COMPARATIVE STUDY OF X-RAY AND SONOGRAPHIC FINDINGS IN PNEUMONIA IN A TERTIARY HOSPITAL: A CROSS-SECTIONAL STUDY IN NEPALESE ADULTS

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ABSTRACT

INTRODUCTION

Pneumonia poses a significant global health concern, particularly in developing nations, necessitating accurate and accessible diagnostic methods. Chest x-ray is the conventional imaging modality, albeit with radiation exposure risks. Lung ultrasonography offers a radiation-free alternative and is increasingly used for pneumonia diagnosis, especially in critical care settings. This study aimed to compare the diagnostic capabilities of chest x-ray and lung ultrasonography in nepalese adults with pneumonia, focusing on sensitivity in detecting specific pneumonia features such as consolidation with air bronchogram and pleural effusion.

MATERIAL AND METHODS

A cross-sectional observational study was conducted at a tertiary hospital in Nepal between September 2022 and September 2023. Participants clinically diagnosed with pneumonia underwent both chest x-ray and lung ultrasonography within 24 hours. Data on demographics, symptoms, physical examination, and imaging results were collected and statistically analyzed.

RESULTS

Among 77 participants, predominantly males with a mean age of 54.86 years, pneumonia was detected in 98.7% and 96.1% of cases through ultrasound and x-ray respectively. Ultrasonography exhibited superior sensitivity in identifying consolidation with air bronchogram (67.5% vs. 45.5%) and pleural effusion (55.8% vs. 31.2%) compared to x-ray. Statistical analysis showed significant differences in the detection of consolidation with air bronchogram (p=0.0005) and pleural effusion (p=0.002) between the two modalities.

CONCLUSION

Lung ultrasonography demonstrates comparable or superior sensitivity to chest x-ray in detecting pneumonia, particularly in identifying specific features. Its radiation-free nature and bedside applicability make it a valuable diagnostic tool, especially in resource-limited settings.

KEYWORDS

Chest x-ray, Pleural effusion, Pneumonia, Radiation, Ultrasonography

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INTRODUCTION

Pneumonia, a historic and pervasive lung infection, causes substantial global morbidity and mortality. It claimed 2.5 million lives in 2019, with a higher impact in developing nations.[1] Classified by infection source, microbial proliferation in the lungs triggers inflammatory responses, leading to hypoxemia and radiological changes. Etiologically diverse, pneumonia involves bacteria, viruses, fungi, and more.[2] Clinical diagnosis relies on symptoms and imaging, while severe cases follow ATS criteria.[3] Despite technological advancements, pneumonia diagnosis remains challenging. Transmission primarily occurs via respiratory droplets, influenced by environmental factors.[4,5]

Pneumonia diagnosis relies on clinical history, physical examination and radiological investigation typically x-ray. While CT scans are the gold standard and reserved for complex cases, lung ultrasound has gained popularity particularly in critical care as a readily available and radiation-free modality.[6]

X-ray serves as the initial diagnostic tool, while CT scans reduce overdiagnosis, identifying complications. Both modalities, however, increase radiation risk.[7] x-ray reveals patchy or confluent infiltrates, causing vascular markings obscuration, suggestive of consolidation. Identifying pneumonia's etiological agent from radiological findings is challenging, but patterns (lobar, bronchopneumonia, interstitial) offer predictive insights, with typical bacteria causing lobar pneumonia in community-acquired pneumonia and gram-negative organisms inducing bronchopneumonia in hospital-acquired pneumonia.[8] Atypical pneumonia, caused by organisms like mycoplasma or viruses, exhibits an interstitial pattern.[9]

Pneumonia diagnosis through lung ultrasonography (USG) involves real-time image and artifact interpretation. The abrupt air-tissue transition causes artifacts, reflected as echogenic lines.[10] Normal pleura appears as a single line, exhibiting synchronous movement with respiration. B-line artifacts, vertical lines indicative of alveolar-interstitial syndrome, increase in pneumonia. Consolidation in pneumonia appears heterogeneously hypoechoic, resembling hepatization.[11,12]

Pleural effusion, transudative or exudative, displays varied echogenicity. USG-guided pleural fluid aspiration aids in diagnosis.[13]

Bedside ultrasonography may provide an early diagnosis of pneumonia and resolve transportation difficulties in unstable patients. USG-guided aspiration of pleural effusion may add diagnostic value and early treatment modification. It also helps in the early detection of complications. Thus, it may have a great impact on the diagnosis of pneumonia in resource-poor and low-income countries. So, in this study we intend to compare the chest x-ray and lung sonography findings in the Nepalese adult population with pneumonia, attending outpatient departments or admitted to our hospital.

MATERIAL AND METHODS

The study was conducted between September 2022 and September 2023 at the Department of Radiology and Department of Pulmonology & Critical Care Medicine outpatient (OPD) and inpatient department (IPD). This single-center cross-sectional observational study was started after approval from the Institutional Review Committee with approval number of 148(6-11) E2.2079/2080. Inclusion criteria for case selection encompassed individuals with a clinical diagnosis of pneumonia visiting a Tertiary hospital. Conversely, exclusion criteria comprised patients with chest wall deformities, those aged 18 years or below, and individuals lacking the availability of a chest x-ray or having undergone an x-ray more than 24 hours before the ultrasound (USG) examination.

The sample size calculation was performed using Cochran's formula, with a confidence level of 95% (z-value of 1.96), an expected proportion of patient diagnosed by ultrasound (p) of 89%, a minimum allowable deviation (d) of 7% (0.07), resulting in a minimum sample size (n) of 77.[14] Participants were selected based on inclusion criteria, and clinicians recorded demographic information, symptoms, and physical examination findings. Clinical evaluation was followed by standard x-ray imaging for patients with a clinical diagnosis of pneumonia. Informed written consent was obtained before the sonography procedure, and to minimize bias, x-ray evaluation was performed after ultrasonography.

The chest x-ray technique involved erect posteroanterior (PA) views, with specific criteria for mobile and bed-bound patients. Each lung was divided into upper, middle, and lower zones, and abnormal findings indicative of pneumonia were categorized, including patchy or confluent ill-defined air space opacities, consolidation with air-bronchogram, and reticulations (Figure 1).

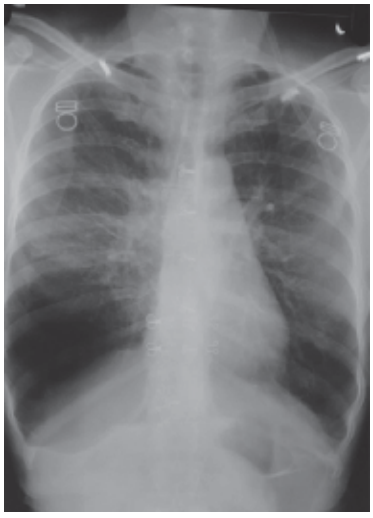

Figure 1. Chest x-ray posteroanterior (PA) view showing the relatively homogenous opacity in the right middle and medial aspect of the right lower zone.

Ultrasonography was conducted using both curvilinear and linear probes, as linear array transducer (7-12 MHz) for superficial structure imaging pleural thickening, subpleural consolidation, and small effusion and pneumothorax, while curved array transducer (2-5MHz) for assessing the large consolidation and quantification of extension of pleural fluid (Figure 2).

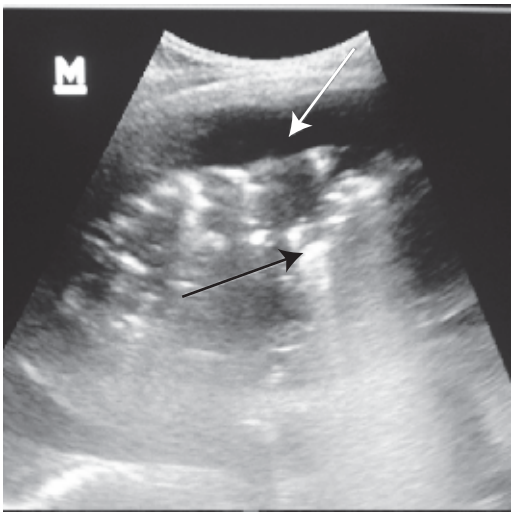

Figure 2. Chest sonography showing peripheral consolidation with echogenic bronchogram (black arrow) and hypoechoic pleural effusion (white arrow)

Transthoracic and transabdominal scans were performed, examining anterior, lateral, and posterior chest regions. Different lung ultrasound findings were recorded in a proforma sheet, categorizing results as normal or abnormal. Normal lung ultrasound was defined as the presence of pleural sliding with A-line, while abnormal findings included consolidation, consolidation with air bronchogram, and the presence of patchy clusters of B-lines. Ultrasonography abnormalities were recorded in both the upper and lower zones of both left and right lungs.

The study emphasized the correlation between lung ultrasound findings and chest x-ray results, with the interval between the two imaging modalities being within 24 hours. Overall, this comprehensive research protocol, encompassing sample size determination, participant selection, imaging techniques, and result categorization, aimed to evaluate the diagnostic capabilities of ultrasonography in comparison to chest x-ray for the detection of pneumonia, providing valuable insights into the potential utility of ultrasound as a diagnostic tool in respiratory care.

The data was collected in the proforma sheet. Chest x-ray and lung ultrasound data were classified into normal and abnormal findings and variables as mentioned above. Thus, the obtained data was entered into Microsoft Excel. Data was analyzed using SPSS version 20.0. Data were statically described in terms of mean and standard deviation of quantitative data. Frequency and percentage calculation of qualitative data was done. Chi-square was conducted to check for the level of significance.

RESULTS

Among the 77 clinically diagnosed cases of participants with pneumonia, most of them were males. The mean age of the participants was 54.86 years. The age distribution of the participants ranged from 19 to 92 years with the highest participant number in the 50-59-year-age group.

Among all the participants with a clinical diagnosis of pneumonia, 96.1% showed abnormality in the x-ray image, and an air bronchogram in the x-ray image was present in 45.45% of participants. X-ray abnormality was seen mostly in the right lower zone followed by the left lower zone. Among all the participants with pneumonia, pleural effusion was detected by chest x-ray in 31.17%. Among all the participants with pneumonia, pleural effusion was detected by chest x-ray in 31.17%. Chest ultrasound showed lung abnormalities in 98.7% of participants with a clinical diagnosis of pneumonia. Consolidation with air bronchogram was seen in 67.53%. of participants. Loss of A-line was seen in the ultrasound examination of all the participants with abnormal ultrasound findings. Among all the participants with abnormal ultrasound findings, 68.3% showed the presence of more than 3-B lines in a cluster.

Most positive ultrasound findings were seen in the right lower zone followed by the left lower zone. Ultrasound was able to detect the pleural effusion in 55.84% of cases. Other associated findings detected in our study were one case of left-sided diaphragmatic hernia, two cases of pleural thickening, and two cases of septated echogenic pleural effusion. Ultrasound showed a higher detection rate for different characteristics of pneumonia (Table 1).

Table 1. X-ray versus ultrasound (USG) findings (n=77)

Characteristics	X ray n (%)	USG n (%)
Abnormal lung findings	74 (96.1)	76 (98.7)
Consolidation with air bronchogram	35 (45.45)	52 (67.53)
Pleural effusion	24 (31.17)	43 (55.84)

Mc Nemar's test showed that compared to x-ray ultrasonography showed statistically significant detection of consolidation with air bronchogram (Table 2). A significant difference in the detection of pleural effusion using both x-ray and Ultrasound as diagnostic modalities was seen (Table 3).

Table 2. Consolidation with air bronchogram detection on x-ray and ultrasonography (n=77)

Consolidation with air bronchogram	USG findings No n (%)	Yes n (%)	Mc Nemar's X^2 Value	*p*-value
X-ray findings				
No	23 (54.76%)	19 (45.24%)	12.19	0.0005
Yes	2 (5.71%)	33 (94.29%)		

Table 3. Pleural effusion detection on x-ray and ultrasonography (n=77)

X-ray findings	USG findings No n (%)	Yes n (%)	Mc Nemar's X^2 Value	*p*-value
Pleural effusion				
No	32 (60.38%)	21 (39.62%)	14.09	0.002
Yes	2 (8.33%)	22 (91.67%)		

All x-ray and USG findings were tested with chi-square test and Yates continuity correction to see if there was any statistically significant difference between males and females. None of the variables were found to be different among male and female sex. Hence, both x-ray and USG findings were not statistically significant among male and female participants (Table 4).

Table 4. Yates's correction for continuity in chest x-ray and Ultrasound characteristics (n=77)

Characteristics	Female n (%)	Male n (%)	X^2 Value	*p*-value
Chest x-ray				
Consolidation with air bronchogram				
No	18 (42.86)	24 (57.14)	0.0005	0.98
Yes	14 (40)	21 (60)		
Pleural effusion				
No	21 (39.62)	32 (60.38)	0.07	0.8
Yes	11 (45.83)	13 (54.17)		
Overall abnormal lung findings				
No	2 (66.67)	1 (33.33)	0.09	0.76
Yes	30 (40.54)	44 (59.46)		
Ultrasound (USG)				
Consolidation with air bronchogram				
No	13 (52)	12 (48)	1.09	0.3
Yes	19 (36.54)	33 (63.46)		
Pleural effusion				
No	14 (41.18)	20 (58.82)	0	1
Yes	18 (41.86)	25 (58.14)		
Loss of A line				
No	2 (66.67)	1 (33.33)	0.09	0.76
Yes	30 (40.54)	44 (59.46)		
Presence of more than 3 B line				
No	11 (45.83)	13 (54.17)	0.07	0.8
Yes	21 (39.62)	32 (60.38)		
Overall abnormal lung findings				
No	0 (0)	1 (100)	0	1
Yes	32 (42.11)	44 (57.89)		

Similarly, t test was applied to all x-ray and USG findings to identify any statistically significant difference with age (Table 5). None of the variables were found to be different from the age of the participants. Hence, x-ray and USG findings were found to be statistically significant with the age of the study participants.

Table 5. T-test with age (n=77)

Characteristics	Mean	t score	*p*-value
X ray			
Consolidation with air bronchogram			
No	51.83	-1.57	0.12
Yes	58.49		
Pleural effusion			
No	54.08	-0.52	0.6
Yes	56.83		
Abnormal lung findings			
No	43.33	-1.45	0.27
Yes	55.32		
USG			
Consolidation with air bronchogram			
No	53.16	-0.58	0.57
Yes	55.68		
Pleural effusion			
No	54.11	-0.18	0.86
Yes	55.21		
Presence of more than 3 B line			
No	57.33	0.74	0.47
Yes	53.74		

DISCUSSION

Radiological investigations play a crucial role in validating clinically diagnosed pneumonia and are instrumental in identifying potential complications or resolution. The baseline examination for pneumonia typically involves x-ray imaging, although its sensitivity is lower compared to the gold standard test, which is the CT scan. Both imaging modalities offer valuable information, but they come with the drawback of radiation exposure. While x-ray entails a considerably lower radiation dose than CT scans, the need for radiation-free investigations regularly is imperative for detecting complications and resolutions without significant health risks and economic burdens.[7]

Lung ultrasonography emerges as a radiation-free alternative for radiological investigations. This modality, capable of being performed at the bedside daily, proves effective in detecting complications and evaluating responses. Our study reveals a slightly higher pneumonia detection rate (98.7% vs. 96.1%) with ultrasound compared to x-ray. Studies conducted by Gonzales et al demonstrate comparable sensitivities for ultrasonography and x-ray at 95% and 91%, respectively.[15]

Additional investigations by Liu et al (94.6% vs. 77.7%), Ye et al (95% vs. 77%), Bourcier et al (95% vs. 60%), and Ticinesi et al (92% vs. 47%) suggest similar sensitivity for lung ultrasound and comparatively lower sensitivity for x-ray.[16-19] Notably, our study indicates comparable, yet superior sensitivity for both x-ray and ultrasonography. This outcome may be attributed to our clinician referring patients for radiological investigations primarily in cases of suspected severe pneumonia or those with complications. The majority of these cases were admitted, indicating a severity bias towards more severe cases rather than mild ones.

In our study, ultrasound identified consolidation with air bronchogram in 52 cases (67.53%), whereas x-ray detected this in 35 cases (45.45%) out of a total of 77 clinically diagnosed pneumonia cases. Notably, 19 cases with ultrasonography identified consolidation with air bronchogram were not visible on x-ray. Statistical analysis using the McNemar test demonstrated significant differences (p=0.0005). However, two cases with air bronchogram detected on x-ray were not identified using ultrasonography. Reissig et al's study showed air bronchogram in 86% of lung ultrasound-positive pneumonia cases, indicating a higher percentage compared to our findings.[20] The lower number of air bronchogram detections in our study may be attributed to the inclusion of hospital-acquired pneumonia cases, primarily caused by gram-negative bacteria and *Staphylococcus aureus.*

Pleural effusion was more frequently observed on ultrasonography (43 cases, 55.84%) compared to chest x-ray (24 cases, 34.17%), and this difference was statistically significant (p=0.002). A similar result was reported by Reissig et al who identified 54.4% basal pleural effusion using ultrasonography.[20] A similar result was also reported by Touw et al who identified (70,70.6%) by ultrasonography compared to chest x-ray (44, 44.4%).[21]

The ability to perform ultrasound at the bedside allowed for immediate findings, overcoming the challenges associated with transporting patients to the x-ray room. Furthermore, ultrasound-guided diagnostic aspiration was feasible. The transportation difficulties and diagnostic delays associated with x-rays, where patients often required wheelchairs and oxygen cylinders, were mitigated by the advantages of ultrasonography.

The study population was heterogeneous with different etiology & stages of disease. Disease-free patients were not included in our study, so we had no control group. A larger sample size would have more accurate results to represent the whole population.

CONCLUSION

Lung ultrasonography emerges as a superior alternative to chest x-ray for pneumonia diagnosis, demonstrating heightened sensitivity in detecting consolidation with air bronchogram and pleural effusion. Its radiation-free nature and bedside applicability render it invaluable, particularly in resource-constrained settings.

CONFLICT OF INTEREST

None

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