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ORIGINAL RESEARCH

Rapid confirmation of endo-tracheal tube placement by upper airway ultrasonography and end-tidal capnography in pediatric patients requiring intubation in PICU and operation theateres

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ABSTRACT

Introduction: Over the past few years, ultrasonography is increasingly being used to confirm the correct placement of endotracheal tube (ETT). In our study, we aimed to compare the rapidity of endotracheal tube placement confirmation by USG and continuous wave capnography. Two primary outcomes were measured in our study. First was the time taken for each method to confirm tube placement. The second primary outcome assessed was the sensitivity and specificity of ultrasonography against the continuous wave capnography to confirm endotracheal intubation. **Methodology:** This is a single centered, prospective observational study conducted in the Department of Anaesthesiology, Dr. S. N. Medical College, Jodhpur. 40 study subjects included aged 5 to 14 years of ASA classification I and II with 24 males and 16 females. The intubation was performed as per standard hospital protocol. As part of the study protocol, ultrasonography was used to identify ETT placement simultaneously with the quantitative waveform capnography (end-tidal carbon dioxide). Confirmation of tube placement and time taken for the same were noted by two separate anaesthesiologists. **Results:** Out of the 40 intubation attempts, one (2.5%) had esophageal intubation. The sensitivity and specificity of diagnosis using ultrasonography were 100% and 100%, respectively. The time taken to confirm tube placement with ultrasonography was 18.4 ± 3.99 sec. compared to waveform capnography which was 21.12 ± 0.79 sec. The time taken by ultrasonography was significantly less and the difference between mean time of two methods is statistically significant ($p \leq 0.001$). **Conclusions:** Ultrasonography confirmed tube placement with equal sensitivity and specificity to quantitative waveform capnography. But then, it yielded results considerably faster than the quantitative waveform capnography.

INTRODUCTION

Airway management skills are crucial for Anaesthesiologists. Tracheal intubation is an essential and a basic requirement in anaesthetic practice. Misplacement of endotracheal tubes in to the esophagus can be disastrous. Hence confirmation of successful ET tube placement [(1)] is very important because the incidence of intubation in to the esophagus is approximately 6%[(2,3)] in emergency situations and 1.75%[(2,3)] in elective settings which can be disastrous. 69% of the deaths [(4)] was related to airway management.

Intubation under direct vision using laryngoscope is considered the "gold standard" but is not a guarantee of correct placement, especially in the infant and young children. Confirmation of correct tracheal tube placement can be made by various measures such as direct visual laryngoscopy, auscultation, expansion of chest wall during ventilation, visualization of vapour condensing in the tube, USG of airway and capnography though each may have its own limitations.

The Advanced Cardiac Life Support (ACLS) 2020 guidelines by AHA recommend Continuous Waveform Capnography in addition to clinical assessment as the most reliable method of confirming

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and monitoring correct placement of an endotracheal tube (ETT). Continuous wave capnography has high sensitivity and specificity [5, 6], and consider as gold standard technique for confirmation of successful ET tube placement. It has false negative results in severe airway obstruction, low cardiac output, severe hypothermia and pulmonary embolism.

Evidence is gradually accumulating that ultrasonography is promising and there is a potential for the incorporation of the upper airway ultrasonography into the future as standard of care in airway assessment, monitoring and imaging modalities. Ultrasound imaging technique is a novel, simple, portable, non-invasive tool helpful for airway assessment and management. It aids in the quick assessment of the anatomy of the airway in emergency, intensive care units and surgical operation theateres. A wide range of clinical applications of USGincludes verification of proper placement of Endotracheal tube[7] and Supraglottic devices, judging the appropriate depth of the same, assessing the airway size, invasive procedures such as percutaneous tracheostomy[8, 9]/needle cricothyroidotomy[10], identifying stenosis of subglottic region[11], predicting an easy or difficult intubation[12], in diagnosing post extubation stridor[13], judging the size of pediatric ET tube[14] and assessing the size of double lumen tube to be used[15].

USG confirmation of correct endotracheal tube placement has some advantages over capnography such as does not affect by pulmonary blood flow, does not require ventilation of lungs and can assess ETT placement immediately after intubation (In capnography, ETCo2 values considered standard after 5 breaths).

The aim of our study was to compare the rapidity of endotracheal tube placement confirmation by USG and continuous wave capnography.

The primary objective of our study was to compare the upper airway ultrasonography and end tidal capnography in confirmation of endotracheal tube placement in term of time (in Sec.) taken from intubation to confirmation of endotracheal tube position in pediatric patients requiring intubation in PICU and operation theateres.

The secondary objective of our study was to determine the sensitivity, specificity, positive predictive value and negative predictive value of upper airway ultrasonography in comparison to end tidal capnography in the rapid confirmation of endotracheal tube placement in pediatric patients requiring intubation in PICU and operation theateres.

METHODOLOGY

The study was conducted in Mathura Das Mathur hospital and Mahatma Gandhi hospital of Dr S. N. Medical college and associated group of hospitals, Jodhpur after obtaining clearance from Institutional Ethical Committee and getting written, informed consent from the patient's parents. Type of our study was prospective observational study.

Total 40 patients were enrolled in this study after getting a written informed consent from the patient's parents. Out of 40 patients, 24 (60%) were males and 16 (40%) were females.

Upper airway USG was performed using a commercially available SonoSite M Turbo ultrasound machine. The linear ultrasound transducer of frequency 5–13 MHz was used to perform the study. A Drager multipara monitor with a side stream $ETCO_2$ analyzer was used for capnography.

Two anaesthesiologists were involved in the study. Aanaesthesiologist (principal investigator) performed all the ultrasonography and verified ET tube placement with the same. Another anaesthesiologist performed the intubation and connected ETT to waveformcapnography. Both anaesthesiologists had no communications with each other either visually or verbally. Confirmation with ultrasonography and waveform capnography was done simultaneously.

Endotracheal intubation with cuffed ETT was performed under Direct Visual Laryngoscopy using Macintosh laryngoscope. Cormack and Lehane Grading was noted at the time of intubation. Time Zero was the time at which intubation completed under Direct Visual Laryngoscopy using Macintosh laryngoscope. End Time noted individually by both anaesthesiologists and was the time when individual anaesthesiologist confirmed tube placement with their modality.

Immediately after intubation, the linear transducer probe placed just above the suprasternal notch and confirmation of placement of tube as tracheal or esophageal was done as follows[20] -

- Tracheal intubation if only one Air–Mucosal (A-M) interface with posterior shadowing was observed [Fig. 2]
- Esophageal intubation if two Air–Mucosal (A-M) interfaces with posterior shadowing were noted, which is called Double Tract Sign [Fig. 1].

Time taken for confirmation of position of tube (in sec.) was noted.

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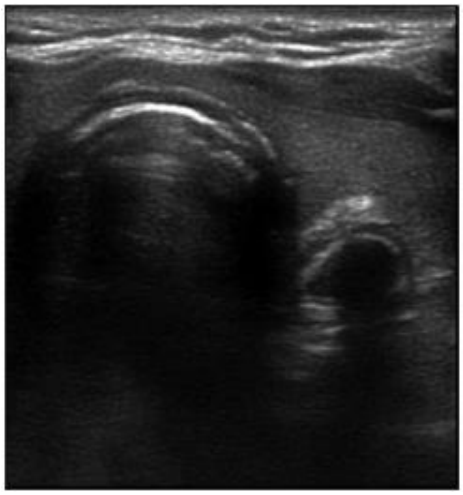

Fig. 1: Sonographic image of esophageal intubation

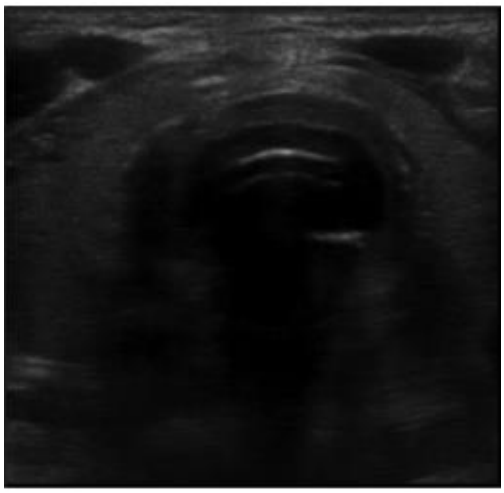

Fig. 2: Sonographic image of tracheal intubation with "Double Tract" Sign

Immediately after intubation, capnography monitor was connected to endotracheal tube by another anaesthesiologist.

The tube was deemed as endotracheal if a typical square waveform capnography was observed along with detection of ETCO2 of more than 4mmHg after five breaths.

Time taken for confirmation of position of tube (in sec.) was noted.

RESULTS

Out of 40 patients, 24 (60%) were males and 16 (40%) were females. The mean age ± standard deviation was 8.9 ± 2.72 years.

The mean confirmation time by USG was 18.4 seconds and that of capnography was 21.12 seconds. The difference between mean time of two methods is statistically significant ($p \leq 0.0001$). The earliest time by capnography was 20 seconds and by USG was 12 seconds. In 1 case, the capnography did not detect any waveform due to esophageal positioning of endotracheal tube.

Table 1

	Mean	SD	t value	p value
ETT Detection TIME By Capnography(Sec.)	21.12	0.79	4.228	<0.0001
ETT Detection TIME By USG (Sec.)	18.4	3.99		

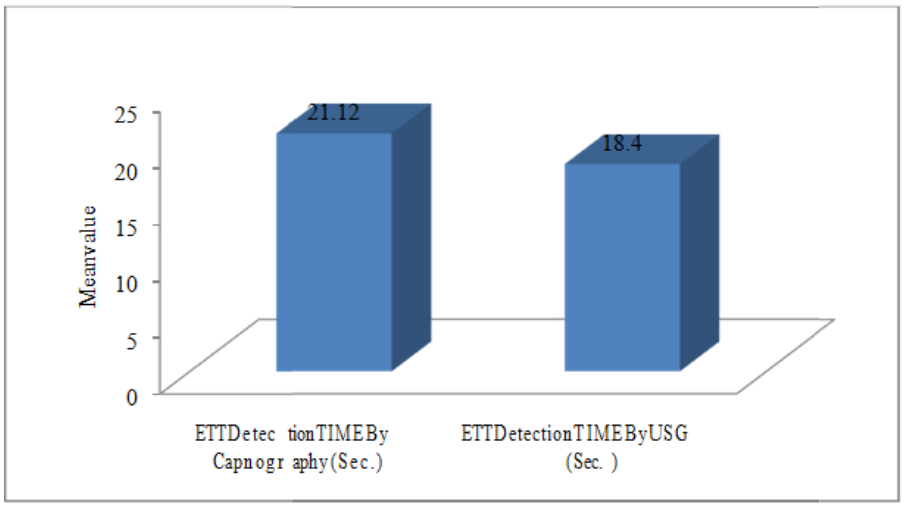

Fig. 3

Table 2

	Median	Range	Mean±SD
ETT Detection TIME By Capnography(Sec.)	21	20-23	21.12±0.79
ETT Detection TIME By USG (Sec.)	18	12-33	18.4±3.99

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Out of 39 patients with tracheal intubation, the USG detected the ETT position in the trachea correctly in all 39 patients (sensitivity is 100%). ETT position in the esophagus was correctly identified by USG in 1 patient out of 1 patient with esophageal intubation (specificity is 100%).

Table 3

		CAPNOGRAPHY		Total	p value
		T	E		
USG	T	39	0	39	
	E	0	1	1	
Total		39	1	40	

The sensitivity, specificity, positive predictive value, and negative predictive value of the ultrasound method in comparison to end tidal capnography are shown in Table 4.

Table 4

Sensitivity	Specificity	PPV	NPV	Accuracy
100%	100%	100%	100%	100%

DISCUSSION

In our study, pediatric age group of 5–14 yrs. were selected because of following reasons:

1. According to IAP, up to 18 yrs. of age are included in pediatric age group.
2. There are fewer studies in pediatric age group about usefulness of upper airway ultrasonography in confirmation of correct placement of an endotracheal tube (ETT).
3. There are numerous anatomical differences in adult and pediatric airway. Only after 10 yrs. of age, pediatric airway is same as adult airway. We have selected pediatric age group of 5–14 yrs. which included both children below 10 yrs. and children above 10 yrs.
4. Children above 5 yrs. are co-operative and able to follow instructions.

In the study conducted by Vimalkoshi Thomas et al [20], ultrasonography detected endotracheal tube placement faster than end-tidal capnography and conventional clinical methods. In this study, upper airway ultrasonography showed a sensitivity of 97.89% and specificity of 100%. In this study, the mean age ± standard deviation was 50.79 ± 16.15 years. In our study, the mean age ± standard deviation was 8.9 ± 2.72 years and upper airway ultrasonography showed a sensitivity of 100% and specificity of 100%.

The upper airway USG was found to be 100% specific for diagnosing esophageal

intubation. In previous studies by Abhishek C et al [18], Priyanka Bansal et al [16], and Adi et al [17] also showed 100% specificity in their studies. The main strengths of our study are its prospective nature and that a single anesthesiologist (principal investigator) performed all ultrasonography.

In the study conducted by Priyanka Bansal et al [16], upper airway ultrasonography has sensitivity of 97% and specificity of 100% in detecting endotracheal tube placement.

In this study the probe was placed horizontally starting from cricothyroid membrane up to suprasternal notch. In our study, the transducer probe was placed only at the level of suprasternal notch which showed more sensitivity and equal specificity.

In the prospective study by Chou HC et al [19], Tracheal Rapid Ultrasound

Examination (TRUE) showed a sensitivity and specificity of 98.9% and 94.1% respectively. In this study, convex transducer probe was placed transversely over suprasternal notch which showed a lower sensitivity and specificity than our study.

Kristensen et al [21] has stated that the linear high-frequency transducer is most suitable for imaging superficial airway structures. USG can be used for direct observation of whether the tube enters the trachea or the esophagus by placing the ultrasound probe transversely on the neck anteriorly at the level of the suprasternal notch during intubation, thus confirming intubation without the need for ventilation or auscultation. In our study, we used linear high frequency probe placed transversely at the level of suprasternal notch only after intubation. If we had used USG at the time of intubation as used in above study, ETT detection time might be less.

After intubation, there are several methods of confirmation of endotracheal tube placement. Primary confirmation which includes direct observation of the tube passing through the glottis, bilateral chest rise, presence of condensed vapour in the tube, auscultation of breath sounds and quantitative waveform capnography measurement is done before securing the endotracheal tube. Capnography is a direct method of endotracheal tube placement confirmation. Our study showed that upper airway USG is also a direct method of visualization of upper airway structures in real time to identify the proper placement of endotraceal tube.

The reliability of quantitative capnography is a suspect in conditions with low pulmonary flow like cardiac arrest or severe shock, bronchoconstriction or other situations like hypothermia in which capnography might be fallacious whereas upper airway USG images remains undisturbed.

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USG is portable, relatively cheap, painless with no radiation hazards and proven safety. Ultrasound is commonly used in emergencydepartments[22] for purposes such as focused intensive care echocardiography,[23] Extended Focused Assessment Sonography For Trauma (EFAST),[24, 25] and for vascular access.[24, 25]The use of ultrasonography to confirm ETT placement is attractive due to its portability and repeatability with good sensitivity and specificity. Tracheal ultrasonography detects esophageal intubation even before ventilating the patient, which prevents unnecessary forced ventilation to the stomach and its associated complications. In overweight and obese patients, upper airway USG has been shown to be superior to auscultation in speed and accuracy in verification of placement of endotracheal tube. Therefore, upper airway USG may be used in the primary confirmation of endotracheal tube placement.

As USG is skill dependent, it requires proper training for proficient use. Its repeatability and generalisability needs to be further studied. Another limitation of USG is that it is not always readily available in operation theateres.

CONCLUSION

Upper airway ultrasonography is as accurate as waveform capnography in detecting endotracheal intubation as well as esophageal intubation. Both upper airway ultrasonography and waveform capnography have good reliability and quick confirmation times, though ultrasonography is about 3 seconds faster. Therefore, both upper airway ultrasonography and waveform capnography can be used as primary procedures for confirmation of endotracheal tube placement.

To conclude, ultrasonography has the potential to become the first line tool for confirmation of endotracheal tube placement and for non invasive airway assessment in the future.

Limitations

In our study, sample size was 40. Study with bigger sample size may yield better results and conclusions.

In our study, pediatric age group of 5–14 yrs. were selected. Study with subjects with wider range of age may yield better results and conclusions.

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