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Accuracy of point of care lung ultrasound in diagnosis of ventilator associated pneumonia in intensive care unit

Wafaa Abd-Elsalam[1], Shaimaa Waheed Zahra[2], Marwa Ahmed Abogabal [2], Wafaa madhy Atia [2]

1- Department of Anesthesia and surgical intensive care, Kafrelsheikh university faculty of medicine, EGYPT
2- 2- Department of Anesthesia and surgical intensive care, Tanta university faculty of medicine, Egypt

Abstract

Objective: the objective of this study was to evaluate the accuracy of lung ultrasound in the diagnosis of pneumonia in critically ill patients admitted to the intensive care unit. **Methods**: This was an observational study conducted between March 2019 and February 2020 on patients older than 18 years who had symptoms associated with ventilator-associated pneumonia after 48 hours from admission to ICU. All patients were subjected to lung ultrasound examination by an intensive care physician who was not involved in the management of the patients. The final ICU diagnosis was the gold standard and was compared to the lung ultrasound diagnosis. **Results:** Among 108 patients included in this study 37 of them were confirmed to have pneumonia by the ICU team. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of lung ultrasound in the diagnosis of pneumonia in the intensive care unit were 94.87 %, 98.55 %, 97.37 %, 97.14 %, and 97.22%. **Conclusion**: lung ultrasound can be used with high accuracy in the diagnosis of ventilator-associated pneumonia.

Keywords: VAP, lung ultrasound, pneumonia, ICU, point of care ultrasound.

Introduction

Ventilator-associated pneumonia (VA-P) is one of commonest ICU-acquired infections. According to the setting and diagnostic criteria, incidences fluctuate largely from 5 to 40%. VAP is linked with an extended duration of mech-anical ventilation and ICU stay. [1, 2]

Ventilator-associated pneumonia is defined as pneumonia occurring after 48 hours of patients being intubated and mechanically ventilated. Diagn-osing VAP needs an excellent clinical suspicion blended with bedside exa-mination, radiographic examination, and microbiologic analysis of respire-atory secretions. These methods take a long time to be obtained especially if the patient is mechanically ventilated and difficult to be transferred to CT besides that it carries the hazard of ionizing radiation. [3]

VAP diagnosis is established when th-ese features are presented simult-aneo-usly: clinical data are present, positive microbiological cultures from lower respiratory tract samples and new or ongoing and constant radiogra-phic infiltrates.[4]

There is no agreement in early VAP di-agnosis; determining whether to treat a patient is often subjective and questio-ned within teams when a VAP is clin-ically presumed based on clinical, bio-chemical and imaging parameters. [5]

Lung ultrasound is simple to be learnt, quick, a bedside tool and noninvasive. Besides that, it's a point of care as physicians can monitor the condition of the patient momentarily and make a fast and accurate decision about their patients in the acute setting. For those reasons, many physicians started to use point of care ultrasound in different fields such as emergency medicine, intensive care medicine and anaesthesia. (5-7)

Accuracy of pulmonary ultrasound in patients with lung pathology is high as pulmonary ultrasound can identify lung aeration changes in a variety of serious clinical conditions, like pneumothorax, congestive heart failure, acute respiratory distress syndrome and pneumonia. (9-11)

This study aims to assess the accuracy point of care of lung ultrasound done by an intensivist, who has training on lung ultrasound for 3 hours, in the diagnosis of ventilator-associated pneumonia.

Methodology:

This is a prospective observational cross-sectional study done in Tanta University Emergency Hospital from the first of March 2019 to the end of February 2020 on 108 patients admitted to the intensive care unit and on mechanical ventilation. Written informed consent was attained from the custodians of the patient. The custodians of the patients had clarification about the study's objective. Every patient had a secret code number to make sure that the privacy and confidentiality of the patients were assured. The study was approved by the Research Ethics Committee of Tanta University Faculty of Medicine. Adult patients (>18 years) presenting to admitted to ICU and mechanically ventilated for 48 hours or more who had clinical data suggesting ventilator-associated pneumonia. As definition of VAP is defined as pneumonia occurring after 48 hours of patients being intubated and mechanically ventilated Patients with these criteria were excluded from the study retrospectively: patients with multiple diagnoses and patients diagnosed with pneumonia before intubation.

lung ultrasound by an intensivist, who did not participate in the management of the patient, was performed on all patients. All the participating intensivists received lung ultrasound training for three hours before the start of the study.

Lung ultrasound was done using Phillips Affiniti 50. Patients were examined using a curvilinear transducer (2–5 MHz). The patient was examined in a longitudinal supine position perpendicular to the ribs. The examination was done in 6 points each hemithorax. Each hemithorax is divided in six regions: two anterior, two lateral, two posterior, according to anatomical landmarks set by anterior and posterior axillary lines Diagnosis of VAP was made when one of the following signs was present on LUS: unilateral B line, Cline, shred sign and or air bronchogram. The gold standard of diagnosing was the final intensive care diagnosis. The specificity, sensitivity, and likelihood ratios and their 95% confidence intervals were calculated.

Results

During the period from the first of March 2019 to the end of February 2020, 108 patients were registered in the study. In this study, the age of patients ranged from 20 to 75 with a mean age of about 53.21 years. 55.5% of patients included in our study were males (60) and 44.4% were females (48).

Mean arterial pressure (MAP) of patients included in our study ranged from 45 to 109 with a mean of 79.19 mmHg ±19.67, mean heart rate (HR) was 87

beat/min ±8.17, mean respiratory rate (RR) was 26 breaths/min ± 4.26, and mean temperature was 37.9°C ±0.39. Mean Oxygen saturation by pulse oximeter (SpO2) was 83.08% ± 2.5. Mean PH was 7.17 ± 0.712. The mean APACHE II score was 11.1 ± 4.49. The mean temperature was 37.5 ±0.37. (Table 1)

Traumatic brain injury represent the most common cause of admission followed by postoperative complication as shown in (table 2)

The final diagnosis made by the intensive care unit (ICU) was as follows, VAP represents 42.5 % of the patients. Among the 108 patients, VAP was found in 39 patients. There were 68 cases of true negative, one case of false-positive and two cases of false negative. The sensitivity of the pulmonary ultrasound was 94.87% (95 %CI 82.68 to 99.37) % while specificity (Spec.) was 98.55 (95 % CI 92.19% to 99.96%). The positive predictive value (PPV), negative predictive value (NPV), and accuracy (acc.) of pulmonary ultrasound were 97.37 % and 97.14%. and 97.22% respectively. Positive likelihood ratio (+ LR) was 68 and negative likelihood ratio (- LR)was 0.05 and Kappa test was 0.7305 with a substantial agreement with the final ICU diagnosis. (Table 3) Accuracy of different patterns in lung ultrasound in diagnosis of ventilator-associated pneumonia is shown in (Table 4)

Table 1. General characteristics of the patients.

Parameter	Range	Mean and SD ±
MAP (mmHg)	45-109	79.19 ±19.67
HR	69-123	87 ±8.17
RR	18-33	25.97 ±4.1
PaO_2	44-75	56 ± 8.16
$PaCO_2$	29-70	44_±13.5
APACHE ll SCORE	5-24	11.1 ±4.49
PH	7.12-7.40	7.17 ± 0.712
Temp	37.2º-39.4º	37.9º ±0.39º

MAP = Mean arterial pressure HR=hear rate RR= respiratory rate
APACHE II SCORE=acute physiology and chronic health evaluation.
Temp = temperature

Table 2: primary diagnosis of the patients at admission

Admission diagnosis	No (percentage)
Traumatic brain injury	57 (52.8)
Stroke	10 (9.2)
Postoperative complication	22 (20.4)
Guillain-Barré syndrome	3 (2.7)
Major Burn	5 (4.6)
COPD exacerbation	11(10.3)

Table 3: Accuracy of lung ultrasound in diagnosis of ventilator-associated pneumonia

Sensitivity	Specificity	PPV	NPV	Accuracy	+ LR	-LR	Cohen's kappa
94.87%.	98.55%	97.37%	97.14%	97.22%	68	0.05	0.7305

PPV=positive predictive value NPV= negative predictive value

Table 4: accuracy of different patterns in lung ultrasound in diagnosis of ventilator-associated pneumonia

	Air bronchogram	C line	Shred sign
Sensitivity	92.31 %	91.67%	100 %
Specificity	100 %	50 %	100 %
PPV	100 %	91.67 %	100 %
NPV	66.67 %	50 %	100 %

Statistical analysis was performed with IBM-SPSS software version 19(IBM inc., Armnok, NY, USA)

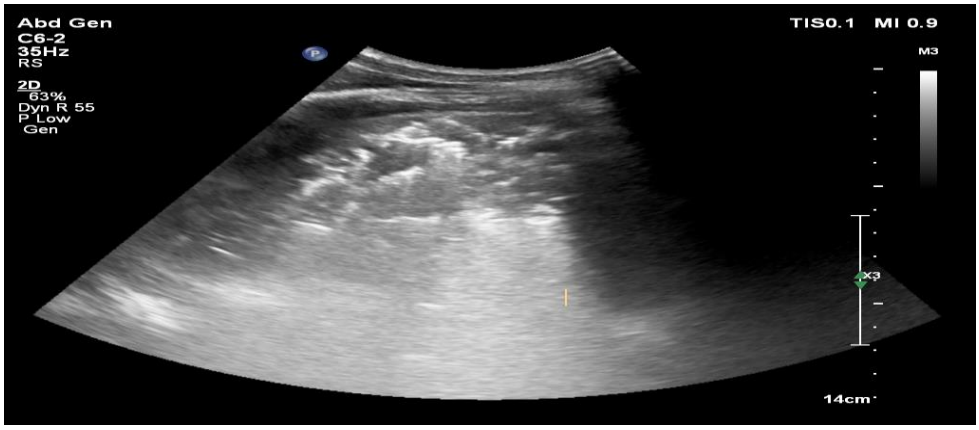

Figure 1: Air bronchogram

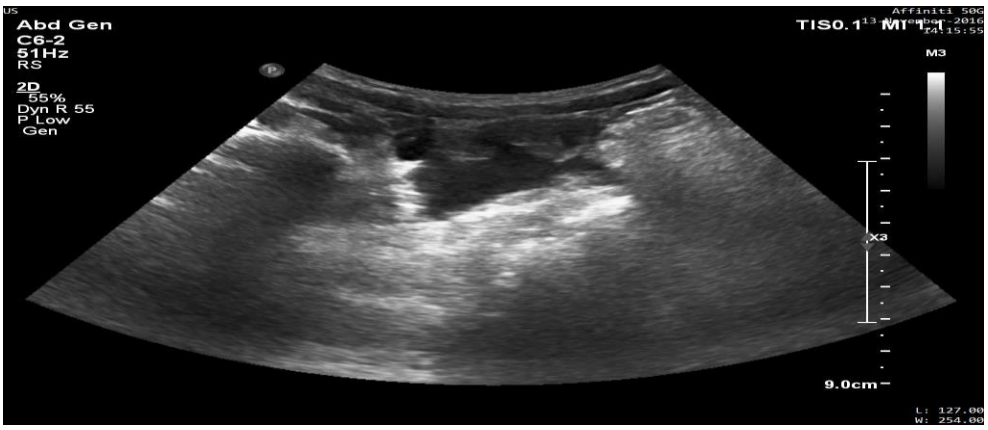

Figure 2: Shred sign

Figure 3: lung consolidation.

Discussion

In this study, three different lung ultrasound signs were associated with pneumonia. These signs are air bronchogram, lung consolidation or Cline and shred sign. (Figures 1,2 and 3)

The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of lung ultrasound in the diagnosis of pneumonia in ICU in this study were 94.87 %, 98.55 %, 97.37 %, 97.14 % and 97.22%.

Xin et al (2018) found that the sensitivity, specificity, positive likelihood ratio and negative likelihood ratio of LUS in the diagnosis of pneumonia were 93.0%, 96.0%, 25.8 and 0.07 respectively[12].

Lichtenstein et al 2008, confirmed that lung ultrasound has 89% sensitivity with 94% specificity in the diagnosis of pneumonia.[10]

Elmahalawy et al 2017, demonstrated that the sensitivity, specificity, PPV and NPV of lung ultrasound in diagnosing pneumonia were 93%, 95%, 98% and 87% respectively and when combined with clinical data, these values increased to become 94%, 93%, 97%, 89% respectively. [13] Also Cortellaro et al., (2012) showed that LUS had a sensitivity of 98% and a specificity of 95% in diagnosing pneumonia. [11]

Dexheimer N et al. (2015), found that the sensitivity and specificity of Lung Ultrasound in the diagnosis of pneumonia were 88% and 90% respectively and the PPV and NPV were 88% and 90%[14].

A metanalysis was made by Long L. et al, in 2017 about the accuracy of lung ultrasound in the diagnosis of pneumonia in adults and they showed that the sensitivity and specificity were 88% and 86%.[15]

Berlet et al found that the sensitivity and specificity of lung ultrasound in the diagnosis of VAP were 100% and 60%.[16]

On the other hand Zagli et al, 2014 studied 221 patients, with 113 in the microbiologically verified ventilator associated pneumonia group and 108 in the control group. (the Chest Echography and Procalcitonin Pulmonary Infection Score) CEPPIS more than 5 was significantly better in predicting VAP (OR, 23.78; sensitivity, 80.5%; specificity, 85.2%) than Clinical Pulmonary Infection Score (CPIS) more than 6 (OR, 3.309; sensitivity, 39.8%; specificity, 83.3%). [17]

Mongodi et al assessed the accurateness of LUS in patients with suspected VAP, and found that one or more regions with a trivial subpleural consolidation had a sensitivity and specificity of 81 % and 41%, Dynamic linear air bronchograms ≥ 1 had sensitivity 44 % and specificity of 81 %. Dynamic linear air bronchograms ≥ 2 had sensitivity 22 % and specificity of 97 %. Dynamic linear air bronchograms ≥ 1 or subpleural consolidations ≥ 1 had sensitivity 90 % and specificity of 34 % Dynamic linear air bronchograms ≥ 1 and subpleural consolidations ≥ 1 had sensitivity 35% and specificity of 88 %.[18]

The strength of this study that the diagnosis was made bedside in short time in high accuracy and high sensitivity and specificity. We could improve the accuracy with more lung ultrasound training.

Limitation of the study

This study was a single-center study. We may need an additional study to assess the time delay between using lung ultrasound and other techniques like a chest x-ray or CT scan. Sample size of the study was small and should be addressed in the next studies. Absence of gold standard to diagnose VAP is the main limitation of the study.

Conclusion

Lung ultrasound, when done by ICU physicians, is a useful tool in the diagnosis of ventilator-associated pneumonia

Conflict of interest:

The author(s) declare no conflict of interest.

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