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Evaluation of Point of Care Ultrasonography for Assessment of Tracheal Tube Placement Under General Anaesthesia: An Observational Study

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Abstract

Background: Endotracheal intubation, a procedure performed by anesthesiologists, emergency medical doctors, and critical care physicians, is crucial for saving lives. Several methods exist to distinguish between placing the tube in the trachea or the esophagus. Despite advancements in differentiating between tracheal and esophageal intubation, accurately determining the correct positioning of the endotracheal tube inside the trachea remains challenging. **Methods:** It was observational study, conducted in the department of Anesthesiology at Indira Gandhi Institute of Medical Sciences, Patna during the period February 2019 to September 2020. A total 188 patients were enrolled who were scheduled for elective surgery, where general anesthesia and oro-tracheal intubation were required. To evaluate the trustworthiness of ultrasound-guided intubation as a technique to confirm endotracheal intubation. **Results:** The most common age group in our study was 21-40 years involving 61.7% (116) patients followed by 41-60 years (35.6%) and the least common age group was ≤20years (2.7%) with a mean age of 36.38 years. Majority of the patients of our study were males (68.1%). The mean duration for Ultrasonography confirmation of endotracheal intubation was 14.098 seconds. Confirmation with capnography using appearance of first waveform was found with a mean time of 27.244 seconds and confirmation using chest auscultation for air entry showed a mean time of 43.36 seconds. We evaluated correlation of mean time difference between ultrasonography, capnography & auscultation using Pearson's correlation. Pearson's correlation test showed a strong positive association between ultrasonography, capnography and chest auscultation. **Conclusion:** It can be concluded that confirmation of ETT position using either auscultation, ultrasonography or capnography is a mandatory requirement because of the high false diagnosis depending on standard auscultatory confirmation alone. Using bed-side ultrasonography is an easy, accurate and fast method than standard auscultation compared to capnography as a gold standard, so it is suggested to be one of the essential theatre equipments whenever possible.

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Key words: Endotracheal intubation, ultrasonography, capnography, auscultation

Introduction: Emergency intubations pose a significant risk of mistakenly placing the tube in the esophagus, which can quickly lead to fatal consequences if not promptly identified and corrected. Qualitative color capnography, commonly used to confirm the positioning of the endotracheal tube, has been found to be inconclusive or unreliable in a considerable number of emergency department patients. Furthermore, capnography necessitates delivering ventilations to the patient, increasing the risk of aspiration if the tube is misplaced in the esophagus. Since no single airway confirmation device has demonstrated 100% accuracy in all patient scenarios, emergency physicians should employ multiple confirmation techniques to minimize the chances of overlooking an esophageal intubation.[1,2]

Auscultation has traditionally been the standard method for determining the location of the endotracheal tube and is endorsed by reputable institutions such as the American Heart Association and prominent Anesthesiology and Perioperative Care textbooks. However, with a sensitivity of only 60 to 65%, auscultation has proven to be an unreliable means of distinguishing between tracheal and bronchial intubation.[3,4]

Point-of-care ultrasound refers to the use of real-time ultrasound performed and interpreted by the provider at the patient's bedside. It is a quick and cost-effective technique, especially with the advent of handheld ultrasound devices, making it readily available in clinical settings where endotracheal intubation is performed. Recent evidence has supported the use of point-of-care ultrasound for detecting esophageal versus tracheal intubations,[5] with reported sensitivity/specificity of 100% in adult patients undergoing surgery and 100%/86%, respectively, in patients undergoing cardiopulmonary resuscitation. In fact, the 2015 American Heart Association Guidelines recommend ultrasound as an adjunct tool to confirm correct tube position when carbon dioxide monitoring is not available. However, limited evidence exists regarding the use of point-of-care ultrasound to determine the precise location of the endotracheal tube within the trachea.[6,7]

This observational study aims to evaluate the accuracy of ultrasound in determining proper tracheal tube placement compared to conventional methods such as auscultation and wave capnography.

Objectives:

To assess correct placement of tracheal tube by ultrasonography and comparing with conventional method (auscultation and wave capnography).

Methods

It was observational study, conducted in the department of Anesthesiology at Indira Gandhi Institute of Medical Sciences, Patna during the period February 2019 to September 2020. A total 188 patients were enrolled who were scheduled for elective surgery, where general anesthesia and oro-tracheal intubation were required. To evaluate the trustworthiness of ultrasound-guided intubation as a technique to confirm endotracheal intubation.

Inclusion criteria

- Patients of ASA grade 1 and2
- Patients of MPS class I and II
- Patients between 18 – 60 years of age of either sex
- Patient assigned for general anaesthesia with orotrachealintubation

Exclusion Criteria

- Included refusal to participate in the study
- Patients with predictors of difficult intubation; Modified Mallampati class 3 and4

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- Thyromental distance <6.5 cm,
- Negative upper lip bitetest
- Restrictedneck
- Movements (flexion <25 degrees, extension <85degrees)
- Previous history of difficult intubation.

Intervention & Data Collection Methods

Before surgery, patients underwent an examination to collect demographic data and assess their clinical condition to ensure they met the inclusion and exclusion criteria. Preoperatively, non-invasive measurements of baseline hemodynamic data, including systolic (SBP), diastolic (DBP), and mean arterial pressure (MAP), were taken. Additionally, arterial peripheral oxygen saturation was measured using pulse oximetry.

All patients received the same anesthetic protocol, which involved premedication with Fentanyl (2 μg/kg) and Propofol (2 mg/kg) for anesthesia induction, followed by Atracurium (0.5 mg/kg) to facilitate tracheal intubation.

For upper airway ultrasonography, a M-Turbo Ultrasound system with a 6-13 MHz linear ultrasound transducer was used. The transducer probe was placed transversely on the neck, anteriorly and superior to the suprasternal notch, before intubation. Immediately after intubation, the probe was used to visualize the tracheal tube in both longitudinal and transverse views. The probe was then moved to the left to examine the esophagus and determine if it was empty or distended by the tube. The results obtained from ultrasonography were compared to the positive results obtained from quantitative conventional methods such as waveform capnography (WC) and auscultation. The time taken by ultrasonography to confirm tracheal intubation was also recorded.

If the endotracheal tube (ETT) was observed to be moving towards, hitting, or passing through the esophagus, the observer immediately instructed the resident to redirect the ETT towards the trachea. After intubation, a second observer confirmed the placement of the ETT in the trachea using quantitative waveform capnography, noting the time of appearance of the first and sixth capnography waveform. A third observer auscultated the chest at five auscultatory sites to check for bilateral air entry and noted the time.

In all patients, the placement of the ETT was confirmed by all three methods: ultrasonography, waveform capnography, and chest auscultation for air entry. The following parameters were recorded: time to intubation confirmed via ultrasound, time to intubation confirmed via appearance of the first waveform on capnography, time to intubation confirmed via appearance of the sixth waveform on capnography, time to intubation confirmed via chest auscultation on all five sites for air entry, time to intubation confirmed via chest auscultation on both sides for air entry, number of times the ETT hit the esophagus or any other structure, and desaturation of peripheral oxygen saturation (SpO2) below 95%.

Statistical Analysis: The data was analyzed using IBM SPSS Statistics version 19. Pearson's correlation test and reliability analysis using interclass correlation coefficient calculation were employed to validate the reliability of ultrasonography compared to capnography and chest auscultation as methods for confirming correct placement of the ETT. Ultrasonography confirmation was compared to capnography confirmation based on the appearance of the first waveform.

Results

Table 1: Sex Distribution among study population (n=188)

Age in year	Male (n=128)		Female (n=60)	
	No of cases	Percentage	No of cases	Percentage
<20	02	1.7	03	4.4

21 – 40	75	63.0	41	59.4
41 – 60	42	35.3	25	36.2
Total	119	100	69	100
Chi-square & p Value	Chi- square value- 1.270		p Value- 0.529	

It shows majority of the patients of our study were males (68.1%). Above analysis we found there was no significant difference between male and female patients regarding age (p value =0.529).

Table 2: Mean & SD value of Anthropometric measurement of study population (n=188)

Demographic Data	Mean	SD
Height	163.61	±9.79
Weight	64.90	±6.46
BMI	24.28	±2.55

The mean levels of anthropometric parameters of the study subjects. The mean height, weight and BMI were 163.61 cms, 64.90 Kgs and 24.28 Kg/m^2 respectively.

Table 3: Modified Mallampati (MMP) class of study population.(n=188)

MMP class	No of cases	Percentage
Class I	69	36.7
Class II	119	63.3
Total	**188**	**100**

It shows that majority of the study subjects belonged to MMP Class II (63.3%).

Table 4: Mean Duration in correct placement of ETT (n=188)

Variable (Time taken for confermation)	Mean	SD
Ultrasound	14.098	±3.18
Capnography (1 waveform)	27.244	±3.58
Chest Auscultation	43.361	±3.64

The mean duration for Ultrasonography confirmation of endotracheal intubation was 14.098 seconds. Confirmation with capnography using appearance of first waveform was found with a mean time of 27.244 seconds and confirmation using chest auscultation for air entry showed a mean time of 43.36 seconds.

Table 5: Mean difference between 3 groups (Ultrasonography, capnography & Auscultation)

	Mean difference	95% CI	t- statistic	P value
Ultrasound vs Capnography	13.146	12.45 – 13.83	37.643	<0.0001
Ultrasound vs Auscultation	29.263	28.56 – 29.95	83.012	<0.0001
Capnography vs Auscultation	16.117	15.38 – 16.84	43.28	<0.0001

The mean difference of duration to confirm correct placement of ETT. While analyzing with unpaired ‘t’test we found was a significant difference between ultrasound and capnography, ultrasound and auscultation and capnography and auscultation (p value=<0.0001).

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Table 6: Mean time difference Correlation between Ultrasonography, Capnography & Auscultation.

Correlations				
		Ultrasound	Crapnography	Auscultation
Ultrasound	Pearson Correlation	1	.152*	.232**
	p Value		.037	**.001**
	N	188	188	188
Crapnography	Pearson Correlation	.152*	1	.144*
	p Value	**.037**		**.049**
	N	188	188	188
Auscultation	Pearson Correlation	.232**	.144*	1
	p Value	**.001**	**.049**	
	N	188	188	188

The correlation of mean time difference between ultrasonography, capnography & auscultation using Pearson's correlation. Pearson's correlation test showed a strong positive association between ultrasonography, capnography and chest auscultation.

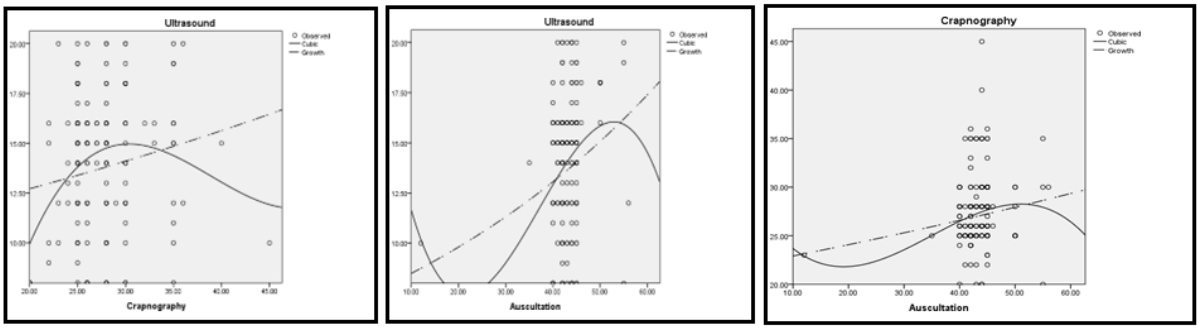

Figure 1: Correlation curve between Ultrasonography Vs Capnography and Auscultation.

Table 7: Ultrasonography in detecting correct placement of the ETT

Ultrasonography	**True Position**		**Total**
	Trachea	**Esophagus**	
Trachea	178	02	180
Esophagus	02	06	08
Total	180	08	188

Statistic	**Value**	**95% CI**
Sensitivity	98.89%	96.04% to 99.87%
Specificity	75.00%	34.91% to 96.81%
Positive Likelihood Ratio	3.96	1.19 to 13.14
Negative Likelihood Ratio	0.01	0.00 to 0.06
Positive Predictive Value (*)	98.89%	96.40% to 99.66%
Negative Predictive Value (*)	75.00%	41.67% to 92.65%
Accuracy (*)	97.87%	94.64% to 99.42%

The specificity, sensitivity and accuracy of ultrasonography in detecting the correct placement off ETT are mentioned in above table. The sensitivity, specificity and accuracy

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were 98.89%, 75% and 97.87% respectively for ultrasonography in detecting the correct placement of ETT.

Table 8: Capnography in detecting correct placement of the ETT

Ultrasonography	**True Position**		**Total**
	Trachea	**Esophagus**	
Trachea	180	00	180
Esophagus	00	08	08
Total	**180**	**08**	**188**

Statistic	**Value**	**95% CI**
Sensitivity	100.00%	97.97% to 100.00%
Specificity	100.00%	63.06% to 100.00%
Positive Likelihood Ratio	-	-
Negative Likelihood Ratio	0.00	-
Positive Predictive Value (*)	100.00%	-
Negative Predictive Value (*)	100.00%	-
Accuracy (*)	100.00%	98.06% to 100.00%

The specificity, sensitivity and accuracy of capnography in detecting the correct placement off ETT are mentioned in above table. The sensitivity, specificity and accuracy were 100%, 1000% and 100% respectively for capnography in detecting the correct placement of ETT.

Table 9: Auscultation in detecting correct placement of the ETT

Ultrasonography	**True Position**		**Total**
	Trachea	**Esophagus**	
Trachea	113	20	133
Esophagus	40	15	55
Total	153	35	188

Statistics	**Value**	**95% CI**
Sensitivity	73.86%	66.15% to 80.62%
Specificity	42.86%	26.32% to 60.65%
Positive Likelihood Ratio	1.29	0.96 to 1.75
Negative Likelihood Ratio	0.61	0.38 to 0.97
Positive Predictive Value (*)	84.96%	80.68% to 88.43%
Negative Predictive Value (*)	27.27%	19.05% to 37.41%
Accuracy (*)	68.09%	60.91% to 74.68%

The specificity, sensitivity and accuracy of auscultation in detecting the correct placement of ETT are mentioned in above table. The sensitivity, specificity and accuracy were 73.86%, 42.86% and 68.09% respectively for auscultation in detecting the correct placement of ETT

Discussion

The study was conducted in Neuro, GIS, Urology OT under Department of Anaesthesiology, Indira Gandhi Institute of Medical Sciences, Patna. Patients were scheduled for elective surgery requiring general anesthesia with oro-tracheal intubation. Patients aged between 18-60 years, total sample size was 188, were enrolled in the study. Age distribution of the patients. It shows that the most common age group in our study was 21-40 years involving 61.7% (116) patients followed by 41-60 years (35.6%) and the least common age group was ≤20 years (2.7%) with a mean & SD value of age was 36.38±11.30 years. Majority of the patients of our study were males (68.1%). Above analysis we found there was no significant

difference between male and female patients regarding age (p value =0.529). Another similar study of **Abhishek C et al**[8] found the mean distribution of age was 38.87 ± 11.969 years. In this study the mean levels of anthropometric parameters of the study subjects. The mean height, weight and BMI was 163.61 cms, 64.90 Kgs and 24.28 Kg/m2 respectively.

In this study, distribution of study subjects according to modified mallampati (MMP) class shows that majority of the study subjects belonged to MMP Class II (63.3%). The mean duration for Ultrasonography confirmation of endotracheal intubation was 14.098±3.18 seconds. Confirmation with capnography using appearance of first waveform was found with a mean time of 27.244±3.58 seconds and confirmation using chest auscultation for air entry showed a mean time of 43.36±3.64 seconds. **Apala Roy Chowdhury et al**[9] found in their study the mean total time taken for endotracheal confirmation with ultrasound was significantly less at 36.50 ± 15.14 seconds compared to confirmation with unilateral chest auscultation (mean total time of 50.29 ± 15.50 seconds; time lag of 13.79 ± 4.12 seconds compared to ultrasound), bilateral chest auscultation for air entry (51.90 ± 15.18 seconds; time lag of 15.41 ± 4.22 seconds), capnography first wave and capnograph sixth wave. In five patients, ultrasound detected ETT hitting the esophagus.

The present study demonstrated that ultrasound confirmation of correct ET intubation is statistically faster than capnography even with first waveform. Moreover capnography relies on physiological factors like ventilation, adequate pulmonary perfusion and gas exchange for its confirmation. In conditions of impaired ventilation like bronchospasm and inadequate pulmonary perfusion like cardiac arrest or pulmonary embolism, capnography may fail to correctly identify an endotracheal intubation.[10]

In the present study found mean difference of duration to confirm correct placement of ETT. While analyzing with unpaired ‘t’test we found was a significant difference between ultrasound and capnography, ultrasound and auscultation and capnography and auscultation (p value=<0.0001). The correlation of mean time difference between ultrasonography, capnography & auscultation using Pearson’s correlation. Pearson's correlation test showed a strong positive association between ultrasonography, capnography and chest auscultation. In a study on 25 patients posted for elective surgery, lung ultrasound (using pleural sliding sign) for verifying endotracheal intubation was compared with auscultation. Median time for verification by lung ultrasound was 40 seconds vs. 42 seconds for auscultation alone, with a mean difference of 0.88 seconds in favor of lung ultrasound.[11]

As the authors performed lung ultrasound and compared auscultation with the total time consumed till bilateral pleural sliding sign was observed, not much significant time difference was observed. However in the present study auscultation with real time trans-cricoid ultrasonography for visualization of passage of endotracheal tube was done which gave a significant time lag of Ultrasonography confirmation of endotracheal intubation was 14.098 seconds. Confirmation with capnography using appearance of first waveform was found with a mean time of 27.244 seconds and confirmation using chest auscultation for air entry showed a mean time of 43.36 seconds. **Muslu *et al*.** conducted a blinded prospective randomized study in seventy-five adult patients posted for elective surgery where anaesthesiologist randomly intubated the trachea or esophagus with direct laryngoscopy and the sonographers had to identify them with ultrasound with transducer placed transversely on the neck above the suprasternal notch.

A prospective study conducted in an urban teaching hospital in New York, concluded that bedside upper airway ultrasonography is a feasible method/tool to verify the placement of endotracheal tube as compared to continuous capnography.[12] **Pfeifer *et al*.** in their study compared the temporal relationship between ultrasound with chest auscultation and capnography in comparing ETT placement in emergency setting. They found that ultrasound is faster than the standard method of auscultation and capnography.[13]

Adi et al in their study to compare the feasibility of bedside upper airway USG to verify ETT location after intubation in comparison to capnography, showed a great strengh of agreement between both modalities in patients of varied age, ethnic group and indication of intubation. They also stressed the importance of USG in ruling out esophageal intubation. They proved that upper airway USG observes the upper airway in real time and correctly identifies whether the tube is in trachea or esophagus. The study enlightens the importance of adequate airway US training among the emergency physicians to use it as a point of care method in patients landing in emergency.[14]

Chun et al evaluated the portable hand held US machine in confirming the correct ETT placement. They recorded the chest wall visceral parietal pleural interface (VPPI), bilaterally in patients during all phases of airway management. They concluded that thoracic sonography may prove to be an important tool in confirming ETT placement especially in extreme conditions such as aerospace medical transport where other modalities such as capnography may not be available and auscultation might not be feasible.[15]

TRUE (tracheal rapid ultrasound scan) as a modality was used by **Masoumi et al**. They placed a convex transducer above the suprasternal notch, but due to lower frequency of convex transducer, superficial structures of airway -trachea, air mucosa interface (lung sliding sign) are difficult to interpret.

These observations were in agreement with that of **Ramsingh et al**. patients were endotracheally intubated. The sensitivity of lung sliding sign was 93% and specificity was 96%. PLUS examination showed an improved ability to detect both right and left bronchial intubation over auscultation. There was 20% improvement in the detection of improper ETT placement comes with the application of a noninvasive ultrasound examination. The positive predictive value (PPV) was 93% and negative predictive value (NPV) was 96% The Chisquare comparison showed statistically significant improvement with ultrasound versus auscultation for the detection of (a) trachea vs. main stem intubation (p=0.0005),(b)trachea versus main left stem intubation (p=0.0004),and (c)trachea versus right main stem intubation (P=0.0371).[16]

Conclusion

Auscultation is frequently used method to detect location of endotracheal tube. The changes of wrong judgment of location of endotracheal tube are higher in auscultation as it is highly dependent on clinical experience of anesthesiologist. Tracheal dilation and bilateral lung pleura movements can be directly observed in ultrasonography which are more sensitive and specific than standard auscultation technique. Endobronchial placement of tube can lead to serious complication e.g. atelectesis of lung which can be prevented by using point of care ultrasonography. It is important to maintain the correct location of endotracheal tube.

It can be concluded that confirmation of ETT position using either auscultation, ultrasonography or capnography is a mandatory requirement because of the high false diagnosis depending on standard auscultatory confirmation alone. Using bed-side ultrasonography is an easy, accurate and fast method than standard auscultation compared to capnography as a gold standard, so it is suggested to be one of the essential theatre equipments whenever possible.

Finally, we can conclude that although capnography is more sensitive and specific in detecting location of endotracheal tube, we recommend using point of care ultrasonography to confirm the location of endotracheal tube due to accurate and fast method.

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