ORIGINAL ARTICLE

Efficacy of Airway Ultrasound in the Confirmation of Endotracheal Tube Placement in Children is Comparable to Capnograph and better than Auscultation

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ABSTRACT

Background: Confirmation of correct placement of endotracheal tube is mostly done by capnography (the gold standard) and auscultation, but both methods have their limitations. Airway ultrasonography is a non-invasive diagnostic imaging technique that has been shown to correctly delineate the airway structures and confirm correct placement of endotracheal tube during general anaesthesia. This study aimed at comparing the accuracy of airway ultrasound with auscultation using capnograph as the gold standard..

Patients and Method: This prospective randomized controlled clinical trial involved 106 American Society of Anesthesiologists I and II patients aged 1-10 years who presented for elective surgery and required general anaesthesia. After intubation, the endotracheal tube placement was confirmed with airway ultrasonography and five-point auscultation and compared with capnography in all the patients. The time of intubation and confirmation of correct placement of endotracheal tube by the three methods: airway ultrasound, auscultation and time to five waveforms on the capnograph were recorded.

Results: When compared with capnography, airway ultrasonography showed accuracy, sensitivity and specificity of 100% while auscultation showed accuracy, sensitivity and specificity of 94.3%, 97.0% and 57.1% respectively. The time required for confirmation of endotracheal tube position was observed to be significantly lower with airway ultrasonography (average time of 6.68 ± 2.1s) than both capnography (25.81 ± 6.9s) and auscultation (29.29 ± 9.0s) respectively with a p value of <0.001.

Conclusion: Data from this study show that airway ultrasonography confirmed correct placement more accurately than auscultation when compared with capnography. Ultrasound is a simple, accurate, non-invasive and fast method for confirming paediatric endotracheal tube placement.

Keywords: Airway ultrasound, Capnograph, Auscultation.

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INTRODUCTION

Early confirmation of the location of the endotracheal tube (ETT) following intubation during general anaesthesia helps in preventing complications such as hypoxia, cardiac arrest and death.

Airway ultrasonography (AUS) a diagnostic imaging technique which utilizes high frequency sound waves to delineate, measure or examine internal body structures or organs is increasingly being used in anaesthesia around the globe.[1] The anatomical structures in the supra-glottic, glottic and subglottic regions can be visualized easily with the help of an ultrasound. Various studies have suggested that ultrasound has the potential to confirm proper endotracheal tube placement.[2,3] Capnography, a non-invasive means of measuring partial pressure of end tidal carbon dioxide in exhaled breathe over time is considered the gold standard of confirming endotracheal tube placement, though, it has its limitations. Auscultation is the use of stethoscope to listen to breath sounds. This study compared airway ultrasonography and auscultatory method with the gold standard in confirming the correct placement of the endotracheal tube after intubation during paediatric anaesthesia.

PATIENTS AND METHODS

This study was a prospective randomized clinical study conducted among 106 paediatric age group (1-10 years) patients with American Society of Anesthesiologists (ASA) I and II physical status for elective surgeries requiring intubation as part of their anaesthetic technique from February to September 2020. Written informed consent was obtained from the parents or guardians of patients.

Sample Size Determination: The sample size was calculated using the formula for the comparison of two means.[4]

Selection Criteria: Patients who were 1-10 years old, scheduled for elective surgery requiring endotracheal intubation and belong to ASA class I or II were included in the study.

Patients at risk of gastric aspiration or difficult intubation, those with history of relevant drug allergies and known asthmatics were excluded from the study.

Pre-Operative Protocol: Standard pre-operative assessment, investigations and fasting was done based on the hospital guideline. Induction of anaesthesia was with intravenous propofol at 3 mg/kg and endotracheal intubation was facilitated with intravenous Atracurium 0.5 mg/kg. Patient was then mask-ventilated with isoflurane at a minimal alveolar concentration (MAC) of 1.2 in oxygen for 5 minutes prior to intubation. During the period of mask ventilation, the high frequency linear probe (5 -13MHz) of a Sonosite iLook ultrasound (serial no: P03014-02 09/02, Sonosite inc, Bothell, WA USA) was placed by the researcher (an expert in airway ultrasonography) in an in-plane orientation at the side of the neck of all eligible patients to identify the correct landmarks; trachea and oesophagus. Standard plane of scanning was then maintained to prevent artefact and bias. At the point of laryngoscopy, the USS probe was moved to the suprasternal notch in an out of plane orientation. During laryngoscopy and endotracheal intubation, the researcher was positioned at the side of the patient with the sonographic screen facing away from the first research assistant. Time of intubation, when the endotracheal tube passed through the rima glottis was taken as T_O. T_O was announced by the first research assistant as “tube in” and stop watches were activated. Immediately after tracheal intubation, manual ventilation was commenced. The first research assistant (who intubated) conducted a five-point auscultation and checked for bilateral chest rise. The hand was raised as a signal to the timekeeper at the end of auscultation. This time was recorded as T_{1A}.

The second research assistant recorded the end tidal carbon dioxide ($ETCO_2$) values and noted the time it took to have at least five waveforms of 3.5 - 4kPa using a stopwatch. This time was recorded as T_{1C}. The researcher recorded the interpretation of ETT placement based on the sonographic findings and noted the time of confirmation of endotracheal tube placement. The time of confirmation of ETT placement by the researcher was noted as T_{1U}.

Using AUS, intubation was considered endotracheal when there was hyperechoic comet tail artefacts with posterior shadowing in the trachea. An intubation was considered oesophageal when there was presence of a second airway adjacent to the midline of the trachea with a hyperechoic artefact, also known as the “double-tract sign”. Patients with oesophageal intubation were extubated, mask ventilated with oxygen in isoflurane at MAC of 1.2 and re-intubated. A proforma was generated at the start of the research. The details recorded were location of the endotracheal tube by the AUS, Capnograph and auscultation. Also recorded were the T_o, T_{1A}, T_{1C} and T_{1U}.

Statistical Analysis

Data entry and statistical analysis was performed using Statistical Product and Service Solutions (SPSS) version 23 computer software. Association between categorical variables was carried out using chi square test while Mc-Nemar test was used to compare repeated categorical assessment. Diagnostic parameters including overall accuracy, sensitivity, specificity, positive predictive value and negative predictive were calculated. A p value of less than 0.05 was considered statistically significant at 95% confidence interval.

RESULTS

Demographic and clinical characteristics of patients showed no statistically significant difference as shown in Table I.

Table I: Patients Demographic and Clinical Characteristics

Variables	n (%)	p- value
Gender		0.367
Males	80 (75.5)	
Females	26 (24.5)	
ASA		0.791
ASA I	89 (84.0)	
ASA II	17 (16.0)	

Table II shows the location of endotracheal tube using airway ultrasound, capnograph and auscultation.

Table II: Location of Endotracheal Tube using Ultrasonography, Waveform Capnography and Auscultation

Variables	Frequency (n=106)	Percentage (%)
Location by USS		
Oesophagus	7	6.6
Trachea	99	93.4
Location by AUSC		
Oesophagus	7	6.6
Trachea	99	93.4
Location by Capnography		
Oesophagus	7	6.6
Trachea	99	93.4

The agreement of ultrasonography and auscultation assessment with waveform capnography is as shown in Table III. The overall accuracy of AUS in relation to capnograph in locating correct placement of ETT was 100%. When compared with capnography, 96 (90.6%) auscultation agreed with the assessment of capnograph in the location of ETT tube in the trachea (*P* value < 0.001).

Table III: Agreement of Ultrasonography and Auscultation with Waveform Capnography for Location of ETT

	Location by capnography		X^2	P-value
	Trachea (n/%)	Oesophagus (n/%)		
Location by USS			106.00	**<0.001***
Trachea	99(93.4)	0(0.0)		
Oesophagus	0(0.0)	7(6.6)		
Location by AUSC			31.039	**<0.001***
Trachea	96(90.6)	3(2.8)		
Oesophagus	3(2.8)	4(3.8)		

*$p<0.05$

The diagnostic accuracy of airway ultrasonography and auscultation in comparison to waveform capnography is presented in Table IV. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of AUS was 100%.

Sensitivity and positive predictive value was 97%, specificity and negative predictive value was 57.1% while accuracy of AUS obtained was 94.3%.

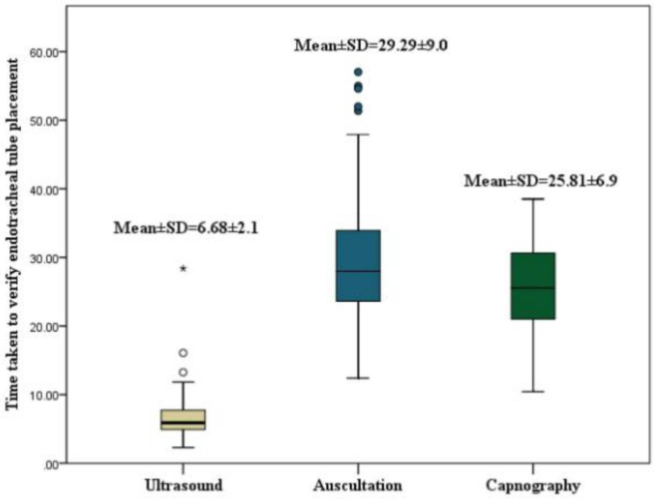
DISCUSSION

According to the 2020 ACLS guidelines, endotracheal tube position should be verified by both clinical assessments and confirmation devices after intubation, or when the patient is moved.[4] Capnography is presently the gold standard for the confirmation of ETT placement.[5] It has however been shown to be inaccurate in conditions with low pulmonary blood flow like cardiac arrest and when there is no ventilation.

Table IV: Diagnostic Accuracy of Ultrasonography and Auscultation in Comparison to Waveform Capnography

Variables	USS	AUSC
True Positive (n/%)	99(93.4)	96(90.6)
True negative (n/%)	7(6.6)	4(3.8)
False positive (n/%)	0(0.0)	3(2.8)
False negative (n/%)	0(0.0)	3(2.8)
Sensitivity (%)	100.0	97.0
Specificity (%)	100.0	57.1
Positive predictive value (%)	100.0	97.0
Negative predictive value (%)	100.0	57.1
Accuracy (%)	100.0	94.3

Figure 1 shows the mean time taken to verify the ETT location. There was a significant difference (*P*-value < 0.001) in time taken to verify endotracheal tube placement in the study groups.



*P<0.001**

Figure 1: Mean time taken to verify ETT

This study also compared the accuracy of AUS and auscultation in detecting correct ETT placement using capnography as the standard. The sensitivity, specificity, positive predictive value (PPV) and negative predictive values (NPV) with the use of AUS were calculated and all found to be 100%. Whereas the accuracy, sensitivity, specificity, PPV and NPV of auscultation were found to be 94.3%, 97.0%, 57.1%, 97.0% and 57.1% respectively. The difference in the accuracy of AUS when compared with auscultation is statistically significant ($p < 0.001$). The high success rate of the AUS in detecting correct ETT placement could be attributed to the use of the high frequency probe used in this study as this would provide quality images. The experience of the researcher with the use of AUS could also have contributed to this as these two factors affect the accuracy of the use of AUS.

Auscultation of the chest and epigastrum has been a generally accepted clinical method of confirming correct tracheal intubation. The sensitivity and specificity of this technique has however been noted to be variable and lower in tracheal tubes with a Murphy eye as used in the present study.[7] Other authors have also reported higher accuracy with the use of AUS compared to auscultation, though with varying results.[8,9] The accuracy, sensitivity and specificity of ultrasound obtained in this study was found to be comparable to that obtained by other researchers. Galicinao et al.[10] in a study of 49 children who were between one day and 17 years in PICU, had a 2-phased study comparing the accuracy of bedside ultrasonography with different clinical method and CECD using both a 10 MHz high frequency linear probe and a low frequency probe. They obtained a similar result of 100% in sensitivity, specificity, PPV and NPV with USS as in this present study. They concluded that the high frequency linear probe produced better quality images compared to the low frequency probe. Although, other studies conducted in the emergency setting reported high accuracy of ultrasound when compared to capnography as the standard, their obtained results were comparably lower than that obtained in the present study. Thomas and colleagues[11] in their study compared USS with capnography and USS with auscultation. When comparing USS with capnography they reported sensitivity of 97.8%, specificity of 100%, PPV 100% and NPV of 71.4%. Capnography confirmed 5% oesophageal and 95% tracheal intubation. However, though USS detected all the 5% oesophageal intubation, it misinterpreted 2% out of the 95% of the tracheal intubation as oesophageal. This could be because the study was in an emergency setting. The accuracy of sonography in the ED might differ from that of an operating room because the emergency room is saddled with pressure for a faster decision of correct endotracheal tube placement as the patients in the emergency room are mostly more unstable than those in the theatre for elective cases.

Studies which compared the accuracy of the auscultation to capnography are very few in the existing literature. The accuracy, sensitivity and specificity of auscultation reported in the present study is comparable to those reported by Arafa et al.[8] They observed the accuracy, sensitivity and specificity of auscultation to be 88.8%, 93.6% and 53.9% compared to 94.3%, 97% and 57.1% in the present study. In their study, they reported cases (12.1%) of aberrant ETT placement, in which the anaesthetist was not sure of the location of the tube. In the present study, no record of aberrant tube placement was recorded, as ETT was categorized as either in the tracheal or in the oesophagus. This might have accounted for the slightly lower value of accuracy observed in their study compared to the present study. However, Ramsingh and co-workers[9] observed that auscultation had an accuracy of 62% compared to 94.3% obtained in this study. They used a five - point auscultation as used in the present study and their study was done in a controlled environment. It was however noted that they recorded a high level of endobronchial intubation in their study. Some authors have postulated that the breath sounds may also be ambiguous in patients with low lung compliance or cases of severe bronchospasm as may occur in patients with endobronchial intubation. It is possible that the accuracy of auscultation obtained from the Ramsingh and coworkers.[9] study is lower because the breath sound picked from auscultation in an endobronchial intubation may be considered as muffled (not sure) or absent in the presence of a noisy environment.

The process of securing the airway using endotracheal intubation is a pivotal skill in anaesthesia and intensive care. Oesophageal or main stem intubation are known complications of endotracheal intubation with grave complications if unrecognized on time.[12] Capnogragh especially the side stream has a known time lag of 10-20 seconds before displaying the waveform. Diagnosis of correct location is made after the 5th or 6th waveform of at least 4KPa. Blockage of gas sampling tube or auto zeroing at the time of intubation may delay confirmation by $EtCO_2$.

In this study, the time taken to locate the correct placement of ETT was assessed using USS, five-point auscultation and capnograph. The mean time for USS, capnograph and auscultation to verify correct ETT location were 6.68 ± 2.1 seconds, 25.81 ± 6.9 seconds and 29.29 ± 9.0 seconds respectively (p value < 0.001). The result shows that USS was significantly faster than both auscultation and capnograph in locating correct endotracheal tube placement. The USS method of locating endotracheal tube placement during intubation is a direct assessment, so it does not require ventilation of the patient. Capnograph and auscultation however required at least five ventilations for a diagnosis to be made.[13] This may explain why the time taken by ultrasonography is significantly faster than that obtained from capnograph and auscultation

Some other studies have also indicated that USS is faster in locating ETT placement.[11,14,15] Thomas et al.[11] compared the time taken by tracheal USS, auscultation and capnograph to confirm ETT placement in 100 adults. Mean time by USS, capnograph and auscultation were 8.27 ± 1.54s, 18.08 ± 2.1s and 20.72 ± 2.58s respectively. It is however observed that the time to confirm ETT placement using capnograph by Thomas et al.[11] is faster than this present study. The varying definition of time of confirmation of ETT placement could have contributed to this. In the present study, T_0 was defined as time when the tube passed through the rima glottis, they defined T_0 as the time of completion of intubation. Also, the type of capnograph used was not stated as the time lag from the side stream used in this study could have contributed to this.

Sethi et al.[14] in their own study, however found that though USS was faster than both auscultation and capnograph, auscultation was faster than capnograph (9.8 ± 1.8s and 22.3 ± 0.9s). Three-point auscultation was done by Sethi et al.[14] as opposed to five-point auscultation done in this study, this may be responsible for the faster time. Though the average time of capnography by Sethi et al.'s study was comparable to the time obtained in the present study (22.3 ± 0.9s versus 25.81 ± 6.9s), it is noted that it took a longer time for USS to confirm the correct placement of ETT in the present study compared to theirs (3.8 ± 0.9 seconds versus 6.68 ± 2.1 s). This may be because they commenced their timing after completion of intubation as opposed to the time of tube passing through the rima glottis which was used in the present study.

CONCLUSION

From this study, it is concluded that ultrasound is 100% accurate, sensitive and specific when compared with capnography, the gold standard when confirming the correct placement of endotracheal tube during intubation. Ultrasound is also significantly faster than both capnography and auscultation in locating the placement of the endotracheal tube.

Conflicts of interest: No conflict of interest is declared.

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