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# ROLE OF LUNG ULTRASOUND IN DIAGNOSIS AND FOLLOW UP OF PNEUMONIA IN ADULTS: IS IT SIGNIFICANT?

By

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## ABSTRACT

**Background:** Pneumonia is a common and serious infectious disease that can cause high mortality. Lung ultrasound (LUS) is increasingly utilized in emergency and critical settings. The role of LUS in evaluation of pneumonia is becoming more and more important.

**Objective:** The current study was performed to compare the diagnostic accuracy of lung ultrasound against other modalities for evaluation and follow up of pneumonia in adult patients.

**Patients and Methods:** One hundred and eight patients (70 males, 38 females) aged 57.33 ± 9.39 years admitted to the Chest Department with pneumonia from March to November 2019. After institute ethical committee clearance and written informed consent, each participant underwent chest X-ray (CXR), LUS and computed tomography (CT) within 6 hours from admission by 2 different radiologists being blind to the results of the other examination to minimize the bias. Follow up US was done after adequate medical treatment (7–14 days) to detect its ability for following the patients up.

**Results:** A total of 108 patients who fulfilled the eligibility criteria were enrolled in this study LUS showed positive findings in 101 (93.5%) patients in the form of isoechoic area in 6 (5.5%) patients, dynamic air bronchogram alone in 25 (23.1%) patients and the last one was associated with all other sonographic signs of the studied patients. During follow up period, 55 (54.5%) of cases showed total resolution, while 33 cases (32.7%) showed regressive course of their sizes. Ten cases (9.9%) showed rather stationary course, while three cases (2.9%) showed progression course. The associated pleural effusion was resolved in 36 cases (90%) out of 40. Compared to CT, LUS showed a sensitivity and specificity of 93.33% and 94.74% for pneumonia detection respectively with 95.4% PPV, 92.4% NPV, and 93.91% accuracy.

**Conclusion:** LUS considered being a good diagnostic and following up tool when pneumonia is suspected, its results were closer to CT with minimal cost.

**Key Words:** Chest X-Ray, Computerized tomography, Lung ultrasound, Pneumonia.

## INTRODUCTION

Pneumonia is a major health problem worldwide, failure of early detection and distribution of treatment may lead to significant morbidity and mortality *(Yang et al., 2016)*.

Absence of specific guidelines for pneumonia diagnosis means that its diagnosis is usually based on clinical signs, symptoms, history-taking, and physical examination *(Caiulo et al., 2013)*. Chest X-ray (CXR) is well known as an essential tool in pneumonia

diagnosis, but it has low sensitivity and specificity as well as it is associated with considerable practical delays related to processing *(Blaivas, 2012)*.

Although computed tomography (CT) has been considered as the ‘‘gold standard” technique in the diagnosis of pneumonia during the last decade, it can’t be used as the first-line for radiological evaluation in all patients with suspected pneumonia due to the high radiation and the fact of being pricey and unavailable in some places. Especially ionizing radiations which magnify the risk of gene mutations and cancer evolution *(Rennis et al., 2017)*.

Lung ultrasound (LUS) was promoted as a modality that can overcome many of the above-mentioned limitations of other tools in the diagnosis of pneumonia in multiple settings *(Lichtenstein, 2009)*. However, few studies were concerned about its usage in the diagnosis and follow up of pneumonia.

**The current study was performed to** assess the role of LUS in the diagnosis and follow-up of pneumonia compared to CT in adult population.

## PATIENTS AND METHODS

This study was a prospective cross sectional randomized study which was conducted in Chest and Radiology Departments from March to November 2019 on 115 patients presented with respiratory distress and suspected to have pneumonia on the basis of clinical examination and chest radiography. Institutional research board approval had been gained, and all patients had assigned informed consents prior to study processing.

Enrolled patients underwent both chest US and chest CT, and 108 patients had final diagnosis of pneumonia and they were included in this study. Other seven patients with uncertain diagnoses were excluded. Pregnant women were also excluded because of the restrictions in the use of CT chest which is required in the study.

All patients underwent demographic data collection, complete history taking, thorough general and local chest examination, routine laboratory investigation, CXR, CT chest scan, and transthoracic LUS.

Chest radiography was performed using Toshiba diagnostic equipment (Toshiba Medical Systems, Japan) by posterior-anterior and lateral views in the upright patients and anterior-posterior view in the supine patients, following standardized hospital diagnostic protocol. The film was digitally reviewed firstly blinded to the results of LUS and CT. CXR was considered positive when at least one typical consolidation was visualized.

A low-dose HRCT scan was performed on admission using multi slice CT scan *(Cortellaro et al., 2012)*. Chest CT was performed by Toshiba aquilion prime 80-dual MDCT (Toshiba Medical Systems, Japan). CT of the chest was performed on admission as the gold standard for diagnosis.

LUS was performed using 3MHz Curvilinear Transducer of Voluson E6 (GE, Germany) with a 3MHz convex transducer and was targeted to evaluate lung consolidations with the morphologic characteristics of pneumonia. Patients were examined anteriorly in a supine

position and the posterior areas were studied in the lateral decubitus or sitting position according to clinical status. Each hemithorax was divided into five areas, two anterior, two lateral, and one posterior, for a total of 10 areas bilaterally. The anterior chest wall was marked off from the parasternal line to the anterior axillary line. This zone was split into an upper region (from the collar bone to the second intercostal space) and a lower region (from the third intercostal space to the diaphragm). The lateral area (anterior to posterior axillary line) was split into upper and lower halves. Finally, the posterior area was identified from the posterior axillary line to the paravertebral line. The US transducer was moved until a rib interspace was located. The probe was then panned horizontally and vertically to the extent possible to allow the broadest sweep through the area being imaged. Raising the arm above the head increases the rib space distance and facilitates scanning. Scanning was performed during quiet respiration, to allow for assessment of normal lung movement, and, in suspended respiration, when a lesion can be examined in detail. The echogenicity of a lesion was compared with that of the liver and characterized as hypoechoic, isoechoic, or hyperechoic.

LUS and CT images were examined for the presence of parenchymal consolidation, lung necrosis, abscess, pleural effusion and the presence of loculation or fibrin strands within the pleural fluid. LUS and CT were performed by one of the investigators who participated in the study. The investigators were intensivists with at least 5 years' experience on ultrasonography.A radiologist reported the US findings blindly to the results of the CT.

Statistically analysis was performed using SPSS software version 23 for Windows (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as the mean±SD, and qualitative data were expressed as absolute frequencies ‘number’ and relative frequencies (percentage). Percent of categorical variables was compared using the Chi Square-test when appropriate. Sensitivities, specificities, positive likelihood ratio and negative likelihood ratio with their respective 95% confidence intervals were calculated. P-value less than 0.05 were considered statistically significant.

## RESULTS

A total of 108 patients who fulfilled the eligibility criteria were enrolled in the current study. They were 38 females (35.2%) and 70 males (64.8%) with their mean age of 57.33±9.39 years (range 22.0-58.0). The patient's clinical characteristics regard to blood pressure, pulse, temperature, respiratory rate and level of consciousness **(Table 1)**.

**Table (1): Demographic data and clinical assessment in the study group (n=108)**

| Parameters | Values |
|---|---|
| Age (years) | 57.33 ± 9.39 |
| Sex (no;%)<br>Male<br>Female | <br>70 (64.8%)<br>38 (35.2%) |
| Systolic blood pressure (mmgH) | 98.21± 15.75 |
| Diastolic blood pressure (mmgH) | 63.88± 13.45 |
| Pulse (rate/min) | 98.55±9.95 |
| Temperature (°C) | 38.73±0.75 |
| Respiratory rate (rate/min) | 34.42±3.98 |
| Conscious level:<br>Confused<br>Normal | <br>13 (12.0%)<br>95 (88.0%) |

Eighty -eight patients (81.5%) were positive by CXR, ultrasound and CT (Figure 1), 101 patients (93.5%) were positive by ultrasound and CT while 104 cases (96.3%) positive by CT. There was significant difference (P=0.014) between LUS and CXR in detecting pneumonia; pneumonia was detected in 101 patients (93.5%) with LUS, whereas in 88 patients (81.5%) with CXR. However, there was no significant difference (P=0.535) between LUS and chest CT in detecting pneumonia; 101 patients (93.5%) had positive signs of pneumonia with LUS compared to 104 patients (96.3%) of pneumonia detected by chest CT **(Table 2)**.

**Table (2): Comparison between CXR and LUS findings in detecting pneumonia**

| Parameters \ Findings | | CXR (N=108) [n (%)] | LUS (N=108) [n (%)] | Chi-square | P value |
|---|---|---|---|---|---|
| Signs of pneumonia | Absent | 20 (18.5%) | 7 (6.5%) | 6.095 | 0.014 |
| | Present | 88 (81.5%) | 101 (93.5%) | | |
| | | LUS (N=108) [n (%)] | Chest CT (N=108) [n (%)] | | |
| Signsofpneumonia | Absent | 7 (6.5%) | 4 (3.7%) | 0.383 | 0.536 |
| | Present | 101 (93.5%) | 104 (96.3%) | | |

CXR, chest x ray; LUS, lung ultrasound;CT, computed tomography

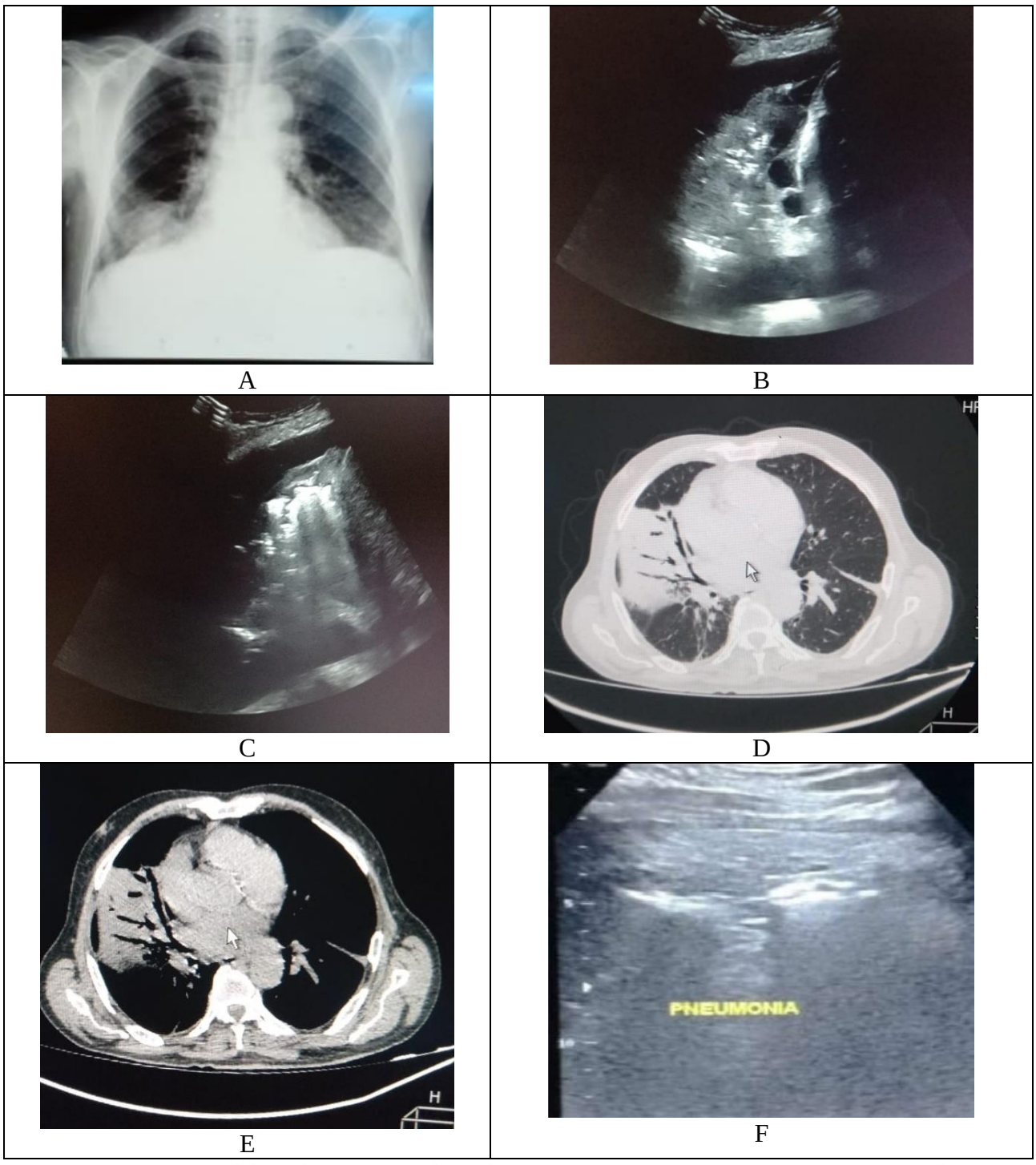


**Figure (1): 36 years old male presented with acute pneumonia a) CXR PA view shows non homogeneous opacity involve right lower lung zone. b-c) LUS showing loss of A lines, subpleural consolidation with liver like echogenecity, poorly defined hypoechoic area with irregular outline, B lines, dynamic air bronchogram (noted during scanning), reduced or absent lung sliding (noted during scanning) and parapneumonic pleural effusion. d-e) Axial CT cuts in lung and mediastinal windows reveled pulmonary consolidation with air bronchogram, F) follow up Lung ultrasound revealed; some improvement of the pneumonic consolidation with no pleural effusion.**

The LUS showed positive findings in 101 (93.5%) patients in the form of isoechoic area in 6 (5.5%) patients, dynamic air bronchogram alone in 25 (23.1%) patients and the last one was associated with all other sonographic signs of the studied patients **(Table 3)**.

**Table (3): LUS findings of pneumonia in the studied cases (n=108)**

| LUS findings | n (%) |
|---|---|
| **Negative** | **7 (6.5%)** |
| **Positive** | **101 (93.5%)** |
| Dynamic air bronchogram | 25 (23.1%) |
| Dynamic air bronchogram and subpleural consolidation | 22 (20.4%) |
| Dynamic air bronchogram and fluid bronchogram | 14 (13.0%) |
| Dynamic air bronchogram and free pleural effusion | 11 (10.2%) |
| Dynamic air bronchogram and B-lines | 9 (8.3%) |
| Dynamic air bronchogram and complex septated pleural effusion | 7 (6.5) |
| Isoechoic area | 6 (5.6%) |
| Dynamic air bronchogram and complex nonseptated pleural effusion | 4 (3.7%) |
| Dynamic air bronchogram and hypoechoic area | 3 (2.8%) |

For the LUS positive (101 cases) who were subjected to follow up US after adequate treatment (within 7–14 days), 55 (54.5%) cases out of the 101 positive cases showed almost total resolution of the pneumonic hepatization while 33 cases (32.7%) showed regressive course of their sizes. Ten cases (9.9%) showed rather stationary course while three cases (2.9%) showed progression of the extension of the pneumonic hepatization. The associated pleural effusion was resolved in 36 cases (90%) out of 40 while 4 cases showed regressive, stationary and progressive course **(Table 4)**.

**Table (4): Follow up results for LUS positive (103 cases)**

| Follow up / Parameters | Follow up US for hepatization | | Follow up US for pleural effusion | |
|---|---|---|---|---|
| | No | % | No | % |
| Total positive cases | 101 | 100 | 40 | 100 |
| Complete resolution | 55 | 54.5 | 36 | 90 |
| Regressive course | 33 | 32.7 | 2 | 5 |
| Stationary course | 10 | 9.9 | 1 | 2.5 |
| Progressive course | 3 | 3 | 1 | 2.5 |

According to the above results, CXR showed in comparison to CT sensitivity and specificity of 83.81% and 95.79% for the detection of pneumonia respectively, with 95.9% PPV, 83.4% NPV and 81.42% accuracy. LUS showed in comparison to CT sensitivity and specificity of 93.33% and 94.74% for the detection of pneumonia respectively with 95.4% PPV, 92.4% NPV and 93.91% accuracy **(Table 5)**.

**Table (5): The diagnostic parameters of CXR and LUS compared to chest CT for the diagnosis of pneumonia**

| Parameters | CXR | LUS |
|---|---|---|
| Sensitivity | 83.81% | 93.33% |
| (95% CI) | (75.3 – 90.3) | (86.7 – 97.3) |
| Specificity | 95.79% | 94.74% |
| (95% CI) | (89.6 – 98.8) | (88.1 – 98.2) |
| PPV | 95.9 % | 95.4 % |
| NPV | 83.4 % | 92.4 % |
| Accuracy | 81.42 | 93.91% |
| (95% CI) | 77.41-87.36 | 87.86-97.52 |

CI: Confidence interval, PPV: Positive predictive value, NPV: Negative predictive value,

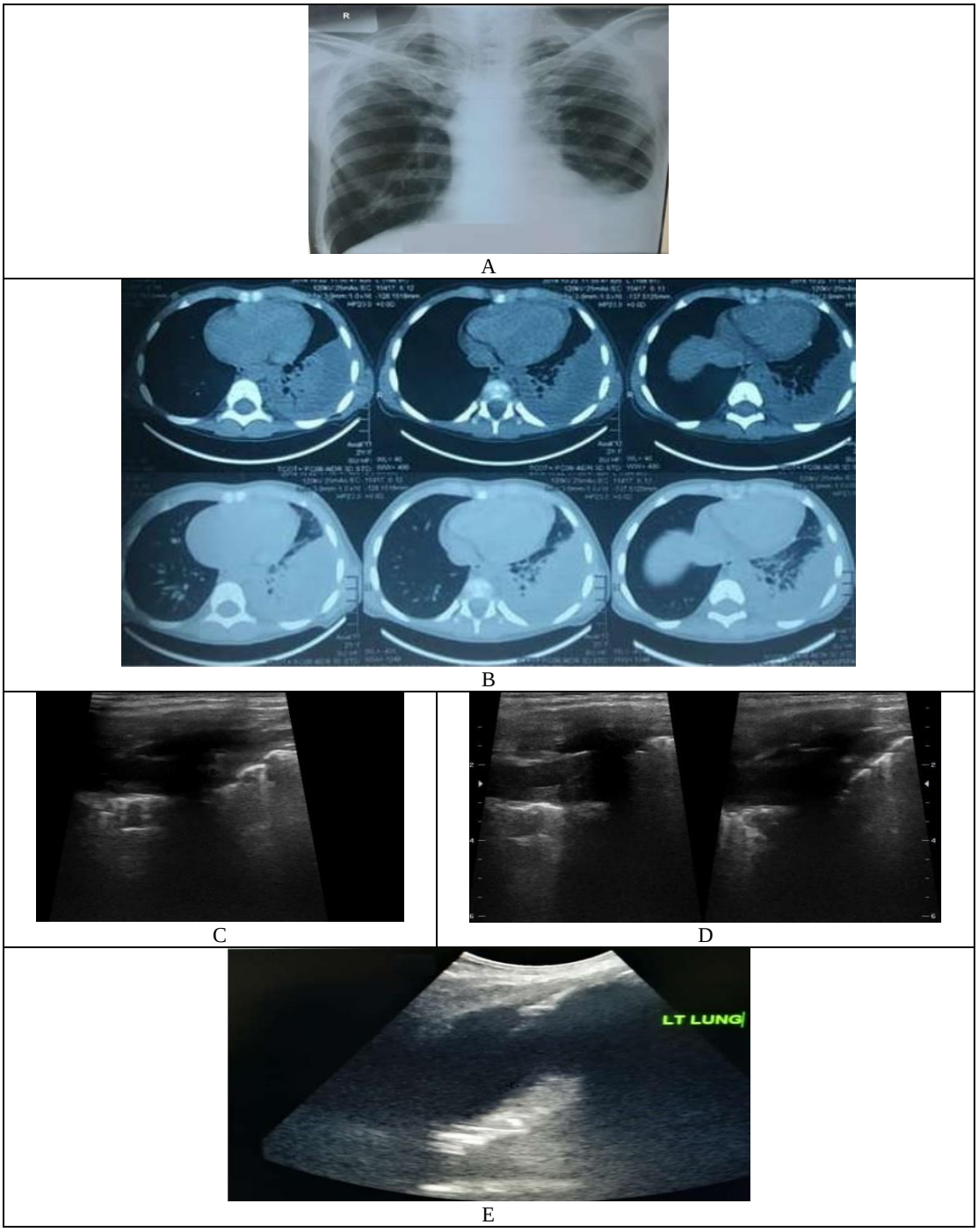


**Figure (2): A 38 years old male patient complaining of fever, cough and RD; A) Chest x ray PA view; non homogenous opacity involve LT lower lung zone, with obliterated LT costophrenic angle by homogenous opacity devoid of lung marking, rising laterally to the LT axilla. B) Non contrast CT chest in lung and Mediastinal windows: consolidation collapse involve LT lower lung lobe, mild LT side pleural effusion. C and D) Lung US: loss of A lines, poorly defined hypoechoic area with irregular outline, solid non aerated airless lung with scalloped pleural borders, mild parapneumonic pleural effusion. E) Follow up by Lung US: shows only mild LT side clear free pleural effusion.**

## DISCUSSION

In our study, LUS was as reliable as CT in detecting cases of pneumonia and in following up positive cases. LUS can substantially decrease the practical delays associated with CXR and avoiding radiation exposure with CT *(Rennis et al., 2017)*. LUS showed positive findings in 93.5% of patients in the form of isoechoic area in 5.5% of patients; dynamic air bronchogram alone in 23.1% of patients and the last one was associated with all other sonographic signs of the studied patients. In agreement with our findings, *Parlamento et al. (2009)*, air bronchogram, was found in 68.8% patients with confirmed pneumonia diagnosis; 50% of the patients with confirmed pneumonia presented with B-lines and dynamic air bronchograms, whereas pleural effusion was found in 34.4% patients.

*Moghawri et al. (2017)* reported that LUS showed positive findings in 96.7% patients in the form of dynamic air bronchogram alone in 19.2% patients, and was associated with all other sonographic signs of the studied patients.

The results of the present study were partially in agreement with those of *Cortellaro et al. (2012)* who stated that pneumonia appeared as a pattern of consolidation with dynamic air bronchogram in 91.3% of patients, and alveolointerstitial syndrome in 52.5%. Pleural effusion was present in 39% of patients with final diagnosis of pneumonia and in 15% of patients without pneumonia, confirming it to be a nonspecific sign.

*Agmy and Ahmed (2013)* performed LUS, CXR, and CT scan on patients presented to the emergency department with suspected pneumonia; air bronchogram was found in 82% patients with confirmed pneumonia. *Alkhayat and Alam-Eldeen (2014)* stated that air bronchogram was seen in 87% of patients and blurred margins, but pleural effusion were present in 54%. This discrepancy with the current study may be attributed to the selection of patients with early pneumonia based on the early clinical data.

During follow up of LUS positive, 54.5% of cases showed total resolution of the pneumonic hepatization, while 32.7% showed regressive course of their sizes, 9.9% showed rather stationary course, while 2.9% showed progression of the extension of the pneumonic hepatization. The associated pleural effusion was resolved in 90%, while 10% of cases showed regressive, stationary and progressive course. These results were in agreement with *Saraya and El Bakry (2017)* concluded that US could be considered as a good diagnostic and follow up tool when pneumonia especially in pediatric age group.

In the current study, CXR showed in comparison to CT sensitivity and specificity of 83.81% and 95.79% for the detection of pneumonia respectively with 95.9% PPV, 83.4% NPV and 81.42% accuracy. LUS showed in comparison to CT sensitivity and specificity of 93.33% and 94.74% for the detection of pneumonia respectively with 95.4% PPV, 92.4% NPV and 93.91% accuracy. These results were in agreement with *Andrea et al. (2016)* where LUS maintained a high diagnostic accuracy compared to CT, but CXR did not.

In agreement with *Moghawri et al. (2017)* where pneumonia was detected in 96.7% patients by LUS. However, there was no significant difference between LUS and chest CT in detecting pneumonia. 96.7% of patients had positive signs of pneumonia with LUS as well as chest CT. Moreover, LUS had a sensitivity and positive predictive value of 97.4%, specificity of 25%, and accuracy of 95% in the detection of pneumonia. Also, *Saraya and El Bakry (2017)* found that, compared to CT, ultrasound showed a sensitivity and specificity of 72.2% and 95% for pneumonia detection respectively with 96.3% PPV, 5% NPV, 3.7% FDR and 80.3% accuracy.

Our data were partially concordant with those of *Cortellaro et al. (2012)* in which the sensitivity of LUS was 96%, whereas that of CXR was 69% of patients.

*Agmy and Ahmed (2013)* reported similar results, where the sensitivity of LUS was 97%. *Parlamento et al. (2009)* also reported that sensitivity of LUS was 96%, whereas that of CXR was 69%. LUS by *Saraya and his colleagues (2017)* showed in comparison to CT sensitivity and specificity of 72.2% and 95% for the detection of pneumonia respectively with 96.3% PPV, 5% NPV, 3.7% FDR and 80.3% accuracy.

CXR by *Fahmy and Kinawy (2018)* showed false-negative examination with no abnormal findings in 18.75% patients and false positive examination in 6.2% patients. The sensitivity was 81.25% (95% CI 73.8-95.6%), while LUS was falsely positive in two cases (6.2%) and false negative in two patients (6.2%). The sensitivity and the specificity of LUS were 87.5% (95% CI 78.9-92.7%) and 89.3% (95% CI 78.3-91.9%) respectively.

In the study of *Amatya et al. (2018)*, LUS was positive with pneumonia, demonstrating a sensitivity of 91%. CXR was positive patients with pneumonia, yielding a sensitivity of 73%. The sensitivity of ultrasound was significantly better than CXR. Specificity of LUS and CXR were similar at 61% and 50% respectively. The positive predictive value of lung ultrasound was 85% and CXR was 78%. The negative predictive value of LUS was 73%, while CXR was 43%. The positive likelihood ratio for diagnosing pneumonia with LUS was 2.34, while the negative likelihood ratio was 0.15. CXR had a positive and negative likelihood ratio of 1.45 and 0.55 respectively.

*Haggag et al., (2019)* found that LUS had a sensitivity of 100% and accuracy of 95% in pneumonia diagnosis compared to the sensitivity and accuracy of 72.3% and 81%, respectively for CXR.

The limitations of our study included a relatively short follow up period and the diagnostic efficacy of US for other complications as lung abscesses and necrotic lesions was not assessed due to lack of such patients.

## CONCLUSION

LUS could be considered as a good diagnostic and follow up tool when pneumonia is suspected, while CT chest may be reserved in cases where ultrasound is technically difficult or when there is discrepancy with clinical findings.

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# دور الموجات الصوتية علي الرئة في تشخيص ومتابعة الإلتهاب الرئوي في البالغين:هل هو فعال؟

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**خلفيـــة البحـــث:** يعتبـــر الإلتهـــاب الرئـــوي مـــن أشـــهر وأخطـــر الأمـــراض المعديـــة المؤديـــة إلـــي إرتفـــاع معـــدل الوفيـــات. ومـــع التوســـع فـــي إســـتخدام الموجـــات الصـــوتية علـــي الرئـــة فمـــن الممكـــن إســـتخدامها فـــي تقيـــيم مـــرض الإلتهـــاب الرئوي.

**الهـــدف مـــن البحـــث:** مقارنـــة إســـتخدام الموجـــات الصـــوتية فـــي تشـــخيص ومتابعـــة الإلتهاب الرئوي في البالغين مقارنة بالوسائل التشخيصية المعتمدة.

**المرضـــي وطـــرق البحـــث:** تمـــت الدراســـة الحاليـــة علـــي مائـــة وثمانيـــة مـــن مرضـــي الإلتهـــاب الرئـــوي (70 مـــن الـــذكور و 38 مـــن الإنـــاث) متوســـط أعمـــارهم هـــو 57.33 + 9.39 عـــام والـــذين تـــم حجـــزهم بقســـم الأمـــراض الصـــدرية، مستشفي الأزهر الجامعي بدمياط في الفترة من مارس وحتي نوفمبر 2019.

بعـــد أخـــذ الموافقـــة الأخلاقيـــة لمكـــان البحـــث والموافقـــة الكتابيـــة مـــن المرضـــي المشـــاركين فـــي الدراســـة تـــم عمـــل أشـــعة عاديـــة علـــي الصـــدر وموجـــات صـــوتية علـــي الرئـــة وأشـــعة مقطعيـــة فـــي خـــلال ســـت ســـاعات مـــن دخـــول المـــريض وتـــم متابعـــة المرضـــي بالموجـــات الصـــوتية علـــي الرئـــة فـــي خـــلال اســـبوعين لمتابعة المرضي المشاركين.

**النتـــائج:** مـــن بـــين مائـــة وثمانيـــة مـــن المرضـــي الـــذين انطبقـــت علـــيهم شـــروط الدراســـة كانـــت نتـــائج الموجـــات الصـــوتية علـــي الرئـــة ايجابيـــة فـــي 93.5% وأثنـــاء فتـــرة المتابعـــة أظهـــرت 54.5% مـــن الحـــالات علامـــات الشـــفاء التـــام بينمـــا 32.7% مـــن الحـــالات أظهـــرت الموجـــات الصـــوتية علـــي الرئـــة انحســـار منـــاطق

الإلتهاب و 9.9% كانت علامات الإلتهاب ثابته بينما كان هناك ثلاث حالات بنسبة 2.9% أظهرت تدهوراً في علامات الإلتهاب الرئوي. كما تم الشفاء التام في 90% من حالات الإنصباب الجنبي المصاحب للإلتهاب الرئوي .

ومقارنة بالأشعة المقطعية فقد أظهرت نتائج الدراسة لحساسية الموجات الصوتية علي الرئة بنسبة 93.3% والخصوصية بنسبة 94.74% ودقة التشخيص بنسبة 93.91%.

**الإستنتاج:** تعتبر الموجات الصوتية علي الرئة جيدة في تشخيص ومتابعة مرضي الإلتهاب الرئوي فقد كانت النتائج قريبة من نتائج الأشعة المقطعية مع إنخفاض التكلفة وتجنب التعرض لمخاطر الأشعة.

**الكلمات الدالة:** الموجات الصوتية علي الرئة، الإلتهاب الرئوي، الأشعة المقطعية.