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Diagnostic Accuracy of Lung Ultrasound in Determining the Position of the Endotracheal Tube in Mechanically Ventilated Children

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ABSTRACT

Introduction: Due to their short and narrow airways, endotracheal intubation in children is difficult and demands a high degree of precision. Chest X-rays (CXR) are the current gold standard for endotracheal tube (ETT) verification. **Objective:** The aim of the current study was to evaluate the role of lung ultrasonography in confirming ETT installation in children receiving mechanical ventilation. **Patients and methods:** A cross-sectional study was carried out at pediatric intensive care unit (PICU), Faculty of Medicine, Zagazig University Children Hospitals. A total of 30 patients, aged between 28 days and 16 years were enrolled in the study. History taking and general clinical examination were performed on all patients. The ETT was inserted and the position is adjusted by the guide of ultrasonography (Alpinion E Cube i7). Thereafter, all patients were subjected to CXR. **Results:** Incidence of correct ETT position with CXR was 53.3% compared to 86.7% with ultrasound (P=0.002). Agreement between ETT position detected by CXR and ETT position detected by ultrasound had a fair level. Only 17 (56.7%) children were survived after endotracheal intubation and 13 (43.3%) died among the 30 studied children. Percent of children's death among children of once intubation was 10%, while percent of children's death among repeated intubation was 33.3%. **Conclusion:** Lung ultrasonography can be used as a fast, safe and effective tool for confirming the correct placement of ETT in mechanically ventilated children, especially in conditions where CXR and capnography are not reliable or inaccessible.

Keywords: Endotracheal intubation, Chest X-ray, Ultrasound, Cross sectional study, Zagazig University.

INTRODUCTION

Due to their short and narrow airways, endotracheal intubation (ETT) in children is difficult and demands a high degree of precision. It is imperative to confirm the proper placement of the ETT because it is frequently mispositioned **(1)**. This could lead to atelectasis or air leak syndromes such as esophageal insertion, unintentional extubations, and inappropriate mainstem bronchial intubations **(2)**.

Pediatric intensive care unit (PICU) requires multiple X-rays to position the ETT because chest x-ray (CXR) is the typical method for doing so. Lung ultrasonography (LUS) can be utilized to evaluate ETT location in the trachea, according to a modest number of feasibility studies **(3)**. Therefore, the aim of the current study was to evaluate the role of lung ultrasonography in confirming ETT installation in children receiving mechanical ventilation.

PATIENTS AND METHODS

A cross-sectional study was carried out at pediatric intensive care unit (PICU), Faculty of Medicine, Zagazig University Children Hospitals. A total of 30 patients, aged between 28 days and 16 years were enrolled in the study.

Inclusion criteria: Mechanically ventilated children needing endotracheal intubation.

Exclusion Criteria: Patients with congenital airway anomalies or anticipated difficult intubation were excluded. Also, patients with anatomical neck problems were not accepted distortion, as the neck distorted anatomy can interfere with LUS evaluation for the ETT position.

History taking and general clinical examination were performed on all patients. The ETT was inserted and the position is adjusted by the guide of ultrasonography (Alpinion E Cube i7). Thereafter, all patients were subjected to CXR. By analysing lung parenchymal movement during the breathing cycle (sliding along the parietal pleural line), the probe position was verified. When a bilateral sliding lung was clearly visible on a LUS and the tip of the ETT could not be detected in the extrathoracic trachea in longitudinal view, the insertion depth of the ETT was deemed to be accurate. Each procedure's duration was noted. Each patient's required number of modifications was noted.

Ethical Consideration:

This study was ethically approved by the Institutional Review Board of the Faculty of Medicine, Zagazig University. Written informed consent was obtained from parents of all participants. This study was executed according to the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans.

Statistical Analysis

The collected data were introduced and statistically analyzed by utilizing the Statistical Package for Social Sciences (SPSS IBM Corp., Armonk, New York) version 23.0 for windows. Qualitative data were defined as

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numbers and percentages. Chi-Square test and Fisher's exact test were used for comparison between categorical variables as appropriate. Quantitative data were tested for normality by Kolmogorov-Smirnov test. Normal distribution of variables was described as mean and standard deviation (SD), and independent sample t-test/ Whitney Mann U test was used for comparison between groups. Kaplan-meier survival analysis was used for evaluation of outcome according to position of endotracheal intubation as detected by ultrasound. P value ≤0.05 was considered to be statistically significant.

RESULTS

Table 1 summarizes the demographic characteristics and weight of the studied children.

Table (1): Demographic characteristics and weight of studied patients (n. 30).

Variables	n.	%
Sex		
Females	10	33.3
Males	20	66.7
Age (years)		
Mean ± SD	3.6 ± 4.3	
Median (range)	1 (33days - 15 years)	
Weight (kg)		
Mean ±SD	11.8 ± 11.3	
Median (range)	7.5 (2.2 - 55)	

Table 2 summarizes the most common complication of EET.

Table (2): Complications of endotracheal intubation of studied children (n. 30).

Complications endotracheal intubation	n.	%
ETT Obstruction	19	63.3
Hypoxemia(low O2 saturation)	12	40.0
Laryngo spasm	11	36.7
trauma to the airway(bleeding)	10	33.3
injury vocal cords	5	16.7

Table 3 summarizes the most common complications of repeated EET.

Table (3): Complications of repeated endotracheal intubation of studied children (n. 24).

Repeated endotracheal intubation	n.	%
ETT Obstruction	16	66.7%
Hypoxemia (low O2 saturation)	9	37.5%
trauma to the airway(bleeding)	9	37.5%
Difficult of intubation	9	37.5%
Cardiac arrest	5	20.5%

Only 17 (56.7%) children were survived after endotracheal intubation and 13 (43.3%) died among the 30 studied children. Percent of children's death among children of once intubation was 10%, while percent of children's death among repeated intubation was 33.3% (**Table 4**).

Table (4): Outcome of endotracheal intubation of studied children (n. 30).

Outcome	n.	%
Survival	17	56.7
Died	13	43.3
Died among children of once intubation	3	10.0%
Died among children of repeated intubation	10	33.3%

Table 5 showed that there was no statistically significant difference between occurrence of complications in studied children and the outcome of EET (P>0.05), except occurrence of hypoxia associated with bad outcome [died] (P=0.035).

Table (5): Outcome of endotracheal intubation in children according to the occurrence of complications.

Variables			Outcome: Survival n.17	Outcome: Died n.13	χ^2	P-value
Hypoxemia	Yes	N	4	8	4.4	0.035*
		%	23.5%	61.5%		
	No	N	13	5		
		%	76.5%	38.5%		
Trauma to the airway	Yes	N	4	6	F	0.26
		%	23.5%	46.2%		
	No	N	13	7		
		%	76.5%	53.8%		
Injury vocal cords	Yes	N	2	3	F	0.63
		%	11.8%	23.1%		
	No	N	15	10		
		%	88.2%	76.9%		
Laryngo-spasm	Yes	N	7	4	F	0.71
		%	41.2%	30.8%		
	No	N	10	9		
		%	58.8%	69.2%		
ETT Obstruction	Yes	N	11	9	F	0.99
		%	64.7%	69.2%		
	No	N	6	4		
		%	35.3%	30.8%		

χ 2: Chi-square test, F: Fisher's exact test, P>0.05 no significant, *P<0.05 significant.

Table 6 showed that there was no statistically significant difference between repeated intubation among studied children and the outcome of EET (P>0.05).

Table (6): Outcome of endotracheal intubation in children according to the repeated intubation.

Variables			Outcome		χ2	P-value
			Survival n. 17	Died n. 13		
Repeated intubation	Yes	N	14	10	F	0.99
		%	82.4%	76.9%		
	No	N	3	3		
		%	17.6%	23.1%		

F: Fisher's exact test, P>0.05 non-significant.

Time of ventilation is more for incorrect EET position than time of ventilation for correct EET position, and the difference is not significant (P-value 0.87) (**Table 7**).

Table (7): Kaplan-meier survival analysis for children on ventilation according to position of endotracheal intubation as detected by ultrasound (n. 30).

Position of ndotracheal intubation	Estimated Mean ventilation of survival per hours	Number of deaths N (%)	Number of survival N (%)	P-value
Correct position	334.7	10 (38.5)	16 (61.5)	0.87
Incorrect position	363.5	3 (75)	1 (25)	

Ultrasound for confirming proper position of endotracheal tube in children compared to X-ray, the sensitivity of 100% and specificity of 28.6%, and accuracy 66.7% (**Table 8**).

Table (8): Validity of ultrasound for confirming proper position of endotracheal tube in children compared to X-ray**.**

Sensitivity	100%
Specificity	28.6%
Accuracy	66.7%

DISCUSSION

In our study, sex distribution was 10 (33.3%) females and 20 (66.7%) males. They had a mean age of 33 days and a range of 33 days to 15 years of 3.6 (SD 4.3) years. Their weight ranged from 2.2 to 55 kg with a mean of 11.8 (SD 11.3) kg.

Shebl and Said [(4)] analyzed the role of tracheal ultrasonography in validating ETT insertion in 200 ICU patients, with a mean age of 28 of 49.1 (SD 12.4). Their diagnosis was chronic obstructive pulmonary disease exacerbation (82 patients, 41%), obesity hypoventilation syndrome in 26 (13%) patients, Acute severe bronchial asthma in 29 (14.5%) patients, severe pneumonia in 46 (23%) patients, and interstitial lung diseases in 17 (8.5%) patients.

For any technique utilized, the amount of time needed to confirm ETT intubation is a crucial consideration. In the present study, time for confirmed ETT position per minute with X-ray is significantly longer than time for confirmed ETT position per minute with ultrasound (P=0.0001).

In a previous study, the time required to do transtracheal ultrasound was between 5 and 45 seconds [(5)]. **Thomas *et al.*** compared the time needed by ultrasound with that of capnography for verifying the ETT place. They discovered that the median time for ultrasonography was considerably less than with capnography [(6)].

Shebl and Said [(4)] discovered that the time required to validate the ETT location by tracheal ultrasound and clinical assessment were 19.21 and 15.13, has a very large statistical difference between them, respectively (P<0.001) [(4)].

The most common complications of endotracheal intubation were its obstruction (63.3%), followed by occurrence of hypoxemia and laryngospasm (40% and 36.7%, respectively), then airway trauma (33.3%) and injury vocal cords (16.7%). However, the most common complications of repeated endotracheal intubation was its obstruction (66.7%), followed by occurrence of hypoxemia, trauma to the airway (bleeding) and difficulty of intubation (37.5%) and cardiac arrest (20.5%).

Subramani *et al.* [(7)] found that Cough was the most frequent (8.4%) ultrasound-related consequence. There were no significant negative consequences. **Ahn *et al.*** [(8)] contrasted auscultation and the lung sliding sign guided by ultrasonography to determine the best placement of the tracheal tube in pediatric patients. They recorded no postoperative complications.

In our study, incidence of correct ETT position with X-ray was 53.3% compared to 86.7% with ultrasound (P<0.05). Agreement between ETT position detected by X ray and ETT position detected by ultrasound is fair level. **Subramani *et al.*** found that ICC agreement co-efficient was 0.78 [(7)].

A total of 17 (56.7%) children were survived after endotracheal intubation and 13 (43.3%) died.

No statistically significant difference existed between the occurrence of complications in studied children and the outcome of EET (P>0.05), except for occurrence of hypoxia associated with bad outcome (P<0.05).

Kaplan-meier survival analysis for children on ventilation according to position of EET as detected by ultrasound revealed that mean time per hours of ventilation for correct EET position by ultrasound and survival is 334.7 hours compared to 363.5 hours for incorrect position; time of ventilation is more for incorrect EET position than time of ventilation for correct ETT position (P>0.05).

The sensitivity of ultrasound for confirming proper position of EET in children compared to X-ray was 100%, the specificity was 28.6%, and accuracy was 66.7%.

Tejesh *et al.* [9] assessed the accuracy of tracheal rapid ultrasound examination to verify ETT. The authors came to the conclusion that tracheal fast ultrasonography examination can be used to establish the ETT's position during intubation in emergency situations quickly. This outcome is consistent with the outcomes of **Masoumi *et al.*** [10]. Also, **Shebl and Said**[4] detected tracheal intubation by ultrasonography with a sensitivity of 96.2%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 69.6%.

Rapid confirming of correct ETT is mandatory for avoiding the serious consequences of incorrect intubation. Many tools for confirming correct ETT placement are present, but each of them has its limitations and no single tool has proved to be 100% reliable [11].

In a previous study, the ideal tracheal tube placement was accomplished in roughly 70% of pediatric patients [12]. In contrast, in a different trial, 89% of patients received the ideal placement of the tracheal tube using the ultrasound-guided lung sliding sign [13]. Another study found that utilizing auscultation; tracheal tubes were positioned improperly in 12% of cases in the right main stem bronchus and in 19% of cases at low-than-ideal places [12].

Quintela *et al.* compared the placement of ETT using US to capnography and CXR in their neonatal (NICU) and pediatric intensive care units (PICU). Intubation was followed by quick confirmation of tracheal versus esophageal site using tracheal US and capnography, and the depth of the ETT was determined by thoracic US and CXR. Inability to detect endotracheal versus esophageal intubation in newborns was not significantly different between US and capnography, but US was much slower than capnography; 34 versus 7, respectively [14].

Tessaro *et al.* [15] examined the precision of tracheal ultrasonography for establishing the proper depth of insertion for ETT cuff inflated with saline. In an average of 4 seconds, the TRUST approach uses point-of-care ultrasonography of the anterior neck to check tube placement and location. To enable visibility, saline rather than air is used to inflate EET cuff. The ETT point that is slightly below the clavicular heads corresponds to the cuff visualization at the level of the sternal notch. They found that using ultrasonography to check the correct depth of ETT implantation in healthy pediatric patients at the level of the suprasternal notch seems to be an accurate and quick procedure.

Chowdhry *et al.* [16] showed excellent agreement between ultrasound and X-ray measurements of the depth of the ETT, while **Taekuchi and Arai**reported employing a linear probe in the transverse position during pediatric resuscitation to immediately validate the placement of the ETT [17].

Subramani *et al.* [18] indicated that in mechanically ventilated children, LUS may be a valuable bedside technique for determining ETT location. **Ahn *et al.*** [8] concluded that for the best tracheal tube location in pediatric patients under the age of 24 months, the ultrasound-guided lung sliding sign was more accurate than auscultation. **Shebl and Said** [4] reported that a quick and secure method to verify the proper installation of EET can be provided using tracheal ultrasound.

Finally, it should be noted that ultrasonography is a noninvasive technique that does not necessitate rigid immobility, particularly in young children. Although it is an operator-dependent approach, it is rather easy to master. Although the cricoid arch calcifications in our patients did not affect the measurement, the age-dependent physiological calcification of the larynx does produce an acoustic shadow. However, our study has a drawback of the limited sample size.

CONCLUSION

Comparatively, the ultrasound-guided lung sliding sign was more reliable at determining the ideal tracheal tube placement X-ray assessment of EET position. LUS can be used as a fast, safe and effective tool for confirming the correct placement of ETT in mechanically ventilated children and especially in conditions where CXR and capnography are not reliable or inaccessible. In order to find the precise range of cut-offs for the ultrasonographic measurements in PICU, larger research or multicenter studies are recommended.

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