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Diagnostic Accuracy Of Ultrasound For Confirmation Of Endotracheal Tube Placement Taking Capnography As A Gold Standard

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ABSTRACT

Introduction: Accurate placement of an endotracheal tube (ETT) is critical for patient safety during medical procedures. The research explores the potential of ultrasound technology to provide a reliable alternative for ETT confirmation, offering insights into its diagnostic performance and the implications for enhancing patient care in surgical settings.

Aims & Objectives: To determine the diagnostic accuracy of ultrasound for the confirmation of endotracheal tube keeping Capnography as a Gold standard.

Place and Duration of Study: It is a Cross Sectional study and the study was carried out in Operation Theater Shaikh Zayed Hospital Lahore, within 6 months after approval of synopsis i.e. from 5th May, 2020 till 4th November, 2021.

Material & Methods: Total 219 patients who fulfilled the inclusion criteria were enrolled. After standardization of anesthetic measures all patients were intubated by direct laryngoscopy. ETT placement was assessed by capnometry and by ultrasonography. Endotracheal tube placement was labeled (as per operational definition) on both the techniques.The analysis of the data was conducted using SPSS version 21.0, a p-value of ≤0.05 was considered significant.

Results: The mean age, BMI, neck circumference and thyromental distance of the patients was 39±8.15 years, 27±3.42 Kg/m 2, 29.5±4.63cm and 6.9±0.50cm. There were 58% males and 42% females in the study. Ultrasonography exhibited sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy rates of 98.5%, 90.6%, 98.9%, 86.1%, and 97.7%, respectively, in its ability to detect the accurate placement of endotracheal tubes (ETT).

Conclusion: The sensitivity, specificity, diagnostic accuracy and promptness of recognition for confirmation of tracheal placement of ETT is higher withultrasonography compared to the gold standardcapnography in patients undergoing elective surgery under general anesthesia.

Keywords: Endotracheal tube, capnography, ultrasound.

INTRODUCTION

Ensuring a stable airway and efficient ventilation is of utmost importance for patients undergoing general anesthesia during any surgical procedure[1]. Misplacement of the endotracheal tube (ETT) can result in significant patient morbidity. The improper positioning of the tracheal tube can give rise to irreversible complications. Failure to promptly detect and rectify ETT misplacement can result in severe consequences, including neurological damage and even mortality, with reported incidence rates ranging from 6% to 16%. Hence, the accurate verification of tracheal tube placement is of critical significance[2,3].

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Operational Definitions:

Endotracheal tube:

An appropriate exchange of carbon dioxide and oxygen is ensured, together with the establishment and maintenance of a patent airway, by use of a catheter called a endotracheal tube.

ETT Placement:

Endotracheal tube (ETT) placement is considered accurately positioned when it meets the following criteria:

1. Confirmation by quantitative waveform capnography, with a sensitivity and specificity of 100%, under the conditions where capnography is applicable (such as during cardiac arrest, poor cardiac output, low pulmonary blood flow, or epinephrine usage).

2. Confirmation by ultrasound, with a diagnostic accuracy of at least 95% sensitivity and specificity, as per the meta-analysis conducted by Saurabh Kumar et al in 2015.

3. In your specific study, ETT placement was labeled as per the operational definition obtained from the above criteria based on the use of capnometry and ultrasonography.

There are a lot of different methods to detect the correct positioning of an endotracheal tube (ETT). However, each of these techniques presents certain limitations, emphasizing the current need for a modality that can accurately detect ETT placement with minimal complications[4].Confirming the precise location of the ETT can pose challenges for many ICU physicians, particularly when the glottis is difficult to visualize during intubation. Traditional methods such as physical examination, pulse oximetry, and chest radiography often fall short in providing definitive ETT position information. Esophageal detection devices, while useful, may not be readily available in many healthcare settings and can be subject to misinterpretation Although capnography is typically advised as a trustworthy method for ETT validation, its broad availability might raise questions and it has drawbacks of its own[5].

The standard method for verifying that the endotracheal tube was positioned correctly is quantitative waveform capnography. It has a sensitivity of 100% and specificity of 100% as well. Capnography has certain limitations. Its application is restricted to those experiencing cardiac arrest, poor cardiac output, low pulmonary blood flow, or excessive epinephrine usage[6].

Capnography is commonly accessible in operating theaters, but its availability in many emergency departments (EDs) is limited. On the other hand, because ultrasonography may be used for guided medical procedures and point-of-care imaging for trauma, it is becoming more and more popular in most emergency departments. Portable, non-invasive, and capable of producing readily replicable pictures are ultrasound machines. Promising results have been obtained after a decade of study on the use of ultrasonography to confirm the insertion of endotracheal tubes[7,8]. A meta-analysis conducted by Saurabh Kumar et al in 2015 revealed that the overall sensitivity and specificity of ultrasonography for the diagnosis of correct placement of endotracheal tube was 95%[4]. In another study, the diagnostic accuracy of ultrasound for endotracheal tube placement was 98.2%[3].

The diagnostic value of ultrasonography for endotracheal tube confirmation has been extensively studied across the world. However, no such data is available in Pakistan. So the rationale of the current study was to assess the diagnostic accuracy and timeliness of ultrasound for the confirmation of the endotracheal tube[8]. This would help in creating awareness among physicians about this quick, inexpensive, easily affordable and a reliable technique for the detection of correct placement of endotracheal tube and thus could prevent further morbidities and mortality associated with the misplacement of endotracheal tube.

MATERIAL AND METHODS

After getting approval from the Institutional Ethical Committee (SZMC/IRB/00110/2021), 219 pre-op patients from the Surgery Department of Shaikh Zayed Hospital Lahore, who fulfilled the selection criteria were enrolled for the study. The study design was cross sectional. Patients of age having 18 to 60 years of both genders who required general anesthesia for elective surgery and patients who fell in Class I and II according to ASA grading were included in this study. Patients with significant neck or lung pathologies, oropharyngeal pathology (haematoma, abscess, tumor etc.) and pregnant females were excluded from the study. Non-probability consecutive sampling method was used.

A total of 219 patients were enrolled in the study, keeping 95% confidence interval, 10% margin of error and sensitivity as 95%[4] (assumed 90%) and specificity of ultrasonography to be 95%[4] (assumed 90%) and prevalence of endotracheal tube was 16%[2]. Demographic information in the form of name, age, gender and BMI were recorded. Clinical assessment was done based on neck circumference, thyromental distance, Anesthesiologists physical status grading. Anesthetic measures were completely standardized. Patients were intubated by direct laryngoscopy. ETT placement was assessed by capnometry and by ultrasonography. Endotracheal tube placement was labeled (as per operational definition) on both the techniques. The analysis of the data was conducted using SPSS version 21.0. Quantitative variables, including age, BMI, neck circumference, and thyromental distance, were expressed as the mean and standard deviation. Qualitative data, such as gender and ASA grading, were represented in terms of frequency and percentages. The data was then stratified based on age, gender, BMI, neck circumference, and ASA grading. Subsequently, a post-stratification Chi-square test was applied, taking p-value of ≤ 0.05 significant. The diagnostic accuracy of ultrasonography was evaluated through a 2x2 table.

RESULTS

As in Fig-1 and Fig-2 the study observed a typical capnogram waveform & detection of the endotracheal tube within the trachea using color doppler imaging is shown. And a total of 219 patients were enrolled. The mean age (in years) of the patients was 39±8.15 (Table-1). The mean BMI (in Kg/m2) of the patients was 27±3.42. The mean neck circumference (in cm) of the patients was 29.5±4.63. The mean thyromental distance (in cm) of the patients was 6.9±0.50 as shown in Table-1. There were 58% males and 42% females in the study. ASA grade I was present in 47% patients and ASA grade II was present in 53% patients as shown in Table-2. Table-3 illustrates the diagnostic accuracy of Ultrasonography for endotracheal tube (ETT) placement, with Capnography as the reference or "Gold Standard." 195(89%), 2(0.9%), 3(1.4%) and 19(8.7%) are the results for true positive, false positive, false negative and true negative respectively. The sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of ultrasonography for detecting correct ETT placement was 98.5%, 90.6%, 98.9%, 86.1% and 97.7% shown in Table-4.

Data was stratified for age, gender, BMI, neck circumference and ASA grade. With respect to age (Table-8), it was found that accuracy of ultrasonography in this age group was 100% and the association was statistically significant (p=0.000). With respect to early middle age (31 to 45 years), the accuracy of ultrasonography was 97.8% and this was statistically significant (0.000) With respect to late middle age (46 to 60 years), the accuracy of ultrasonography was 95.2% and this association was statistically significant (p=0.000) (Table-5).

With respect to gender (Table-6), it was found that accuracy of ultrasonography in male patients was 96.8% and the association was statistically significant (p=0.000) and in the female patients, the accuracy of ultrasonography was 98.9% and the association was statistically significant (p=0.000).

With respect to BMI (Table-7), the accuracy of ultrasonography in patients with normal BMI (20-25 kg/m2) was 97.6% and this was statistically significant (0.000), in overweight patients (BMI 26-30 kg/m2) the accuracy of ultrasound was 97.7% and the association was statistically significant (p=0.000) and in obese patients (BMI >30 kg/m2) the accuracy of ultrasound was 100%.

With respect to neck circumference (Table-8), the accuracy of ultrasonography in patients with <32 cm neck circumference was 98.5% and this was statistically significant (0.000), in patients with a neck circumference of 32 to 35 cm the accuracy of ultrasound was 96.8% and the association was statistically significant and in patients with a neck circumference of >35 cm the accuracy of ultrasound was 94.7% and this association was statistically significant (p=0.003).

With respect to ASA grade (Table-9), the accuracy of ultrasonography in patients with ASA grade I was 97.1% and this was statistically significant (0.000) and in patients with ASA grade II the accuracy of ultrasound was 98.3% and the association was statistically significant (p=0.000).

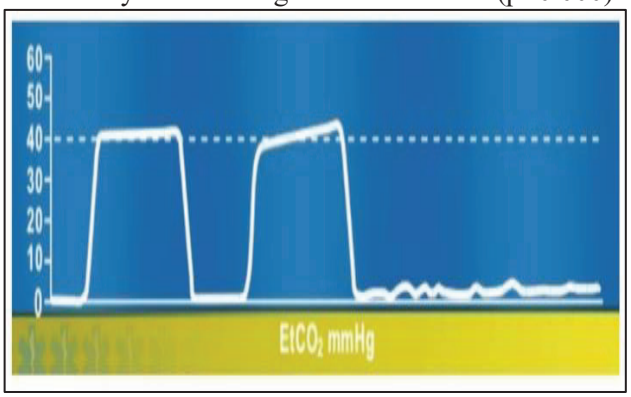

Fig-1: The Study Observed A Typical Capnogram Waveform

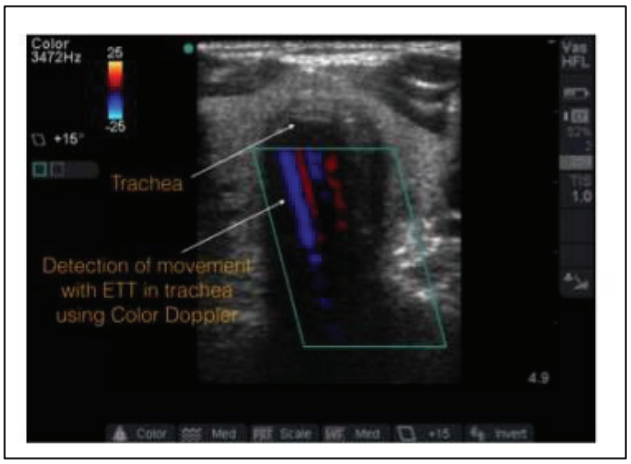

Fig-2: Detection Of The Endotracheal Tube Within The Trachea Using Color Doppler Imaging.

Variables	Mean±Sd
Age	39±8.15
BMI Kg/m^2	27±3.42
Mean neck circumference	29.5±4.63
Mean thyromental distance cm	6.9±0.50

Table-1: Mean Age (In Years) Of The Patients

Parameters	Characterstics	Frequency	Percentage
Gender	Male	127	58%
	Female	92	42%
ASA Grade	Grade I	103	47%
	Grade II	116	53%

Table-2: Gender Distribution Of Patients

ETT Placement On Ultrasonography	ETT Placement On Capnography	
	Positive	Negative
Positive	True positive 195 (89%)	False positive 2 (0.9%)
Negative	False negative 3 (1.4%)	True negative 19 (8.7%)

Table-3: 2x2 Table Showing Diagnostic Accuracy Of Ultrasonography Keeping Capnography As Gold Standard

Parameter	Formula	Percentage %
Sensitivity	TP/(TP + FN)	98.5%
Specificity	TN/(FP + TN)	90.6%
Positive predictive value	TP/(TP + FP)	98.9%
Negative predictive value	TN/(FN + TN)	86.1%
Diagnostic accuracy	100 x (TP+TN)/N	97.7%

Table-4: Sensitivity, Specificity, PPB, NPV And Accuracy Of Ultrasound For confirmation Of Endotracheal Tube Placement

Age Group	Findings On Ultrasound	Findings On Capnography		Total	P-value
		Positive	Negative		
Young Age Group (18 To 30 Years)	Positive	37 (88.1%)	0 (0%)	37 (88.1%)	0.0
	Negative	0 (0%)	5 (11.9%)	5 (11.9%)	
	Total	37 (88.1%)	5 (11.9%)	42 (100%)	
Early Middle Age (31 To 45 Years)	Positive	122 (90.4%)	1 (0.7%)	123 (91.1%)	0.0
	Negative	2 (1.5%)	10 (7.4%)	12 (8.9%)	
	Total	124 (91.9%)	11 (8.1%)	135 (100%)	
Late Middle Age (46 To 60 Years)	Positive	36 (85.7%)	1 (2.4%)	37 (88.1%)	0.0
	Negative	1 (2.4%)	4 (9.5%)	5 (11.9%)	
	Total	37 (88.1%)	5 (11.9%)	42 (100%)	

Table-5: Stratification Of Diagnostic Accuracy Of Ultrasonography With Respect To Age

Gender	Findings On Ultrasound	Findings On Capnography		Total	P-value
		Positive	Negative		
Male	**Positive**	116 (91.3%)	2 (1.6%)	118 (92.9%)	0.0
	Negative	2 (1.6%)	7 (5.5%)	9 (7.1%)	
	Total	118 (92.9%)	9 (7.1%)	127 (100%)	
Female	**Positive**	79 (85.9%)	0 (0%)	79 (85.9%)	0.0
	Negative	1 (1.1%)	12 (13%)	13 (14.1%)	
	Total	80 (87%)	13 (14.1%)	92 (100%)	

Table-6: Stratification Of Diagnostic Accuracy Of Ultrasonography With Respect To Gender

BMI	Finding on ultra-Sound	Findings On Capnography		Total	P-value
		Positive	Negative		
Normal BMI (20-25 Kg/m^2)	Positive	150 (87.7%)	2 (1.2%)	152 (88.9%)	0.0
	Negative	2 (1.2%)	17 (9.9%)	19 (11.1%)	
	Total	152 (88.9%)	19 (11.1%)	171 (100%)	
Overweight (25.1-30 Kg/m^2)	Positive	41 (93.2%)	1 (2.3%)	42 (95.5%)	0.0
	Negative	0 (0%)	2 (4.5%)	2 (4.5%)	
	Total	41 (93.2%)	3 (6.8%)	44 (100%)	
Obese (>30 Kg/m^2)	Positive	4 (100%)	0(0%)	4 (100%)	-
	Negative	0 (0%)	0 (0%)	0 (0%)	
	Total	4 (100%)	5 (11.9%)	4 (100%)	

Table-7: Stratification Of Diagnostic Accuracy Of Ultrasonography With Respect To BMI

Neck circumference	Findings on capnography	Findings on ultrasound		Total	P-value
		Positive	Negative		
<32 cm	Positive	125 (91.2%)	1 (1.7%)	126 (92%)	0.0
	Negative	1 (1.7%)	10 (7.3%)	11 (8%)	
	Total	126 (92%)	11 (8%)	137 (100%)	
32 to 35 cm	Positive	53 (84.1%)	1 (1.6%)	54 (85.7%)	0.0
	Negative	1 (1.6%)	8 (12.7%)	9 (14.3%)	
	Total	54 (85.7%)	9 (14.3%)	63 (100%)	
>35 cm	Positive	17 (89.4%)	0 (0%)	17 (89.4%)	0.003
	Negative	1 (5.3%)	1 (5.3%)	2 (10.6%)	
	Total	18 (94.7%)	1 (5.3%)	19 (100%)	

Table-8: Stratification Of Diagnostic Accuracy Of Ultrasonography With Respect To Neck Circumference

ASA Grade	Findings on ultra-sound	Findings On Capnography		Total	P-value
		Positive	Negative		
Grade I	Positive	95 (92.2%)	1 (1%)	96 (93.2%)	0.0
	Negative	2 (1.9%)	5 (4.9%)	7 (6.8%)	
	Total	97 (94.2%)	6 (5.8%)	103 (100%)	
Grade II	Positive	100 (86.2%)	1 (0.9%)	101 (87.1%)	0.0
	Negative	1 (0.9%)	14 (12.1%)	15 (12.9%)	
	Total	101 (87.1%)	15 (12.9%)	116 (100%)	

Table-9: Stratification Of Diagnostic Accuracy Of Ultrasonography With Respect To ASA Grade

DISCUSSION

Traditionally, the ability of airway experts to visualize the vocal cords and clinical indicators—such as evaluating for equal airflow in both lungs and using capnography—has been crucial in verifying the precise insertion of an endotracheal tube (ETT).However, in challenging airway situations and emergency scenarios, visualizing the vocal cords can be problematic. The effectiveness of any technique in confirming ETT placement is typically assessed through its sensitivity and specificity[11]. Over time, several methods have been developed, yet none has demonstrated absolute reliability in consistently distinguishing between tracheal and esophageal intubations[12]. The current study results revealed the sensitivity and specificity for detecting correct placement of ETT by using ultrasound is 98.5% and 90.6% respectively, when compared to capnography. Ultrasound had a diagnostic accuracy of 97.7% with capnography as gold standard. Highest accuracy of ultrasound was found in young aged (20-30 years), female patients, who were obese, had a neck circumference of less than 32 cm and had an ASA grade II. These findings align with the outcomes of two prospective investigations conducted by Werner et al.[13] and Milling et al., [14] both of which reported that under ideal procedure circumstances, tracheal ultrasonography might achieve up to 100% results in terms of sensitivity and specificity. In a separate study, Moghawri et al. uncovered that ultrasonography demonstrated a sensitivity of 95.8% and a specificity of 93.3% in accurately diagnosing the correct placement of an endotracheal tube (ETT)[15]. In another study, Ariff et al. revealed that the sensitivity and specificity of ultrasonography for diagnosing ETT placement was 99.7% and 91% 65. Shebl et al. revealed that the sensitivity and specificity of ultrasound for correct detection of ETT was 96.2 and 100% respectively[16]. Our study similarly revealed that ultrasound had a high sensitivity and specificity for correct detection of placement of ETT in the trachea. In a study, the accuracy of ultrasound was revealed to be 100% for correct detection of ETT placement in the trachea, whereas, another study revealed it to be 90.43%[17]. These findings are in line with our study findings revealing that the accuracy of ultrasonography was very high. In the research conducted by Zamani et al., it was determined that the subjects undergoing ultrasound-assisted intubation accuracy assessment exhibited a high body mass index (BMI) and a reduced thyromental distance.[18]

In our own study, we similarly observed that the most successful detection rates were achieved in individuals with elevated BMIs. Furthermore, Zamudio and Casas discovered that a high BMI and an increased neck circumference were indicators of challenging laryngoscopy. Interestingly, the ultrasound-based detection was not substantially influenced by BMI or neck circumference.[19]

In our study, the correct detection of ETT was also higher in patients with large neck circumference as well as in small neck circumference and also in patients who had a higher BMI had higher rates of detection. Thus the findings of our study are in line with previous studies conducted. This also aligns with the findings of Karacabey et al., who demonstrated that real-time tracheal ultrasound offers a notably high degree of sensitivity and specificity in confirming the correct placement of an endotracheal tube, and it provides results more swiftly compared to capnography.[20]Another study by Shivaji K. et al. demonstrated that confirming correct ETT placement by ultrasound is more swift as compared to using EtCO2 by capnography[8].The use of a portable, hand-held USG equipment to guarantee correct ETT implantation was evaluated by Chun et al[21]. They bilaterally recorded the patients' visceral parietal pleural interface (VPPI) on the chest wall throughout every phase of airway care. They concluded that, in extreme cases where other modalities like as capnography might not be available and auscultation might not be viable, thoracic sonography would prove to be a useful tool for verifying ETT installation. Notably, they enhanced the technique by incorporating the ultrasonographic lung sliding sign to prevent the risk of one-lung ventilation in cases of bronchial intubation. The current study had certain limitations. Firstly, it was carried out at a single center so the results cannot be generalized. Secondly, comparison of ultrasound with bronchoscopy was not made, so it cannot be commented which of the two is superior in terms of detecting ETT placement correctly.

CONCLUSION

The current investigation found that when patients were undergoing elective surgery under general anesthesia, ultrasonography exhibited a high sensitivity, specificity, diagnostic accuracywith no time lag while identifying proper ETT tube insertion in the trachea as compared to the gold standard capnography. Ultrasound is a rapid, non-invasive, easily available and reliable tool for identification of ETT placement correctly. Future studies must be

carried out on larger sample size and at different centers and must include comparison with other diagnostic modalities to validate the findings of the current study.

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