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Lung ultrasound compared to fiber-optic bronchoscopy in detecting proper endotracheal tube position in intubated patients in the intensive care unit

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ABSTRACT

Background: Accidental endobronchial intubation can lead to serious complications in critically ill patients, which can be avoided through early detection and proper positioning of the endotracheal tube. This cross-sectional study estimates lung ultrasound's sensitivity in detecting the proper position of the endotracheal tube compared to auscultation and fiberoptic bronchoscopy.

Methods: Sixty intubated adult ICU patients were examined by auscultation, ultrasound, and fiberoptic bronchoscope by three different blinded physicians to detect the position of the ETT (endotracheal, right, and left endobronchial). An ultrasound examination was done by evaluating the lung sliding sign. Statistical analysis included sensitivity, specificity, PPV, and NPV.

Results: Auscultation showed 64% sensitivity, 100% specificity, 100% positive predictive value, 90.2% negative predictive value, and 91.7% accuracy. Compared to fiberoptic bronchoscopy, lung ultrasound showed 85.7% sensitivity, 100% specificity, 100% positive predictive value, 95.8% negative predictive value, with of 96.7% accuracy.

Conclusion: Compared to fiberoptic bronchoscopy and auscultation, lung ultrasound has a very high sensitivity for detecting the proper endotracheal tube position.

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Lung ultrasound; endobronchial intubation; fiberoptic bronchoscopy; ETT position

1. Introduction

A crucial step in maintaining the airway under general anesthesia is endotracheal intubation. Assuring correct endotracheal tube insertion (ETT) is essential right away after intubation since undetected esophageal intubation might have disastrous consequences. It was found that 69% of the fatalities related to anesthesia had an airway management component [1]).

*I*n both prehospital and inpatient settings between 5% and 15% of cases involve bronchial intubations. These intubations go unnoticed in 6% to 25% of cases [2].

Changes in the patient's position or other actions that raise the diaphragm may also impact the ETT position. Intubating one lung results in serious complications. First, the contralateral lung will have poor ventilation and oxygenation without gas exchange. Second, pneumothorax and unilateral pulmonary edema may both occur as a result of barotrauma from high volumes. Third, when a minor ETT retraction would have been sufficient, an unnecessary thoracostomy may be performed for a suspected pneumothorax [3,4].

With a claimed sensitivity of about 60 to 65%, auscultation has been demonstrated to be unreliable for differentiating between tracheal and bronchial intubation [5].

Ultrasonography is rapid, inexpensive, and currently widely available in places where endotracheal intubation takes place. According to recent research, ultrasonography has demonstrated 100% sensitivity and specificity for patients in the operating room as well as 100% and 86% for patients receiving cardiopulmonary resuscitation. These results support the use of ultrasound for detecting esophageal versus tracheal intubations [6].

When carbon dioxide monitoring is unavailable, updated Guidelines recommends using ultrasound as an additional technique to validate the proper tube position [7].

However, there is little evidence that ultrasound can be used to locate the ETT in the trachea.

The lung sliding sign, which is a sonographic indicator of healthy lung ventilation, is characterized by the sliding of both layers of the pleura, and it confirms endotracheal intubation by direct observation of lung expansion [8,9].

2. Aim of the study

2.1. Primary outcome

The estimation of the sensitivity of lung ultrasonography for detecting proper endotracheal tube position

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compared to fiber optic bronchoscopy in intubated ICU patients.

2.2. Secondary outcomes

Incidence of inadvertent endobronchial intubation in ICU patients.

Comparison of auscultation, ultrasound, and bronchoscopy in determining the proper position of the ETT.

3. Patients and methods

After obtaining approval from the Research Ethical Committee of Ain shams University the current cross-sectional study was conducted in the ICU of Ain shams University Hospital, with the registration number FMASU M D 274/2020, and Pan African Clinical Trial registration number PACTR202207819349638

The study period was two years.

3.1. Sample population

*P*atients who were intubated during their ICU stay and were older than 18 years old were included in the study.

Patients who were on a high inotropic support were excluded as the sedation used during fiber-optic bronchoscopy posed a risk to the patient's hemodynamics. Patients with any lung pathology that could affect the study technique, such as pneumothorax, emphysema, and mesothelioma, and patients with a BMI>33 (obese patients) were excluded.

Study tools :Hitachi Aloka Prosound Ultrasound System (Hitachi, Ltd., Higashi-Ueno, Taito-Ku, Tokyo, Japan) 13–6 MHz high-frequency linear probe.

Study Procedure: The study was performed after ethical committee approval and informed consent from the patient's legal guardian after a full explanation of the procedure, potential side effects, and complications.

A total of four intensivists participated in the study. Throughout the duration of the study, the primary physician was responsible for monitoring the patient's vital signs and was able to stop the procedure if the patient showed any signs of hemodynamic instability.

The second intensivist, who was responsible for performing the auscultation, identified the ETT location by auscultating breath sounds at the second and fifth intercostal spaces at the mid-clavicular and mid-axillary lines of both lungs.

The third intensivist then performed an Ultrasound examination by placing the linear probe on the the third rib space anteriorly at the mid-clavicular line on both sides of the chest, to detect the lung sliding sign using both the 2D and the M-mode modalities.

Presence of the lung sliding sign on both sides of the chest implied tracheal intubation, lung sliding present on the right side only indicated right main stem bronchial intubation, whereas its presence on the left side only indicated left main stem bronchial intubation. The absence of a Sliding Lung Sign on both sides indicated oesophageal intubation.

Then, after proper sedation, the fourth intensivist (fiber-optic expert) performed the fiberoptic examination to detect the position of the ETT.

At the end, the physician who performed the fiber-optic examination ensured that the ETT was positioned properly, as recommended.

All physicians included in the study were blinded to the results of each other.

All participating physicians had more than 2-year post-residency experience.

A true positive result: a case in which ultrasound or auscultation suggested endobronchial intubation and was confirmed by bronchoscopy.

A true negative result: a case in which ultrasound or auscultation suggested proper placement of the ETT and was confirmed by bronchoscopy.

A false positive result: a case in which ultrasound or auscultation indicated endobronchial tube position, but bronchoscopy indicated that the ETT was properly positioned.

A false negative result: a case in which ultrasound or auscultation suggested proper placement of the ETT while bronchoscopy suggested endobronchial intubation.

4. Results

Sixty patients were included in the study and were subjected to the interventions. Demographic data showed that 55% were males, with an age range from 43–74 years, and a body mass index (BMI) ranging from 20–33 Kg/M. (Table 1). Lung ultrasound in the form of pleural sliding sign showed that 48 patients with proper position of endotracheal tubes, while 11 patients were right endobronchial intubated, and one patient with left endobronchial intubation. The mean time of the intervention was 129.28 ± 50.82 seconds. Results of fiberoptic bronchoscopy demonstrated properly positioned ETT in 46 patients, right endobronchial intubation in 13 patients, and one patient with left endobronchial intubation in a mean time of 378.85 ± 125.25 seconds. Auscultation of breath sounds at

Table 1. Demographic data distribution among study group (n = 60).

Demographic data	Total (*n*=60)
Sex	
Female	27 (45.0%)
Male	33 (55.0%)
Age (years)	
Range	43–74
Mean±SD	57.40±7.33
BMI [wt/(ht)^2]	
Range	20–33
Mean±SD	26.96±3.83

Table 2. Distribution among study groups (n = 60).

Position	Lung ultrasound	Fiberoptic	Auscultation
Endotracheal	48 (80.0%)	46 (76.7%)	51 (85.0%)
Right Endobronchial	11 (18.3%)	13 (21.7%)	8 (13.3%)
Left endobronchial	1 (1.7%)	1 (1.7%)	1 (1.7%)
Time (s)			
Range	64–302	185–593	20–64
Mean±SD	129.28±50.82	378.85±125.25	41.05±12.59

Table 3. Comparison between Lung Ultrasound, Fiberoptic, and Auscultation according to time "s".

Time (s)	Lung Ultrasound	Fiberoptic	Auscultation	F-test	p-value
Range	64–302	185–593	20–64	32.683	<0.001**
Mean±SD	129.28±50.8B	378.85±125.25A	41.05±12.59C		

F-Repeated measurements ANOVA.
Means that do not share the same letter but are significantly different at p-value (*p*<0.05).
**p-value <0.001 is highly significant.

Table 4. Relation between endobronchial and endotracheal in fiberoptic and lung ultrasound.

	Fiberoptic							
	Endobronchial		Endotracheal		Total		Chi-square test	
Lung Ultrasound	No.	%	No.	%	No.	%	x2	p-value
Endobronchial	12	85.7%	0	0.0%	12	20.0%	49.286	<0.001**
Endotracheal	2	14.3%	46	100.0%	48	80.0%		
Total	14	100.0%	46	100.0%	60	100.0%		

x2Chi-square test; **p-value <0.001 highly significant.

the second and fifth intercostal of both lungs showed endotracheal tubes in 51 patients, right endobronchial in 8 patients, and one patient with left endobronchial position in a mean time of 41.05 ± 12.59 seconds (Table 2). There was a statistically significant higher mean time in fiberoptic, followed by lung ultrasound, and the lowest value in auscultation, with a p-value ($p < 0.001$) (Table 3). There was a high statistical significance between fiberoptic and lung ultrasound (Table 4), and auscultation (Table 5) with a p-value ($p < 0.001$ highly significant).

Comparison between lung ultrasound and auscultation in relation to fiberoptic bronchoscopy as a gold standard technique for proper ETT position showed a statistically significant higher sensitivity for ultrasound (Table 6).

5. Discussion

In the current study, ultrasound had a sensitivity of 85.7% for detecting endobronchial intubation compared to a sensitivity of 64.3% for auscultation. According to the physician, this could be due to the fact that Breath sounds are easily affected by a variety of factors, including voice transmission from the contralateral side, the voice in the environment, the sensitivity of the stethoscope, and it also has some subjectivity. These factors caused the sensitivity of auscultation to be as low as (60%-65%), which does not make it a reliable tool. Therefore, the clinical evaluation is significantly improved in terms of sensitivity when a brief ultrasound examination is conducted.

Table 5. Relation between endobronchial and endotracheal in fiberoptic and auscultation.

	Fiberoptic							
	Endobronchial		Endotracheal		Total		Chi-square test	
Auscultation	No.	%	No.	%	No.	%	x2	p-value
Endobronchial	9	64.3%	0	0.0%	9	15.0%	34.790	<0.001**
Endotracheal	5	35.7%	46	100.0%	51	85.0%		
Total	14	100.0%	46	100.0%	60	100.0%		

x2Chi-square test; **p-value <0.001 highly significant.

Table 6. Comparison between lung ultrasound and auscultation in relation to fiberoptic bronchoscopy.

	Lung Ultrasound		Auscultation		
Outcome	Value (%)	95% CI.	Value (%)	95% CI.	p-value
Sensitivity%	85.7%	57.2% to 98.2%	64.3%	35.1% to 87.2%	<0.001
Specificity%	100.0%	92.3% to 100%	100%	92.3% to 100%	1.000
PPV%	100.0%	–	100%	–	1.000
NPV%	95.8%	86.4% to 98.8%	90.2%	82% to 94.9%	0.122
Accuracy%	96.7%	88.5% to 99.6%	91.7%	81.6% to 97.2%	0.122

The gold standard approach for determining the ETT position is fibro-optic bronchoscopy. However, it is not always available, requires additional time, is an invasive procedure, and can be challenging when mucus or blood is present in the airway.

Ultrasound accuracy was greater than auscultation. Nevertheless, the difference was statistically insignificant. This could be attributed to the limited number of patients. Since only 14 patients were detected with endo-bronchial intubation, which made the possibility of obtaining a false positive result (ETT detected by US or auscultation to be endobronchial and by fiberoptic to be endotracheal) extremely small, thereby affecting the PPV and the NPV.

*I*n a study by Ramsingh and colleagues they compared ultrasound and auscultation to determine the ETT position in patients under general anesthesia and demonstrated that ultrasound is superior to auscultation, and they reported an ultrasonic evaluation time of 160 ± 238 seconds, which was longer than that in the current study. These changes were most likely caused by the utilized method. Ramsingh also detected the cricothyroid membrane and the ETT cuff in addition to the pleural sliding sign, which stretched out the evaluation time. At least three breath cycles were required regardless of whether ultrasound or auscultation was used [10].

Many studies were performed comparing lung ultrasound and auscultation in determining the position of double-lumen tubes. Alliaume et al. results showed that auscultation was not reliable for verifying the position of the DLT, as FOB was needed to properly position the double-lumen tubes in about 80% of patients [11].

A study by Sustic et al. showed that adding ultrasound to clinical assessment improved the accuracy of the double-lumen tube positioning compared to clinical assessment alone. Wei-Cai Hu, Swapnil parab, and Alvarez Diaz found comparable results when comparing ultrasound to auscultation in positioning double-lumen tubes in elective thoracic surgeries requiring single lung ventilation [12–15].

De Bellis and colleagues also illustrated that more than 30% of DLTs confirmed by auscultation to be appropriately inserted needed to be adjusted after FOB [16].

The incidence of accidental endobronchial intubation in our study was 23.3%. A study by Al Qahtani et al. revealed that 13% of intubated patients in the ICU had inadvertent endobronchial intubation [17].

5.1. Limitations

Our first limitation is the small sample size to obtain accurate data on the incidence of accidental endobronchial intubation and the accuracy of ultrasound in the identification of bronchial intubation in the general population; hundreds of patients would be needed.

The second limitation is that the study was done in a single center.

Obese patients were not included in our study as the distance from the pleura to skin is an important factor. The breath sounds and the pleural sliding would be readily disturbed if the distance was too far.

Lung sliding is absent with other lung pathologies rather than endo-bronchial intubation, such as pneumothorax, lung fibrosis, pleural adhesions, and mucous plug. These conditions also show limitations with auscultation, so patients with lung pathologies were excluded from this study. Additional studies will be needed to determine the reliability of lung ultrasound in these conditions.

6. Conclusion

Lung ultrasound has a very high sensitivity in detecting proper endotracheal tube position when compared to fiberoptic bronchoscopy and auscultation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

[1] Cook TM, Woodall N, Frerk C. Fourth National audit project. Major complications of airway management in the UK: results of the fourth National audit project of the royal college of anaesthetists and the difficult airway society. Part 1: anaesthesia. Br J Anaesth. 2011;106 (5):617–631.

[2] Geisser W, Maybauer DM, Wolff H, et al. Radiological validation of tracheal tube insertion depth in out-of-hospital and in-hospital emergency patients. Anaesthesia. 2009;64(9):973–977.

[3] Wirtz DD, Ortiz C, Newman DH, et al. Unrecognized misplacement of endotracheal tubes by ground prehospital providers. Prehosp Emerg Care. 2007;11 (2):213–218.

[4] Kramer , Melzer <, Sprung C, *et al*. Unilateral pulmonary edema after intubation of the right mainstem bronchus. Crit Care Med. 2020;17: 472–474.doi: 10.1097/00003246-198905000-00019. 1989 KRAMER, M. R., MELZER, E., & SPRUNG, C. L. (1989). Unilateral pulmonary edema after intubatlon of the right mainstem bronchus. Critical care medicine, 17(5), 472-474.

[5] Vezzani A, Manca T, Brusasco C, et al. Diagnostic value of chest ultrasound after cardiac surgery: a comparison with chest X-ray and auscultation. J Cardiothorac Vasc Anesth. 2014;28(6):1527–32.

[6] Chou HC, Chong KM, Sim SS, et al. Realtime tracheal ultrasonography for confirmation of endotracheal tube placement during cardiopulmonary resuscitation. Resuscitation. 2013;84(12):1708–12.

[7] Neumar RW, Shuster M, Callaway CW, et al. Part 1: executive Summary: 2015 American heart association

guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2015;132(18 suppl 2):S315–67.
[8] Chun R, Kirkpatrick AW, Sirois M, et al. Where's the tube? Evaluation of hand-held ultrasound in confirming endotracheal tube placement. Prehosp Disaster Med. 2004;19(04):366–369. DOI:10.1017/S1049023X00002004
[9] Sim SS, Lien WC, Chou KM, et al. Ultrasonographic lung sliding sign in confirming proper endotracheal intubation during emergency intubation. Resuscitation. 2012;83(3):307–12.
[10] Ramsingh D, Frank E, Haughton R, et al. Auscultation versus point-of-care ultrasound to determine endotracheal versus bronchial intubation. Anesthesiology. 2016;124(5):1012–20. DOI:10.1097/ALN.0000000000001073
[11] Alliaume B, Coddens J, Deloof T. Reliability of auscultation in positioning of double-lumen endobronchial tubes. Can J Anaesth. 1992;39(7):687–90.
[12] Sustic´ A, Protic´ A, Cicvaric´ T, et al. The addition of a brief ultrasound examination to clinical assessment increases the ability to confirm placement of double-lumen endotracheal tubes. J Clin Anesth. 2010;22(4):246–9. DOI:10.1016/j.jclinane.2009.07.010
[13] Álvarez-Díaz N, Amador-García I, Fuentes-Hernández M, et al. Comparación entre la ecografía pulmonar transtorácica y el método clínico para confirmar la posición del tubo de doble luz izquierdo en anestesia torácica. Estudio piloto. Rev Esp Anestesiol Reanim. 2015;62(6):305–12. DOI:10.1016/j.redar.2014.06.005
[14] Parab SY, Divatia JV, Chogle A. A prospective comparative study to evaluate the utility of lung ultrasonography to improve the accuracy of traditional clinical methods to confirm position of left sided double lumen tube in elective thoracic surgeries. Indian J Anaesth. 2015;59(8):476–481.
[15] Hu WC, Xu L, Zhang Q, et al. Point-of-care ultrasound versus auscultation in determining the position of double-lumen tube. Medicine (Baltimore). 2018 Mar;97(13):e9311.
[16] de Bellis M, Accardo R, Di Maio M, et al. Is flexible bronchoscopy necessary to confirm the position of double-lumen tubes before thoracic surgery? Eur J Cardiothorac Surg. 2011;40(4):912–6. DOI:10.1016/j.ejcts.2011.01.070
[17] Al-Qahtani AS, Messahel FM, Ouda W. Inadvertent endobronchial intubation: a sentinel event. Saudi J Anaesth. 2012; 6(3):259–62. *PMID: 23162400; PMCID: PMC3498665*. DOI:10.4103/1658-354X.101218.