ORIGINAL ARTICLE

Comparative Study of Lung Ultrasound Versus Chest X-ray in Diagnosis of Ventilator Associated Pneumonia in Intensive Care Unit

Mofeed A. Abdelmaboud [a], Mohamed A. El Badawy [a], Mohamed A. Alkenawy [b], Ahmed A. Abdelaal [a,*]

[a] Department of Anesthesia, Intensive Care and Pain Management, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt
[b] Department of Diagnostic and Interventional Radiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt

Abstract

Background: ***Despite its critical role in saving lives in the ICU, ventilator-associated pneumonia (VAP) is a common complication of mechanical ventilation that raises healthcare expenses, length of time patients spend on the machine, the number of antibiotics prescribed, and the risk of death.***

Aim and objectives: ***To evaluate the efficacy of chest ultrasound compared to chest x-ray in detecting VAP.***

Subjects and methods: ***In this prospective cohort study, 58 male patients admitted to Al-Azhar University Hospitals in Cairo, Egypt, with the purpose of diagnosing ventilator-associated pneumonia were included, from February 2024 till December 2024; this study compare Patient data (temperature, TLC, sputum culture, Pao2/Fio2 ratio and PEEP), Ultrasound finding (AB profile, B′ profile, C profile, A+PLAPS profile), X-ray chest finding (focal infiltration, bilateral infiltration, diffuse infiltration), CT chest finding (ground glass opacity, consolidation, nodule, thickened bronchial wall, cavity, bronchiectasis, atelectasis), Specifity, sensitivity and accuracy of chest Us and X-ray.***

Results: ***Regarding x-ray findings, focal infiltration in 19(32.76%) patients, bilateral infiltration in 13(22.41%) patients and diffuse infiltration in 15(25.86%) patients. When comparing the use of chest x-ray and lung ultrasound for the diagnosis of ventilator-associated pneumonia, the results were significantly superior for the former (92% vs. 85% specificity, 80% vs. 60% accuracy). There was agreement between CT and lung ultrasonography (Kapaa=0.566) and chest x-ray (Kapaa=0.284), respectively.***

Conclusion: ***Although CT results were consistent with both the lung ultrasound and the chest x-ray, the lung ultrasound was more accurate. It demonstrated superior sensitivity, specificity, and accuracy compared to chest x-ray in identifying ventilator-associated pneumonia; it is a fast, dependable diagnostic for use at the bedside.***

Keywords: Lung ultrasound; Chest x-ray; Pneumonia; ICU; VAP

1. Introduction

With greater mortality rates among patients with mid-range severity scores at admission and surgical intensive care unit (ICU) patients, the estimated attributable mortality of VAP is roughly 10%. Microbiological testing to confirm infection is highly recommended. There is still some debate over the best sample technique to adopt. Our current method of routinely identifying and treating VAP may need to be adjusted in the near future in light of new microbiological technologies.[1]

Minimizing mechanical ventilation exposure and promoting early liberation are the cornerstones of ventilator-associated pneumonia prevention. Unfortunately, large-scale randomized trials are required to validate the idea that preventative bundles, which integrate numerous methods, may enhance outcomes. Most instances should have a treatment duration of no more than 7 days. Antibiotics should be limited as soon as antibiotic susceptibility results are available, patients should be reviewed daily to confirm ongoing suspicion of disease, and doctors should consider stopping antibiotics if cultures are negative.[1]

Accepted 19 January 2025.
Available online 31 March 2025

* Corresponding author at: Anesthesia, Intensive Care and Pain Management, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt.
E-mail address: 996ahmedabdo@gmail.com (M. A. Abdelmaboud).

https://doi.org/10.21608/aimj.2025.446501

One of the most common imaging diagnostic tests is the chest x-ray (CXR). For the most part, diagnostic VAP algorithms are designed to account for changes in radiological results. Nevertheless, there is evidence that the CXR results are not very specific for usage in the ICU due to their inherent subjectivity and limitations. Despite being the gold standard, computed tomography (CT) has a number of limitations, including radiation exposure (particularly in children) and difficulties with patient relocation.[2]

With lung ultrasonography (LUS), there are many benefits in the intensive care unit. In particular, it accurately delineates the etiology of undifferentiated opacities on CXR, with good agreement with computed tomography findings, and it may be employed in real time at the bedside without radiation. Furthermore, LUS can be employed to sequentially monitor the aeration of the lungs.[3]

Examining the relative merits of chest x-ray and chest ultrasound for the detection of VAP was the driving force for this research.

2. Patients and methods

In this prospective cohort study, 58 male patients admitted to Al-Azhar University Hospitals for Boys in Cairo, Egypt, between February 2024 and December 2024 for the purpose of a VAP diagnosis were included. The Ethics Committee of the Faculty of Medicine for Boys at Al-Azhar University in Cairo, Egypt, gave their approval to the study. Every patient's family member or legal guardian gave their signed, informed consent.

Inclusion criteria:

Patients' relatives accepted to join the study; mechanically ventilated patients with at least 48h of ventilation; age: between 21-65 years; respiratory failure ventilated patients type 1 or 2; clinically suspected ventilator associated pneumonia; Concern was expressed in a clinical setting; the CDC introduced a revised definition for VAP: Indicators such as high body temperature (fever or hypothermia), low white blood cell count (≤4000 WBC/mm3) or high white blood cell count (>12,000 WBC/mm3), the appearance of purulent sputum for the first time or a change in the sputum's characteristics, an increase in respiratory secretions, an increase in the need for suctioning, and an increase in the ventilator's settings.

Exclusion criteria:

Patient relatives' refusal, lung malignancy, patients with chest wall deformity, and pregnant patients.

Methods:

All patients included in the study were assessed by:

Patient characteristics: age(years), gender, body weight(kg), height(m) and BMI (Kg/m2). Detailed medical and surgical history, complete clinical examination (chest examination mainly), temperature(T), routine laboratory investigation including total leucocytic count(TLC), sputum culture, and ventilator settings (PaO2/FiO2 ratio and PEEP).

CDC's new definition for VAP:

The revised CDC definition for ventilator-associated pneumonia (PVAP) needs to meet all of these requirements: Increasing the ventilator setting: the deterioration of respiratory function meets certain criteria for identifying hypoxemia, which is defined as a rise in the daily minimum Following a baseline time of stability or improvement, the patient must maintain a PEEP of 3cm H2O or a FiO2 of 0.20 for a minimum of 2 calendar days. the number of white blood cells (≥12,000 cells/mm3 or ≤4,000 cells/mm3). If the temperature is greater than or equal to 38°C or lower than 36°C, even though a new antibiotic has been started. Respiratory secretions that are red and swollen, or a positive culture.4

Equipment used in the study:

US machine: Venue Fit R4W US; Type of probe: linear (L4-12t), and curved(c1-5); Portable X-ray machine: mobile digital x-ray system roller 30. CT-chest for confirmation of diagnosis: Toshiba's activion 16.

Figure 1. Equipment(US & portable x-ray&CT) used in the study.

Study modalities:

All suspected patients were subjected to radiological examination using CT chest, chest ultrasound or chest x-ray on day 1, 3, 5 after clinical suspicion. When it comes to diagnosing VAP, the gold standard is CT-chest, however the results of both the US and chest x-ray are comparable.

Lung ultrasound (LUS):

Using a transthoracic-appropriate curved(c1-5) transducer, the lungs were visualized. Only one operator, who had no knowledge of the CT results, assessed the ultrasonography.

So that you can scan with your right hand and use your left hand to handle the ultrasound buttons, position the machine on the patient's right side. A comprehensive LUS assessment was performed on each patient, examining both the front and back of the chest.

Patients were examined in a supine posture; Lung ultrasonography was done at six precise sites in 6-points protocol, three on each hemithorax, with the transducer perpendicular or transverse to the chest wall. The 6-point protocol identified 6-standard places on the chest wall: R1, R2, L1, L2, and 2 PLAPS-points(L3 and R3).

Point 1 on the R1/L1 axis evaluates the front of the breast. Direct your signal toward the top of the patient's head. Anchor your probe in the area between two ribs sign and place it at the mid-clavicular line, specifically at the second intercostal space of the right (R1) and left (L1) lungs, respectively.

The lateral chest is examined by R2/L2 Point-2 (R2 and L2). Position your probe at the midaxillary line, which is around the 6th-7th intercostal gap, on the right side (R2) or the left side (L2). In males, you should position your probe between two ribs, just laterally to the nipple line.

PLAPS (R3/L3) The back of the chest is evaluated at Point-3 (or R3 and L3). The PLAPS point, which stands for "posterior and/or lateral alveolar and/or pleural syndrome" in the context of lung ultrasonography, is widely used to describe this location. Finding pleural effusions or consolidations was where the PLAPS really shone. Direct your signal toward the top of the patient's head. The PLAPS point is under the patient's skin, where the posterior axillary line meets a rib gap between the 10th and 12th ribs. Slide the probe under the patient at this position. Locate the diaphragm, kidney, and liver (or spleen, depending on which side you look at it from). The expansion and contraction of the lung cause these structures to be visible and invisible, respectively. Additionally, make sure to observe the spine, which, in normal lungs, does not rise past the diaphragm's edge. When it goes beyond the diaphragm, it's referred to as the "spine sign.".

Findings of the US:

In a B'-profile, lung slippage is eliminated while maintaining a B profile (predominant B+lines). The A/B profile is characterized by a preponderance of A lines on one side and B+ lines on the other. C Profile=consolidation(s) primarily located in the subpleuric space.

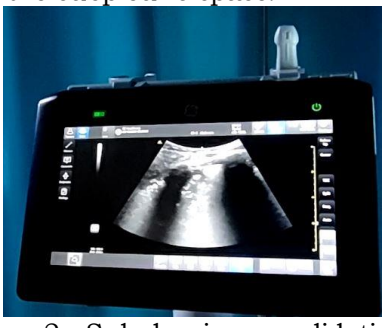


Figure 2. Subpleuric consolidation in R2.

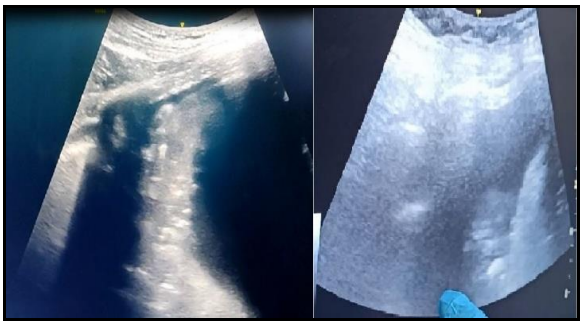


Figure 3. Consolidations Rt&Lt PLAPS point.

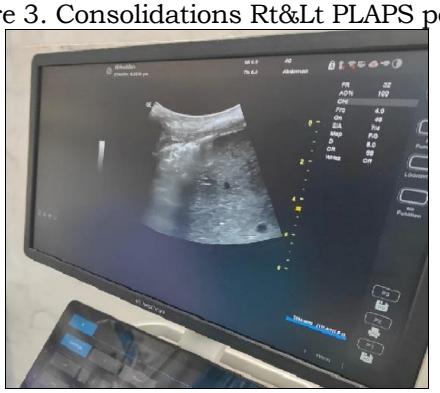


Figure 4. Consolidation(c-profile) rt PLAPS point.

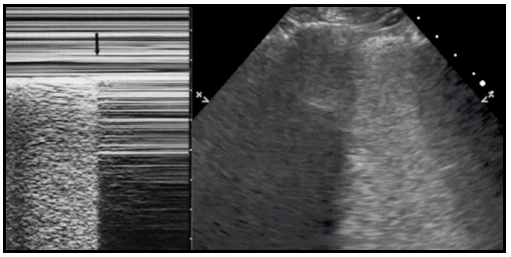


Figure 5. AB profile in R1&L1.

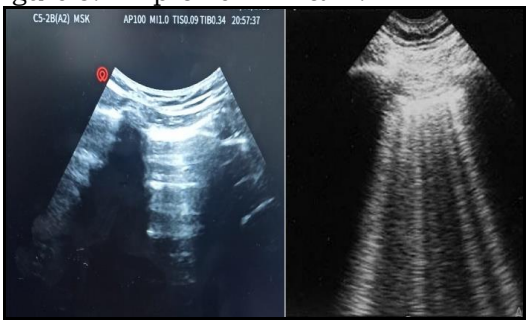


Figure 6. B' profile in L2.

Chest X-Ray (CX-R):

Radiation, such as X-rays, also includes light and radio waves. The body is one of the many objects that X-rays may penetrate. An X-ray machine makes a brief burst of radiation, which travels through the body and captures an image on photographic film or a specialized detector, after it is precisely pointed at the area of the body being inspected. There is a wide range of x-ray absorption rates across the body. Muscle, adipose tissue, and organs permit a greater amount of X-rays to pass through than dense bone does. Hence, x-rays of bones seem white, those of soft tissues appear gray, and those of air seem black. The ribs and spine take up most of the X-ray radiation in a

chest X-ray, thus they seem white or light gray. As a result of its low radiation absorption rate, the lung tissue looked black on the scan. On x-ray, you can see infiltrates in three different locations: the chest, both sides, and throughout.

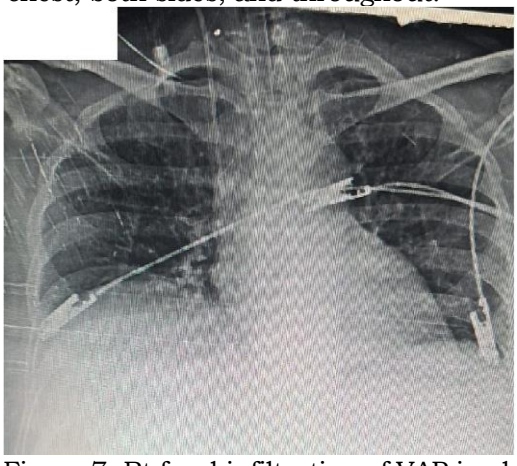


Figure 7. Rt focal infiltration of VAP in chest X-ray.

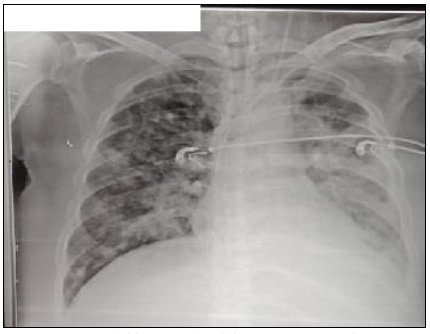
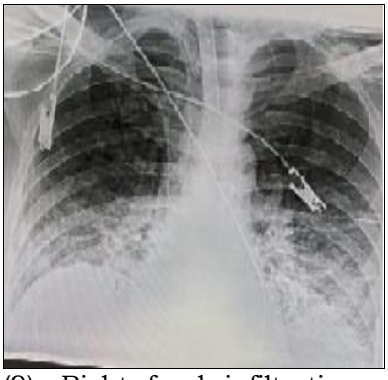


Figure 8. Diffuse infiltration of VAP in chest X-ray.



Figure(9): Right focal infiltration of VAP in chest x-ray

CT Chest:

An impartial radiologist reviewed the results of a non-contrast chest multiple detector computed tomography (MDCT) scan. Definitions of CT findings were provided by the Fleischer Society's nomenclature committee. MDCT was executed using 16-slice imaging equipment. From the top of the thorax to the bases of the lungs, scans were taken while the patient was lying down. Evaluation was made using spiral MDCT scans and thin MDCT high-resolution computed tomography (MDCT-HRCT).

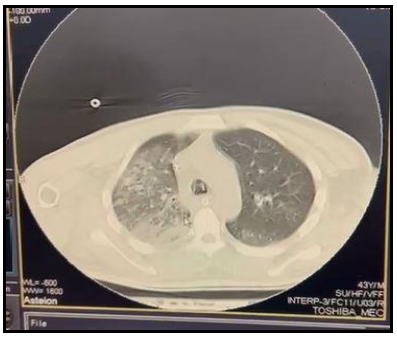


Figure 10. Ground glass opacity of VAP in CT-chest.

The use of MDCT-HRCT scans allowed for the discovery of fibrotic alterations (architectural distortion), septal or non-septal lines, ground glass opacities, and extensive lung parenchymal involvement. Mediastinal, pleural, and lung lesions were assessed using MDCT images. Image of the chest from a computed tomography scan may reveal ground glass opacity (GGO), consolidation, nodule, or thicker bronchial wall.

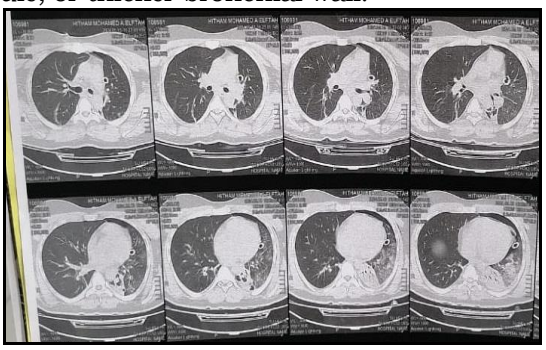


Figure 11. Consolidation of VAP in the CT chest.

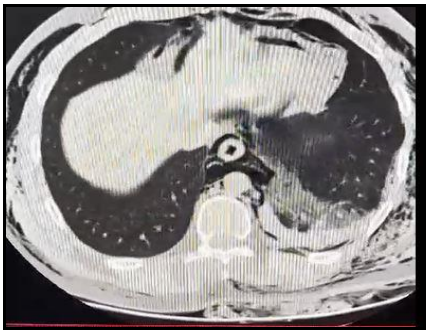


Figure 12. Consolidation of VAP in the CT chest.

Measurements:

Details on the patient, including their age, gender, weight, height, and body mass index (Kg/m2). Health information (temperature, total lymphocyte count, sputum culture, partial pressure of oxygen, and peak expiratory elastance pacing). Identification of abnormalities with ultrasound (AB, B', C, and A+PLAPS profiles). X-ray pictures of the chest showing infiltration (localized, bilateral, or widespread). Findings on computed tomography of the chest (CT):

atelectasis, bronchiectasis, ground glass opacity, consolidation, nodule, thicker bronchial wall, cavity. Reliability, sensitivity, and precision of chest ultrasound and X-ray.

Sample size calculation:

The number of patients was determined prior to the work field after a power calculation according to data gathered from a previous study.

The total sample size was calculated using G*power 3.1.9.7 sample size calculation test, depending on the following criteria: two-sided confidence level:95%, power of the test 80%, and an error of 5%.

The minimum sample size required is 52-subjects, and an increase of 10%(approximately 6-patients) for dropout)Thus, the study investigated 58 patients to test the hypothesis.

Statistical analysis:

We used SPSS v29 (IBM Inc., Chicago, IL, USA) for our statistical analysis. The mean and standard deviation (SD) were used to display the quantitative variables. The frequency and percentage of qualitative characteristics were displayed. It was deemed statistically significant if the two-tailed P-value was less than 0.05. Analysis of Kappa: In this scale, 0 indicates no agreement, 0.0-0.20 indicates a slight agreement, 0.21-0.40 indicates fair agreement, 0.41-0.60 indicates moderate agreement, 0.61-0.80 indicates substantial agreement, and 0.81-1.00 indicates nearly perfect agreement.

Diagnostic sensitivity is a measure of how often a group of patients receives a correct diagnosis. Measures the frequency of false negative results in a healthy population; this is known as diagnostic specificity. True positive findings as a percentage of total positive results is known as the positive predictive value (PPV). The NPV, or negative predictive value, is the proportion of negative outcomes that are actually negative out of all the negative outcomes.

3. Results

Table 1.Demographic data of the studied patients.

		(N=58)	
AGE (YEARS)	Mean±SD	46.6±11.99	P value=.06
	Range	23-65	
SEX	Male	32(55.17%)	P value=.07
	Female	26(44.83%)	
WEIGHT (KG)	Mean±SD	74.8±11.66	P value=.06
	Range	56-98	
HEIGHT (M)	Mean±SD	1.68±0.08	P value=.08
	Range	1.54-1.81	
BMI (KG/M^2)	Mean±SD	26.5±4.26	P value=.06
	Range	18-34.3	

There were no significant differences regarding demographic data.

Table 2. CT findings of the studied patients(1).

	(N=58)
POSITIVE	53(91.38%)
NEGATIVE	5(8.62%)

Regarding CT findings, 53(91.38%) patients were positive and 5(8.62%) patients were negative.

Table 3. CT findings of the studied patients(2).

	(N=58)
GROUND GLASS OPACITY	18(31.03%)
CONSOLIDATION	11(18.97%)
NODULE	8(13.79%)
THICKENED BRONCHIAL WALL	5(8.62%)
CAVITY	4(6.9%)
BRONCHIECTASIS	2(3.45%)
ATELECTASIS	5(8.62%)
NEGATIVE	5(8.62%)

Regarding CT findings, Ground glass opacity was present in 18(31.03%) patients, consolidation was present in 11(18.97%) patients, nodule was present in 8(13.79%) patients, thickened bronchial wall was present in 5(8.62%) patients, cavity was present in 4(6.9%) patients, bronchiectasis was present in 2(3.45%) patients and atelectasis was present in 5(8.62%) patients.

Table 4.US findings of the studied patients(1).

	(N=58)
POSITIVE	50(86.21%)
NEGATIVE	8(13.79%)

Regarding US findings, 50(86.21%) patients were positive and 8(13.79%) patients were negative.

Table 5. US findings of the studied patients(2).

	(N=58)
AB PROFILE	8(13.79%)
B` PROFILE	7(12.07%)
C PROFILE	6(10.34%)
A+PLABS PROFILE	29(50%)
NEGATIVE	8(13.79%)

Regarding US findings, AB profile was present in 8(13.79%) patients, B` profile was present in 7(12.07%) patients, C profile was present in 6(10.34%) patients and A+PLABS profile was present in 29(50%) patients.

Table 6. X ray findings of the studied patients(1).

	(N=58)
POSITIVE	47(81.03%)
NEGATIVE	11(18.97%)

Regarding x-ray findings, 47(81.03%) patients were positive and 11(18.97%) patients were negative.

Table 7. x-ray findings of the studied patients(2).

	(N=58)
FOCAL INFILTRATION	19(32.76%)
BILATERAL INFILTRATION	13(22.41%)
DIFFUSE INFILTRATION	15(25.86%)
NEGATIVE	11(18.97%)

Regarding x-ray findings, focal infiltration was present in 19(32.76%) patients, bilateral infiltration was present in 13(22.41%) patients and diffuse infiltration was present in 15(25.86%) patients.

Table 8.Role of lung ultrasound and chest x-ray in diagnosis of ventilator associated pneumonia.

	CT FINDINGS									
	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy	P-value
US	49	4	1	4	92%	80%	98%	50%	91%	Kappa 0.566 P-value 0.375
CHEST X-RAY	45	3	2	8	85%	60%	96%	27%	83%	Kappa 0.284 P-value 0.109

Lung ultrasound showed better sensitivity(92%

vs. 85%), specificity(80% vs. 60%), and accuracy(91% vs. 83%) than chest x-ray in diagnosis of ventilator associated pneumonia. Lung ultrasound and chest x-ray had agreement with CT(Kapaa=0.566 and P-value=0.375) and (Kapaa=0.284 and P-value=0.109) respectively.

4. Discussion

Most nosocomial infections in the intensive care unit are VAPs. Clinical trials conducted in the last several years have shown that VAP can develop in 10–20% of individuals who require mechanical ventilation for longer than 48 hours. On the other hand, everyone seems to agree that VAP is a huge burden. Death rates and lengths of stay in the intensive care unit (ICU) are double that of patients who acquire ventilator-associated pneumonia (VAP) compared to comparable individuals who do not develop VAP.[5]

Reducing mortality and morbidity in intensive care unit patients relies heavily on early detection of VAP.[6] Potential clinical diagnostic criteria for venous alveolar packing (VAP) include imaging techniques, bronchoalveolar lavage specimen collection and interpretation protocols, and host reaction biomarkers, among others. The reliability of various approaches to VAP diagnosis is debatable since no universally accepted gold standard exists.[6,7]

In the current study, TLC ranged between 12-12.9 109/L with a Mean±SD of 12.12±0.32 109/L on the 1st day, ranged between 12.8-14.6 109/L with a Mean±SD of 13.58±0.46µL on the 2nd day, and ranged between 13.7-15.6µL with a Mean±SD of 14.62±0.46µL on the 3rd day.

Temperature ranged between 38.1-39.7 °C with a Mean±SD of 38.1±0.67 °C on the 1st day, ranged between 38.2-41.2°C with a Mean value±SD of 39.6±0.74 °C on the 2nd day, and ranged between 38.7-42.6 °C with a Mean value±SD of 40.5±0.82 °C on the 3rd day.

TLC and temperature were significantly higher on the 2nd day and 3rd day compared to the 1st day(P-value<0.001).

Abdelaleem et al.,[8] conducted a prospective observational analytic cohort study 136-patients aged>18 years old to assess prognostic biomarkers in predicting mortality in respiratory patients with VAP. They reported that TLC was 12.87±4.74 109/µL in respiratory patients with VAP collected every day in duration on mechanical ventilation about mean 12.5 day.

In the present study, the PaO2/FIO2 ratio ranged between 173-192 with a mean±SD of 181.7±6.01 on the 1st day, ranged between 166-187 with a mean value±SD of 175.1±6.07 on the 2nd day, and ranged between 152-180 with a mean value±SD of 167.7±6.36 on the 3rd day. PEEP ranged between 4-6 cmH2O with a mean value±SD of 5±0.77cmH2O on the 1st day, ranged between 7-9cmH2O with a mean value±SD of 8±0.77cmH2O on the 2nd day, and ranged between 10-16 cmH2O with a mean±SD of 11.2±1.2 cmH2O on the 3rd day. PaO2/FIO2 ratio was significantly lower on the 2nd day and 3rd day than on the 1st day. PEEP was significantly higher on the 2nd day and 3rd day than on the 1st day.

Sachdev et al.,[9] found that the mean value of the PaO2/FIO2 ratio was 155±41.6 in patients with definite VAP; this was observed after daily evaluation in the morning in all patients on MV for more than 48 hours; total duration of the study 9-months.

In our study, regarding sputum culture, 54(93.1%) patients were positive, and 4(6.9%) patients were negative. Regarding CT findings, 53(91.38%) patients were positive, and 5(8.62%) patients were negative. Regarding US findings, 50(86.21%) patients were positive, and 8(13.79%) patients were negative. Regarding x-ray findings, 47(81.03%) patients were positive, and 11(18.97%) patients were negative.

Ali et al.,[10] They conducted a prospective cohort research comparing the use of bedside lung ultrasound to chest x-ray in assessing the severity of respiratory distress, cough, fever, and hypoxemia in one hundred critically sick patients older than 18 years of both sexes. They reported that in patients with pneumonia, regarding CT findings, 56(56%) patients were positive, and 44(44%) patients were negative. Regarding US findings, 51(51%) patients were positive, and 49(49%) patients were negative. Regarding x-ray findings, 38(38%) patients were positive, and 62(62%) patients were negative.

In the current study, regarding CT findings, ground glass opacity was present in 18(31.03%) patients, consolidation was present in 11(18.97%) patients, nodule was present in 8(13.79%) patients, thickened bronchial wall was present in 5(8.62%) patients, cavity was present in 4(6.9%) patients, bronchiectasis was present in 2(3.45%) patients and atelectasis was present in 5(8.62%) patients.

In consistent with our findings, Makram et al.[11] conducted a study on 72 individuals of either gender between the ages of 18 and 70 with clinically suspected pneumonia in the ICU. They reported that pneumonia was positive in 61 patients. Regarding LUS findings in those patients, AB profile was present in 9(14.7%) patients, B` profile was present in 7(11.5%) patients, C profile was present in 7(11.5%) patients, and A+PLABS profile was present in 38(62.3%) patients.

This study found that when comparing sensitivity (92% vs. 85%), specificity (80% vs. 60%), and accuracy (91% vs. 83%), lung ultrasound was superior than chest x-ray for diagnosing ventilator-associated pneumonia. Both

the chest x-ray and the lung ultrasonography were in accord with the CT scan (Kapaa=0.284 and Kapaa=0.566, respectively).

Ali et al.,[10] found that LUS showed better sensitivity(89.3% vs. 60.7%), specificity(97.7% vs. 90.9%), and accuracy(93% vs. 74%) than chest x-ray in diagnosis of pneumonia.

4. Conclusion

While both the chest x-ray and the lung ultrasound confirmed the CT results, the lung ultrasound was clearly the better of the two. When compared to chest x-rays, this fast, dependable, and bedside technique demonstrated superior sensitivity, specificity, and accuracy in the diagnosis of ventilator-associated pneumonia.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

Funding

No Funds : Yes

Conflicts of interest

There are no conflicts of interest.

References

1. Papazian L, Klompas M, Luyt CE. Ventilator-associated pneumonia in adults: a narrative review. Intensive Care Med. 2020;46(5):888-906.
2. Becerra-Hervás J, Guitart C, Covas A, et al. The Clinical Pulmonary Infection Score Combined with Procalcitonin and Lung Ultrasound (CPIS-PLUS), a Good Tool for Ventilator Associated Pneumonia Early Diagnosis in Pediatrics. Children (Basel). 2024;11(5):592.
3. Staub LJ, Biscaro RRM, Maurici R. Accuracy and Applications of Lung Ultrasound to Diagnose Ventilator-Associated Pneumonia: A Systematic Review. J Intensive Care Med. 2018;33(8):447-455.
4. Peña-López Y, Ramírez-Estrada S, Rello J. Ventilator-associated events: definitions and uses. Encyclopedia of Respiratory Medicine. 2021 Sep 17:523.
5. Pradhan S, Shrestha PS, Shrestha GS, et al. Clinical impact of lung ultrasound monitoring for diagnosis of ventilator associated pneumonia: A diagnostic randomized controlled trial. J Crit Care. 2020;58:65-71.
6. Howroyd F, Chacko C, MacDuff A, et al. Ventilator-associated pneumonia: pathobiological heterogeneity and diagnostic challenges. Nat Commun. 2024;15(1):6447. Published 2024 Jul 31.
7. Fernando SM, Tran A, Cheng W, et al. Diagnosis of ventilator-associated pneumonia in critically ill adult patients-a systematic review and meta-analysis. Intensive Care Med. 2020;46(6):1170-1179.
8. Abdelaleem NA, Makhlouf HA, Nagiub EM, et al. Prognostic biomarkers in predicting mortality in respiratory patients with ventilator-associated pneumonia. The Egyptian Journal of Bronchology. 2021 Dec;15:1-8.
9. Sachdev A, Chugh K, Sethi M, et al. Clinical Pulmonary Infection Score to diagnose ventilator-associated pneumonia in children. Indian Pediatr. 2011;48(12):949-954.
10. Ali NM, Maguid H, Gamil NM, et al. Evaluation of the role of bedside lung ultrasound versus chest x-ray in critically ill patients. Zagazig University Medical Journal. 2019 Nov 1;25(6):887-97.
11. Makram EF, Essawy TS, Alnahas AM, et al. Comparative study of Ultrasound and chest X-ray in diagnosis of pneumonia in Intensive Care Unit. Benha Journal of Applied Sciences. 2023 Jan 25;8(1):79-86.