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Use of ultrasonography in the diagnosis of pneumonia in intensive care patients

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ABSTRACT

Aims: A significant portion of respiratory system infections seen in intensive care units is ventilator-associated pneumonia, which has a high mortality rate and diagnosis may be delayed. Bedside lung ultrasonography (USG) offers the advantages of standard diagnostic methods as chest radiography or thorax computed tomography (CT). We aim to evaluate the bedside lung USG correlation with the chest radiography or thorax tomography.

Methods: It was conducted prospectively on 60 patients between the ages of 18-85 who were admitted to intensive care with respiratory failure within an 8-month period. Anterioposterior chest radiographs were taken on the first day of mechanical ventilation for the patients included in the study. Ultrasonographic examination was performed separately for both hemithoraxes and recorded digitally. Simultaneously with the ultrasonographic examination, PEEP, FiO2, blood gas examination results and the highest body temperatures in the last 24 hours were recorded. The quality and quantity of tracheal secretions were evaluated, and sampling was performed for complete blood examination and tracheal aspirate culture-antibiogram. Lung Injury Score (LIS) and Clinical Pulmonary Infection Score (CPIS) were calculated from the data obtained. In this process, independent of the research, the same day examination results of patients who required CT for diagnosis and treatment planning were evaluated together with USG and chest radiography. Tomographic examinations were evaluated by a radiologist.

Results: In the examination of 120 hemithoraxes of 60 patients we included in the study, we were able to detect 74.17% of the pathological images obtained with chest radiography and ultrasonographic examination with bedside USG and 70.84% with chest radiography. Of the 20 patients who underwent tomographic evaluation, pathology was observed in 40 hemithoraxes in 82.5% by tomography, in 85% by USG, and in 75% by chest radiography. 82.7% of the consolidations detected by tomography and 77.5% of the infiltrations detected by chest radiography were shown by USG, and 12.5% of the consolidations that could not be detected by lung radiography were also detected. 58.8% of the patients with consolidation detected by CT, we observed that there was growth in the tracheal aspirate of 56.2% of the patients whose ultrasonographic examination revealed consolidation. In the examination of 120 hemithoraxes of 60 patients we included in the study, we were able to detect 74.17% of the pathological images obtained with chest radiography and ultrasonographic examination with bedside USG and 70.84% with chest radiography. Of the 20 patients who underwent tomographic evaluation, pathology was observed in 40 hemithoraxes in 92.5% by tomography, in 85% by ultrasonography, and in 75% by chest radiography. While isolated consolidation was detected equally on USG and CT imaging, there was a high false-positive rate of 48% on chest radiography. 58.8% of the patients with consolidation detected by CT, we observed that there was growth in the tracheal aspirate of 56.2% of the patients whose ultrasonographic examination revealed consolidation.

Conclusion: Bedside lung USG is a fast, non-invasive, repeatable and reliable diagnostic method in patients followed in intensive care, and is compatible with traditionally used laboratory and clinical parameters. This reveals that USG, which is known to have other advantages such as cost, applicability, and not using radiopaque, will become an indispensable examination for ICU.

Keywords: Bedside lung ultrasonography, chest radiography, thorax tomography, consolidations, pneumonia, intensive care unit

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INTRODUCTION

Infection and infection-related sepsis are among the main problems such as morbidity, mortality (the main cause of non-cardiac deaths), hospital stay and cost (40% of the total intensive care cost) in patients treated in intensive care unit (ICU).[1,2] Among these infections, respiratory system infections rank first with a rate of 63.5%.[3] A significant portion of respiratory system infections seen in ICUs is ventilator-associated pneumonia, which has a high mortality rate and diagnosis may be delayed. On the other hand, ALI-ARDS is a common condition in intensive care patients. Although one of the factors in the development of ALI-ARDS is pneumonia, pneumonia may also develop in patients with ALI-ARDS. Pleural effusion can often accompany pneumonia or ALI-ARDS. Pleural effusion is frequently observed in intensive care patients who are under mechanical ventilator support and using sedative, analgesic and paralytic drugs and can often be difficult to diagnose it through routine physical examination and to visualize it on a chest X-Ray.[4] Since the coexistence of pneumonia, ARDS, ALI/ARDS, consolidation and pleural effusion is frequently encountered in intensive care unit patients, it has been understood that it is difficult to distinguish these intertwined pathologies from each other and their correlation with computed tomography (CT) is low.[5-7] CT, on the other hand, can only be applied to a limited number of patients due to restrictions such as the high radiation dose received, high cost, and the need to transport patients out of ICU, so it cannot become standard practice. When the transfer risk of intensive care patients is high, it is not always possible to perform gold standard examinations such as CT, which has the potential to give us more guidance compared to chest radiography, and to perform them repeatedly.[8]

Bedside lung USG offers the simple use of traditional diagnostic methods and the advantages of gold standard diagnostic methods.[8] It appears as an alternative that allows rapid and accurate diagnosis in a limited time in intensive care, is the basis for monitoring the treatment process and making strategy changes when necessary, is easy to apply and can be learned by intensive care physicians.

This prospective study examines the usability, reliability, contribution to clinical diagnosis, and the traditional and gold standard acceptance of bedside lung USG in the diagnosis of pneumonia and/or pleural effusion in patients with respiratory failure and invasive mechanical ventilator support that we follow in our ICU. We aim to evaluate its correlation with the methods given.

METHODS

Study Design

The study was conducted in accordance with the Declaration of Helsinki, ethics committee approval was obtained from the Ankara University Clinical Researches Ethics Committee (Date: 09.06.2009, Decision No: 154-4941). The personal information of the patients was not used, only the data obtained from the medical records were evaluated. Therefore, permission was obtained from the hospital manager for the examination of records, and there was no need to obtain individual patient consent.

Data Collection

This research was conducted by Ankara University Faculty of Medicine Department of Anesthesiology and Reanimation. It was conducted prospectively on 168 patients between the ages of 18-85 who were admitted to intensive care with respiratory failure within an 8-month period (between 09.2010 and 04.2011). Patients with breast deformity or who were pregnant were not included in the study. Of these patients, 100 patients who needed invasive mechanical ventilation were included in the study and 68 patients who did not need it were excluded from the study. Anterioposterior chest radiographs were taken on the first day of mechanical ventilation for the patients included in the study. Chest radiographs were evaluated by a specialist who worked in the intensive care unit but was not involved in the study. In his graphs; 60 patients with infiltration and/or pleural effusion were included in the study and each hemithorax was evaluated separately. Bedside lung USG was performed by a specialist within the first 6 hours following the detection of infiltration/pleural effusion on chest radiography. For USG examination, Sono Site M-Turbo (Sono Site Inc. USA) portable USG device and convex and linear probes were used. For chest wall examination; a high-frequency linear probe (5-7.5 mHz) was used, and a low-frequency (3.5 mHz) convex probe was used to detect pleural and pulmonary pathologies.[9] Ultrasonographic examination was performed separately for both hemithoraxes and recorded digitally. Simultaneously with the ultrasonographic examination, PEEP, FiO2, blood gas examination results and the highest body temperatures in the last 24 hours were recorded. The quality and quantity of tracheal secretions were evaluated, and sampling was performed for complete blood examination and tracheal aspirate culture-antibiogram.

Lung Injury Score (LIS) and Clinical Pulmonary Infection Score (CPIS) were calculated from the data obtained. In this process, independent of the research, the same day examination results of patients who required thorax CT for diagnosis and treatment planning were evaluated together with USG and chest radiography. Tomographic examinations were evaluated by a radiologist. USG examinations were performed by an anesthesiologist who received USG training.

Statistical Analysis

Data analysis was done using SPSS 11.5 package program. While number and frequency (percentage) were used as descriptive statistics for variables obtained by counting, mean±standard deviation value was used for variables obtained by measurement.

RESULTS

Demographic characteristics, body-mass index (BMI), LIS, CPIS of a total of 60 patients, 27 of whom were admitted to intensive care for surgical and 33 for non-surgical reasons, were included in the study. and tracheal aspirate growth results are shown in Table 1. CPIS>6: There is pulmonary infection; CPIS≤6: No pulmonary infection; lung injury score; LIS>2.5: ARDS; It was evaluated as LIS<2.5 ALI). With these results, 11 patients had ARDS (18.3%) and 49 patients had ALI (81.7%). According to CPIS scoring, the clinical picture was in favor of lung infection in 47 patients (78.3%), while it was not in favor of lung infection in 13 patients (21.7%). In the comparison of

chest X-Ray and USG, the comparative chest X-Ray and USG results of a total of 120 hemithoraxes in 60 patients included in the study with a preliminary diagnosis of pneumonia and/or pleural effusion are shown in Table 2.

Table 1. Demographic data and BMI, LIS, CPIS, tracheal aspirate reproductive results

Demographic data (n=60)		
Age (mean±SD)		55.5±18.4
Gender (F/M)	Female	24
	Male	36
Reason for ICU admission	Surgical	27
	Non-surgical	33
BMI (mean±SD)		26.8±7.2
LIS (mean±SD)		1.82±0.7
CPIS (mean±SD)		7.7±1.6
Growth in tracheal aspirate	Yes	27
	No	33

BMI: Body-mass index, LIS: Lung Injury Score, CPIS: Clinical Pulmonary Infection Score, SD: Standard deviation, F: Famele, M: Male

Table 2. Comparison of chest radiography and ultrasonography (percentages are given as a ratio of 120 hemithoraxes)

	Chest radiography	Ultrasonography
Effusion	5 (4.16%)	22 (18.33%)
Infiltration	71 (59.16%)	29 (24.16%)
Effusion+infiltration	9 (7.5%)	38 (31.66%)
Pathology	85 (70.84%)	89 (74.17%)
Normal	35 (29.16%)	31 (25.83%)
Total	120 (100%)	120 (100%)

In the ultrasonographic examination of 35 hemithoraxes that were evaluated as normal on chest radiography, consolidation was detected in 1 hemithorax (2.85%), pleural effusion was detected in 7 (20%), and pleural effusion with consolidation was detected in 2 (5.71%). In other words, 28.57% of the hemithoraxes that were considered normal on chest radiography had a pathology that could be detected ultrasonographically, and 90% of these pathologies were isolated or combined effusion with consolidation.

Comparison of Lung Radiography and Computed Tomography

40 hemithoraxes of 20 patients evaluated by computed tomography tomographic and chest radiography results are shown in Table 3. While pathological findings were detected in 37 of 40 hemithoraxes (92.5%) by computed tomography, pathological findings were detected by chest radiography in only 30 of these hemithoraxes (75%). In other words, the rate of not being able to see tomographic pathology on chest radiography was 17.5% 18.9 %.

Pathological findings were demonstrated by tomography in 70% of the hemithoraxes, which were thought to be normal by chest radiography. While the probability of detecting tomographic effusion by chest radiography was 20.8%, in other words, 79% of existing effusions were missed by chest radiography.

Table 3. Comparison of chest radiography, ultrasonography and computed tomography: (percentages are given as the ratio of 40 hemithoraxes)

	Chest radiography	Ultrasonography	Computed tomography
Consolidation	25 (62.5%)	13 (32.5%)	13 (32.5%)
Consolidation+effusion	4 (10%)	10 (25%)	16 (40%)
Effusion	1 (2.5%)	11 (27.5%)	8 (20%)
Pathology	30 (75%)	34 (85%)	37 (82.5%)
Normal	10 (25%)	6 (15%)	3 (7.5%)

Comparison between Ultrasonography and Computed Tomography

Tomographic and ultrasonographic results of 40 hemithoraxes of 20 patients evaluated by CT are shown in Table 3. While pathology was detected tomographically in 37 (92.5%) of 40 hemithoraxes, pathology was found ultrasonographically in 34 (85%). In other words, the rate of not detecting tomographic pathology in USG was 8.1%. In total, the probability that tomographically detected consolidation could not be demonstrated by USG was 20.68%. Compared to the results of CT in detecting consolidation or consolidated area under effusion, it was determined that the rate of false negativity in USG was 20.6%. In the tomographic examination of 6 hemithoraxes that were found to be normal ultrasonographically, 3 were found to be normal and 3 were found to be consolidation/consolidation+effusion. Of the 29 hemithoraxes in which consolidation was detected by CT, infiltration was detected in 29 of them (100%) when evaluated by chest radiography, while consolidation was detected in 23 of them (79.31%) by ultrasonographic examination. While effusion could be detected by chest radiography in 5 (20.8%) of 24 hemithoraxes where effusion was detected, effusion was observed in 21 (87.5%) of the same hemithoraxes when examined by USG.

Comparison of Tracheal Aspirate Results with Ultrasonography

Patients included in the study, the results of tracheal aspirate gram staining and ultrasonographic examination are as shown in Table 4. Among the total number of patients, all 27 patients with growth in their tracheal aspirates, consolidation was detected by ultrasonographic examination in 21 of 33 patients (63.6%) whose tracheal aspirate showed no growth.

Table 4. Tracheal aspirate results, comparison of CPIS and ultrasonography

	Ultrasonography				
Tracheal aspirate	**Effusion**	**Consolidation**	**Consolidation +effusion**	**Normal**	**Total**
Growth	0	7	20	0	27
Non-growth	8	8	13	4	33
Total	8	15	33	4	60
CPIS	**Effusion**	**Consolidation**	**Consolidation +effusion**	**Normal**	**Total**
Negative (CPIS<6)	7	1	1	4	13
Positive (CPIS>6)	1	14	32	0	47
Total	8	15	33	4	60

CPIS: Clinical Pulmonary Infection Score

Comparison of Clinical Pulmonary Infection Score and Ultrasonography

Patients included in the study, the relationship between the calculated clinical pulmonary infection score and the USG performed is as shown in Table 4. In 2 of 13 patients (15.3%) whose infection score was considered negative, consolidation was also detected by ultrasonographic examination in 46 of 47 patients (97.8%) whose infection score was considered positive.

Comparison of Clinical Pulmonary Infection Score and Tracheal Aspirate

There was growth in tracheal aspirate examination in 27 of 47 patients (57.4%) with a positive calculated infection score, in all 13 patients with a negative infection score; no growth was found in tracheal aspirate examination. In other words, while it was clinically supported in favor of infection, the number of patients who had no growth in tracheal aspirate and were considered to have pneumonia was 20 (60.6%). Of the 20 patients who underwent tomography imaging, 10 of whom had growth in tracheal aspirate sampling had infiltration in 4, infiltration and pleural effusion in 6, while in the tomographic examination of 10 patients without growth, 3 had infiltration, 3 had effusion, and 4 had infiltration and effusion together. In other words, of the 17 patients in whom infiltration was detected by CT, which is considered the gold standard in diagnosis, the number of patients with growth in their tracheal aspirates was 10 (58.8%). Moreover, again, there was no growth in the tracheal aspirate in any of the 3 patients whose infiltration was not detected on CT. As a result, tomographic infiltration was detected in all patients (n: 10) with growth in tracheal aspirate, while 7 of the patients without growth in tracheal aspirate cultures had tomographic infiltration (Table 5).

Table 5. Comparison of tracheal aspirate reproduction results with CT and ultrasonographic evaluation

	Effusion	Consolidation	Consolidation +effusion	Total
Tracheal aspirate growth	CT/USG	CT/USG	CT/USG	CT/USG
Yes	3/5	3/3	4/2	10/10
No	0/0	4/5	6/5	10/10
Total	3/5	7/8	10/7	20/20

CT: Computed tomography, USG: Ultrasonographic

In comparing the clinical pulmonary infection score and Computed Tomography results, the relationship between the calculated clinical pulmonary infection score and computed tomography results of the patients included in the study is as shown in Table 6. Clinical infection score was positive in 15 of 17 patients (88.2%) with consolidation detected on computed tomography.

Table 6. Comparison of clinical pulmonary infection score and computed tomography results

	Computed tomography				
CPIS	Effusion	Consolidation	Consolidation +effusion	Normal	Total
Negative	3	0	2	0	5
Pozitive	0	7	8	0	15
Total	3	7	10	0	20

CPIS: Pulmonary infection score

DISCUSSION

In the examination of 120 hemithoraxes of 60 patients we included in the study, we were able to detect 74.17% of the pathological images obtained with chest radiography and ultrasonographic examination with bedside USG and 70.84% with chest radiography. Of the 20 patients who underwent tomographic evaluation, pathology was observed in 40 hemithoraxes in 92.5% by tomography, in 85% by USG, and in 75% by chest radiography. While isolated consolidation was detected equally on USG and CT imaging, there was a high false-positive rate of 48% on chest radiography. 58.8% of the patients with consolidation detected by CT, we observed that there was growth in the tracheal aspirate of 56.2% of the patients whose ultrasonographic examination revealed consolidation.

In the correlation between CPIS and USG, in 95.8% of the patients whose ultrasonographic examination revealed consolidation; had positive CPIS. We calculated the CPIS as negative in all patients in whom no consolidation was observed on ultrasonography. In the comparison of CPIS and computed tomography, 88.2% of the patients with consolidation detected in CT had a positive CPIS Score. CPIS has high false positivity and negativity.

The most valuable examination for identifying lung pathologies is CT. Other disadvantages of tomographic examinations are that patients followed in intensive care require a risky transport procedure by a monitored and trained team, limited use of contrast material in patients with multiple organ dysfunction, high radiation dose received by CT, and limited reproducibility of the procedure to the patient.[10,11] Under these conditions, lung USG has been prioritized. Compared to CT, which directly displays lung morphology; since USG can visualize artifacts resulting from lung damage, it inevitably contributes less to the diagnosis. However, the fact that it is a technique that can be applied at the bedside, is cheap, repeatable, suitable for recording and re-examination and comparison, is easy to learn and compare, and eliminates radiation exposure makes this method valuable. Additionally, an advantage of this technique compared to CT is that the intravenous contrast material given for diagnosis in CT may be harmful to the damaged lung.[12]

In a study conducted by Gazon et al.,[13] chest radiography and USG were used in intensive care patients; Considering its consistency in diagnosing pleural effusion and alveolar consolidation, it has been concluded that USG detects a higher rate of abnormalities. It has been clearly shown in our study that the infiltrations detected in chest radiography are detected in USG to a large extent.

In their study, Marco et al.[14] confirmed this diagnosis with USG in 92% of the patients diagnosed with pneumonia by chest radiography, and they were able to detect pleural effusion in 111 patients with chest radiography and in 120 patients with USG. The reason why the diagnosis of pneumonia can be detected better in USG in this study than in our study may be that the patients included in the study had community-acquired pneumonia and that there was an experienced radiologist in the study.

Parliament et al.[15] also demonstrated the superiority of USG in the diagnosis of pleural effusion in their study.

In the clinical study conducted by Reissig et al.,[16] the effectiveness of X-Ray and USG in the diagnosis and follow-

up of pneumonia in intensive care patients has been examined and it has been shown that USG can be used in this field.

We were able to detect all of the pleural effusions detected on chest radiography by USG, and in addition, we were able to detect pathology by USG examination of the hemithoraxes where infiltration and/or pleural effusion could not be detected on chest radiography. The compatibility of USG with tomography in detecting effusion was significantly higher than chest radiography. Indeed, in our literature review, the success of USG, especially in detecting effusion, has been shown in many studies.[17-19] The reason for this is that USG is more sensitive than chest radiography in distinguishing small pleural effusions.[20] In the study conducted by Xirouchaki et al.,[21] in which bedside chest radiography and USG were compared in intensive care patients, the superiority of USG, especially in diagnosing pleural effusion, was clearly demonstrated. In the study conducted by Zanobetti et al.,[22] USG showed more sensitivity than chest radiography, especially in detecting pleural effusion.

In the clinical study of Lichtenstein et al.[23] in which they compared auscultation, chest radiography and USG in ARDS on 119 patients, alveolar consolidation; the diagnostic accuracy of chest radiography and USG was found to be 75% and 97%, respectively, and the diagnostic accuracy of pleural effusion was found to be 47% and 93%, respectively. The success they attribute to USG in detecting consolidation may be due to the fact that all the patients they included in their studies had ARDS.

Lung USG in patients who are obese, have multiple trauma, are accompanied by subcutaneous emphysema, and have pathological conditions related to the thorax wall and pleura, imaging of centrally located lesions will be difficult, requiring specialized practitioners. In such cases, examinations should be carried out by experienced people. In terms of ultrasonographic evaluation, Although BMI was calculated for all patients with the idea that increasing BMI would create difficulty in evaluation, the values of the patients with the lowest and highest BMI among the patients we included in the study were 13.36 and 66.6, respectively. We observed that BMI values within these limits do not pose a difficulty in performing lung USG.

Consolidation seen with pleural effusion in intensive care patients on mechanical ventilation is easy to detect and can be achieved in a short time by practitioners who have received this training.[24] In our study, we concluded that it may be easier to detect consolidated lung areas ultrasonographic ally in the presence of accompanying pleural effusion.

One of the aims of this study is to reduce the need for chest radiography and tomography in patients followed up with respiratory failure in ICUs. In the study conducted by Peris et al.,[25] it is stated that there may be a relationship between the routine use of lung USG in intensive care and the decrease in the number of scans with chest radiography and CT. At the same time, it is to reduce the cost of patient care in ICU and to ensure accurate, reliable and timely diagnosis. In this context, lung USG may be a new and good alternative for lung monitoring.

Some researchers reported that condolitation will be visualized better if it has a connection with the lung surface area. Because the consolidated area is rich in water and therefore sonographic waves are transmitted better.[26,27] With this; small consolidations are less common due to poor echogenicity and lack of surface connection. However, early detection of small consolidated areas may be associated with early diagnosis. In our opinion, imaging by users with good intensive care experience and the choice of USG devices equipped with advanced technology will increase success.

In intensive care patients, in a study, the diagnostic rate of tracheal aspirate sampling, which is used to diagnose ventilator-associated pneumonia, was found to be 52%, and in the same study, CPIS was found to have high sensitivity in diagnosing ventilator-associated pneumonia.[28] The results of our study are similar.

In our literature review, false positivity was higher in tracheal aspirate, whereas false negativity was higher in ours.[29,30] While this shows the success of our culture technique in terms of not causing contamination, it also reveals the disadvantage of being non-selective. In this case, USG-guided selective tracheal aspirate culture may be recommended. However, if instead of blind tracheal aspirate, sampling was done from the infiltration area with bronchoscopic mini-BAL or protected brush for culture, the results might have been different. Meanwhile, the possibility of selective culture sampling after detection of infiltration localization by USG may be an approach that may make its use in intensive care more important.

When CPIS and tracheal aspirate reproduction results are compared; while all patients with growth in tracheal aspirate were clinically supported in favor of infection, we observed growth in 57.4% of the patients who were clinically considered to have pneumonia (CPIS>6) in the tracheal aspirate examination.

We also compared the ease of use, side effects, and diagnostic performance of chest radiography and USG. Chest radiography, which we routinely use in our ICU; in patients with respiratory failure, it is considered a reference to evaluate lung status. However, the limited diagnostic performance and effectiveness of this method have been reported in various clinical studies.[31,32] In our study, bedside lung USG; we observed that it has superior performance both in diagnostic terms and in patient follow-up, as it is easily repeatable and has the ability to store data digitally.

Limitations

Our study has some limitations. It is single-centered, the examinations were performed in the supine position (the apex and retrocardiac area were not clearly visualized), and not every patient had a tomography image. Studies with larger patient populations are needed.

CONCLUSION

Bedside lung USG is a fast, non-invasive, repeatable and reliable diagnostic method in patients followed in intensive care, and is compatible with traditionally used laboratory and clinical parameters. This reveals that USG, which is known to have other advantages such as cost, applicability, and not using radiopaque, will become an indispensable examination for ICU.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Ankara University Clinical Researches Ethics Committee (Date: 09.06.2009, Decision No: 154-4941).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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