient, which prevents unnecessary forced ventilation to the stomach and its associated complications.

Several previous studies have provided promising results of tracheal ultrasound for endotracheal tube placement confirmation. Ma et al. used the transcricothyroid ultrasound to confirm tracheal intubation in the cadaveric model, and demonstrated high sensitivity and specificity.[8] Two prospective studies showed up to 100% of sensitivity and specificity of tracheal ultrasound in live humans under a well-controlled operating room setting.[9,10] In a recent study performed on 30 ED patients, high sensitivity and specificity values were reported using combined ultrasonographic methods.[11]

In this study we compared different methods of endotracheal tube confirmation. Each method have their disadvantages.

In Direct visualization method 24 patients (10%) had difficulty in visualization of vocal cord. Out of 44 patients of trauma there were 26 patients with severe faciomaxillary injury. Out of these 26, 18 patients had difficulty in visualization of vocal cord due to distorded anatomy. Another 6 patients had difficulty in mouth opening so in that case there was a difficulty in visualization of glottic structures. Thus direct visualization method had sensitivity 99.06% and specificity 84.62%. In this calculation we excluded 24 patients in which visualization is not possible.

Observing condensation of endotracheal tube is also a method of confirmation of endotracheal tube. But there are high chances of incorrect result because Condensation is not always evident in expired gas and can also be present in gas emanating from the stomach. Observing condensation in endotracheal tube method had 88.89% sensitivity and 38.10% specificity.

In pulse oximetry method 12 patients (5%) had unrecordable reading of pulse oximeter. In this method there are high chances of incorrect results because of it is dependent on perepheral perfusion. Hypotension, haemoglobinopathies, peripheral arterial disease, hypothermia, poor perfusion, anemia, and nail polish etc patients could show low oxygen saturation on pulse oximeter. In this study sensitivity of this method was 86.49% and specificity of this method was 32.61%.

Five point auscultation method is used widely for confirmation of endotracheal tube placement. Obesity, lung diseases, Gastric distention due to previous bag mask ventilation etc factors can interfere in confirmation. Breath sounds may be heard in both sides but may result in misdiagnosis in up to 15 % of all esophageal intubations. Air passing through esophagus producing wall vibration can be transmitted to the lung. In this study five point auscultation showed 91.03% sensitivity and 43.24% specificity.

CONCLUSION:

Ultrasonography detected the tube placement faster and accurately than the other methods. The time difference is statistically significant and considering that the scenario is time critical, it has significant clinical importance. Present study demonstrated that transtracheal sonography has an acceptable degree of sensitivity and specificity for the confirmation of endotracheal intubation. Ultrasonography is a valuable adjunct and should be considered when capnography is unavailable or unreliable. Moreover, most confirmatory methods require multiple ventilations, which may increase the risk of gastric distention and aspiration if the endotracheal tube is incorrectly placed. Ultrasonography offers the advantages of being rapid, easily available, and noninvasive, and does not require ventilations to confirm placement.

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Conflict of Interest : None