Original Article

Diagnostic value of lung ultrasonography compared with chest radiography among children with pneumonia in Rivers State University Teaching Hospital, Port Harcourt

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Abstract

Background: Pneumonia is an acute inflammatory condition affecting the lung alveoli. The current gold standard for diagnosis pneumonia in children is chest radiography (CXR). Lung ultrasound scan (LUS) may be used as a safer diagnostic alternative since it does not use ionizing radiation.

Aim: The study is to evaluate the diagnostic value of LUS compared with CXR among children with pneumonia.

Materials and Methods: It was a prospective cross-sectional study among 100 patients aged between 0 and 5 years, diagnosed with pneumonia. The spectrums of LUS findings were compared with chest radiographic findings of the same patients to ascertain the diagnostic value LUS. The LUS was performed using a 3.5–5.0 MHz convex probe and a high-frequency (7.5–10.0 MHz) linear transducer fitted to a Logic PRO 6.0, general electric ultrasound machine.

Results: The mean age of the participants was 17.6 (±12.4) months with males and females accounting for 60% and 40%, respectively. CXR and LUS detected pneumonia in 78% and 93% of patients respectively ($P = 0.002$). In LUS, the most common findings were subpleural consolidation (73.0%), and pleural-line distortions (66%), while the commonest CXR findings were interstitial opacities (69%), and homogeneous consolidations (37%). The sensitivity and specificity of LUS in this study are 96.2% and 18.2%, respectively, with positive and negative predictive values of 80.6% and 57.1%, respectively.

Conclusion: LUS had a higher positive detection rate than CXR. Its high sensitivity, lack of ionizing radiation, and portability make it a useful first-line imaging modality in the diagnosis and manage pneumonia.

Keywords: Chest radiography, lower respiratory tract infection, lung ultrasonography, lung ultrasound scan, pediatrics, pneumonia

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INTRODUCTION

Pneumonia is a clinical condition characterized by fever and respiratory symptoms as well as evidence of pulmonary parenchyma involvement on auscultation or the presence of opacities on the chest radiograph.[1] It is

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the most common cause of death in children with acute infections worldwide and accounts for 20% of death in Nigerian children.[2,3] It causes more death in children than acquired immunodeficiency syndrome (AIDS), malaria, and measles.[4,5] The World Health Organization (WHO) estimates that there are 156 million new cases of pneumonia each year, worldwide.[6]

The death rate due to pneumonia in developed countries is low (<1/1000 per year).[7] In developing countries like Nigeria, pneumonia is not only more common but more severe.[4,8] In 2008, Nigeria was considered the 5th among nations with the highest number of episodes of clinical pneumonia with an estimated 6.1 million new episodes,[1] with poorer outcomes.[9]

Worldwide, there is no uniform guideline for the diagnosis of pneumonia. Consequently, the diagnosis is predicated on history taking, physical examination, and identification of clinical features such as fever, cough, and breathlessness.[10-12] Confirmation of severe or complicated pneumonia is usually by identification of new infiltrates on CXR.[1,10] However, ionizing radiation coming from CXR may expose children to an increased risk of mutation of their genes and development of cancer later in life, because their tissues are relatively more radiosensitive.[10] An increasingly relevant alternative to CXR for the diagnosis of pneumonia in children is lung ultrasonography (LUS).[10,11] In emergency settings, intensive care units, and several other clinical scenarios, ultrasonography (US) have extensively been used to detect pulmonary consolidations, pleural effusions, pneumothorax, and pulmonary edema due to certain advantages it offers such as its ease of operation, provision of real-time images, and no risk of ionizing radiation.[10,13]

Some other benefits of LUS may include the ability to monitor the progress of pediatric patients with pneumonia more effectively since it is easily repeatable with no side effects,[10,14] This study intends to explore the efficacy of LUS as a safe, bedside alternative tool with no ionizing radiation for diagnosis and monitoring of treatment of pneumonia. The study will also evaluate the diagnostic value of LUS compared with CXR among children with pneumonia. This is necessitated by the fact that the current gold standard for confirmation of severe or complicated pneumonia is the chest radiography (CXR),[1] which is associated with some risk due to the exposure to ionizing radiation in early childhood.[10,15] LUS offers the promise of an alternative diagnostic tool that is cheaper, faster, safely repeatable, more accessible, and ionizing radiation free for diagnosis and monitoring the progress of pneumonia treatment.[13,16] Not only that, bedside LUS has been demonstrated to be both feasible and accurate with experienced clinical sonologist.[16] Coupled with the fact that there is an increase in the cases of acute respiratory tract infection in children in the study environment.[17]

MATERIALS AND METHODS

This was a hospital-based prospective cross-sectional study of children referred to the Radiology Department of Rivers State University Teaching Hospital (RSUTH), Port Harcourt, with a diagnosis of pneumonia made by a consultant pediatrician from July to November 2019. LUS findings were correlated with CXR (current gold standard) findings to ascertain the diagnostic value of the former.

This study was carried out in the Radiology Department of RSUTH formerly known as Braithwaite Memorial Specialist Hospital, Port Harcourt. RSUTH is a 375-bed, government-owned, tertiary hospital located in the old GRA of Port Harcourt town, close to the Rivers State government house. It provides healthcare services to patients from Port Harcourt metropolis, the entire Rivers state as well as neighboring states such as Abia, Imo, Bayelsa, and Akwa Ibom States.

The sample size formula for cross-sectional studies was used in the calculation of the sample size for this study. A study done by Yaguo and Uchenwa-Onyenegecha,[18] showed that the prevalence of pneumonia in Port Harcourt was 6.6%.

$$n = \frac{Z^2 pq}{e^2}$$

Where Z = significant level corresponding to a value of 1.96

p = proportion with outcome of interest (6.6%)

q = 1-p (1–0.066) =0.934

e = level of precision = 0.05

$$n = \frac{1.96^2 \times 0.066 \times 0.934}{(0.05)^2} = \frac{0.2368}{0.0025}$$

= 94.82 = 95

Allowance for 5% nonresponse

Na = n/1-nonresponse

Where Na = adjusted sample size

n = minimum sample size (95)

Nonresponse = 5% (0.5)

Na = 95/1 – 0.05 = 100

The research participants were drawn from patients already clinically diagnosed with pneumonia by Consultant Paediatricians from the Paediatric Department and sent to the Radiology Department, of the RSUTH Port-Harcourt. Patients who met the inclusion criteria for this study were enrolled in the study after obtaining informed written consent from the parents or caregivers to allow their children to participate in the study.

Ethical considerations

Approval was obtained from the RSUTH Research Ethics Committee, before the commencement of the study. Informed consent form was prepared according to Helsinki declaration which states that "the participants must be volunteers and informed participants in the research project" and "every precaution should be taken to respect the privacy of the subjects and the confidentiality of parents' information."

The research participants were informed of the right to withdraw consent for authorization of the use of their imaging findings at any time without reprisal. The use of patients' images was voluntary after obtaining informed written consent as stated above and explaining the benefits and safety of the research to the patients. The analysis of findings was not done at any extra cost as patients were asked to undergo the investigation for their management. Information has been handled with the utmost confidentiality and there was no penalty for patients who did not wish to participate.

Study procedure

Chest radiography

Chest radiography was performed on every patient on the day of presentation to the radiology department. They were first given ID number on arrival in the department. Posterior–anterior chest radiography was performed on patients who were cooperative and able to stand, whereas anterior-posterior radiograph in the supine position was performed in small children, uncooperative patients, and those unable to maintain a standing position. For uncooperative patients, the caregivers were made to wear lead apron and stay close to help the patient maintain good position. After the exposure, the radiographers got the images processed. These images were saved on the console with the ID number while the patients were taken to the ultrasound suit for LUS. The researcher was blinded to the images at this time. Two consultant pediatric radiologists reported the images at the workstation (console) later and these reports were correlated with the LUS findings using the ID number.

Chest radiographic image analysis

1. Normal CXR: This was described as a normal chest radiograph with optimal penetration, good patient positioning, and no active focal lung lesion or infiltrates in the lung fields
2. Consolidations: These were defined as ill-defined homogenous opacities obscuring blood vessels with or without air bronchograms, which may extend to the fissure or pleura but without crossing it and with no volume loss
3. Interstitial opacities: Described as subtle, inhomogeneous, and more widespread opacities found in different regions of the lungs
4. Atelectasis: These were seen as sharply defined opacities obscuring vessels without air-bronchograms with associated volume loss resulting in the displacement of diaphragm, fissure, hila, or mediastinum
5. Nodules or masses: These were defined as discreet, well-marginated, rounded opacities ≤3 cm in diameter
6. Focal reticulonodular pattern: These were described on chest X-ray when there is a combination of reticular pattern (criss-crossing or cobweb-like opacities) and nodularity
7. Hilar adenopathy: This was taken as streaky hazy areas of fullness around the hilum
8. Pleural effusions: Were described as blunting of unilateral or bilateral costophrenic angles with meniscus sign and with or without lamella component.

Chest ultrasonography

LUS were performed immediately after the chest radiographs. The procedure was explained to the parent/caregiver by the researcher and consent sought and received. The chests were exposed and the patients were made to lie on the couch (supine for stable patients and with the head of the bed raised for those of them that were dyspneic). The patients were first made to relax and their cooperation gotten by careful and simple demonstration to convince them that the procedure was not painful. No sedation was used. At this point, children who were not cooperative enough to allow a good study were excluded. Each hemithorax was imaginarily divided into five areas: two anterior, two lateral, and one posterior, for a total of 10 areas bilaterally.

The anterior chest was marked off from the parasternal line to the anterior axillary line. This zone was further split into an upper region (from the clavicle to the second–third 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. A moderate amount of prewarmed ultrasound gel was applied on the chest wall and LUS was performed according to the said divisions. A 3.5 MHz convex probe which allows visualization and quick survey of the deep structures of the lungs was first used. This was followed by a high-resolution 7.5 MHz linear probe which was used to provide a detailed depiction of any pleural or peripheral lung abnormality. The transducer was maneuvered until a rib interspace was located. It was then glided horizontally and vertically to the extent possible to allow the broadest sweep through the area being imaged. Placing the arm above the patient's head to maximize the rib interspace and turning them from one side to the other to assess the posterior area enhanced scanning.

Scanning was performed during quiet respiration, to allow for assessment of normal lung movement. When lesions of interest were identified, the freeze and track-ball buttons were used accordingly to examine such in detail. After the LUS, the patients' chest was wiped clean of the ultrasound gel and the caregiver assisted in dressing them up.

Data analysis

Data analysis was performed using the IBM Statistical Package for Social Sciences (SPSS) windows version 20.0 statistical software (SPSS Inc, Chicago, Illinois, USA). Data were also presented appropriately using tables and charts. Categorical variables generated from the study were expressed as counts and percentages while the numerical variables were summarized using mean and standard deviation, median, and range. The validity of lung US in relation to chest radiography was determined using sensitivity, specificity, predictive values (positive/negative), false-negative error rate, and false positive error rate. McNemar Chi-square was used to determine a significant difference in the positive detection rate (of pulmonary infiltrates) between LUS and CXR. Statistical significance was set at $P < 0.05$.

RESULTS

The study was conducted on 100 children, aged between 0 and 60 months (5 years), with a provisional diagnosis of pneumonia made by pediatric certified fellows and referred to the radiology department for CXR confirmation. The mean age was 17.60 (±13.20) months with those aged 12 months and below been the majority (57%), while those aged between 37 and 48 months occupied the least proportion (5.0%) as shown in Table 1. Sixty of the children were boys while 40 were girls as shown in Figure 1.

The ultrasonographic chest findings were normal findings, B-lines (comet tail artifacts), subpleural consolidation, air-bronchograms, pleural line distortions, and pleural effusions as shown in Figures 2-7, respectively.

According to Figure 8, subpleural consolidation, pleural line distortions, comet tail artifacts (B-lines), pleural thickening, and pleural effusion in the ratio of 73%, 66%, 51%, 15%, and 5%, respectively. Air-bronchograms were found in 56% of all the children but in 76.7% of children with subpleural consolidation as also shown in Figure 8.

The CXR radiographic finding shows that interstitial opacity was the most frequently identified lesion (69%) whereas atelectasis was the least (1%) while cardiomegaly was found incidentally in 4 of the children [Figure 9].

Interstitial opacities were the commonest findings on CXR in most children and were identified in 69% of the children. These opacities were subtle and generalized in nature, affecting more than a lung zone in 55% of the children. CXR also showed homogeneous consolidations in 37% of the children. 27% of these children had these lesions

Table 1: Gender and age distribution of participants

Age (months)	Male (%)	Female	Total (%)	Mean age±SD (months)
0–12	35	22	57	8.93±1.84
13–24	13	9	22	18.41±4.63
25–36	5	3	8	31.88±2.70
37–48	5	3	8	41.00±4.00
49–60	2	3	5	52.60±2.30
Total	60	40	100	17.60±13.20

SD – Standard deviation

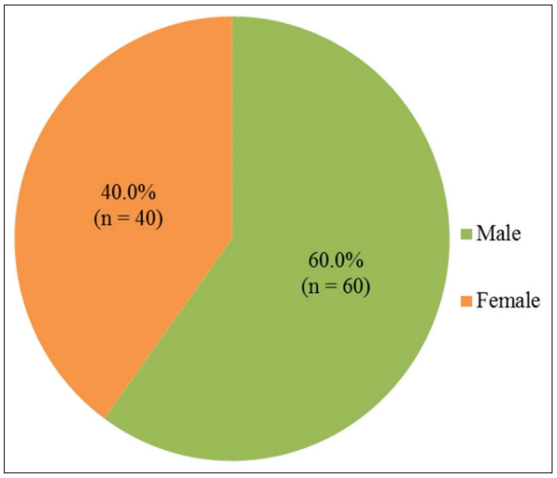

Figure 1: Gender distribution of participants

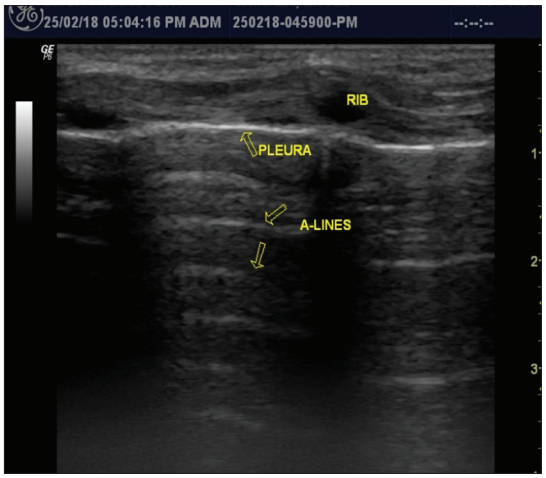

Figure 2: Transverse lung ultrasound scan using curvilinear transducer showing the normal lung, pleural line and A-lines

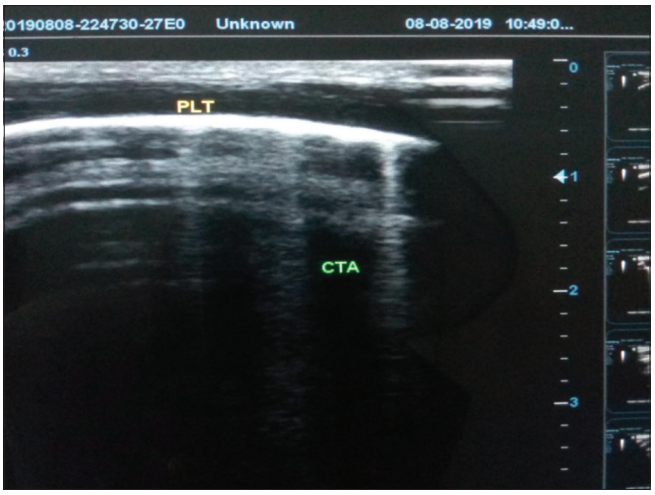

Figure 3: Transverse lung ultrasound scan using high frequency transducer showing comet tail artefacts (B-lines)

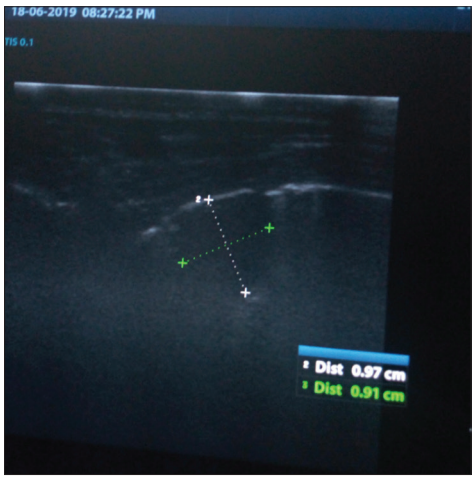

Figure 4: Lung ultrasound scan showing sub-pleural consolidation (arrow)

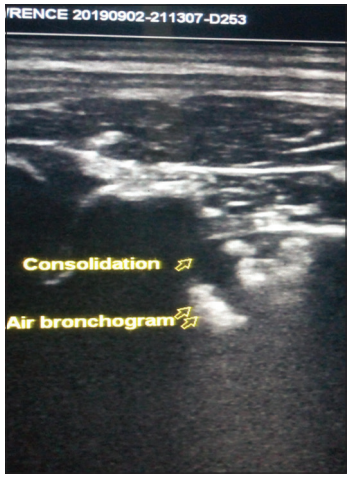

Figure 5: Lung ultrasound scan showing air bronchograms (tiny echogenic particles) within irregular sub-pleural consolidation

in both lungs and mostly in the mid-lung zones. Nodular opacities which appeared rounded and well marginated were seen in 21% of the children; in 19/21 of these (90.5%), it was present in both lung fields. All children with nodular opacities also had interstitial opacities. The commonest findings on LUS were subpleural consolidations (73%), pleural line distortions (66%), air-bronchograms (56% overall and 76.7% in children with consolidation), and B-lines (51%).

Table 2 summarizes that lesions such as subpleural consolidation, air-bronchograms, and pleural thickenings were identified more in the upper and middle lung zones. Pleural line distortions were more widespread, involving more than one zone. Pleural effusions were seen in the lower zones.

Figure 10 shows that the positive detection rate of lesions on LUS was higher than CXR. While LUS was able to detect lesions in 93 children, CXR was only able to do so in 78 children. The study showed a McNemar $\chi^2 = 9.333$ and a $P = 0.02$.

Figure 11 shows the commonest findings on lung ultrasound scan and chest radiograph among children with pneumonia. According to the figure, interstitial opacities and homogeneous consolidations were the commonest finding among both the males and female participants.

Figure 12 shows that solitary lesions were seen more on CXR than LUS. Most of the children with pneumonia had 2 or more different types of lesions on LUS, for instance, a child with pneumonia could have subpleural consolidation and pleural line distortion or B-lines, whereas, the same child could have homogeneous consolidation only as the only abnormal finding on CXR.

From Table 3, we can deduct the following: The sensitivity, specificity, positive predictive, and negative predictive

Table 2: Location of lesion reported by ultrasound scan of children with pneumonia

Findings from US	Upper zone, *n* (%)	Middle zone, *n* (%)	Lower zone, *n* (%)	Generalized, *n* (%)	Apex, *n* (%)	No lesion, *n* (%)
Sub-pleural consolidation	28 (28.0)	27 (27.0)	11 (11.0)	4 (4.0)	3 (3.0)	27 (27.0)
Pleural line distortions	9 (9.0)	14 (14.0)	6 (6.0)	37 (37.0)	-	34 (34.0)
Air bronchogram	20 (20.0)	25 (25.0)	10 (10.0)	1 (1.0)	-	44 (44.0)
Comet tail sign	6 (6.0)	30 (30.0)	8 (8.0)	7 (7.0)	-	49 (49.0)
Pleural thickening	6 (6.0)	3 (3.0)	3 (3.0)	3 (3.0)		85 (85.0)
Pleural effusion	-	-	5 (5.0)	-	-	95 (95.0)
Fluid bronchogram	0	0	0	0	0	100 (0.0)
Vascular pattern	0	0	0	0	0	100 (0.0)

US – Ultrasound scan

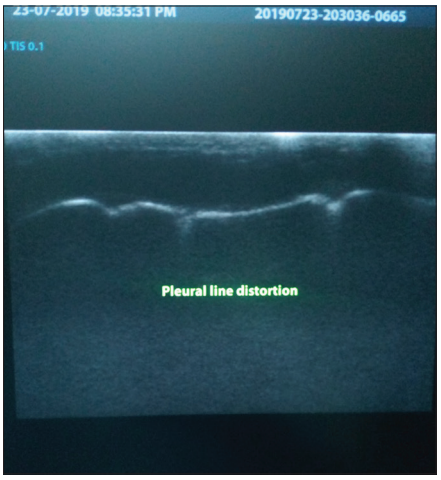

Figure 6: Lung ultrasound scan showing pleural line irregularities/ distortions

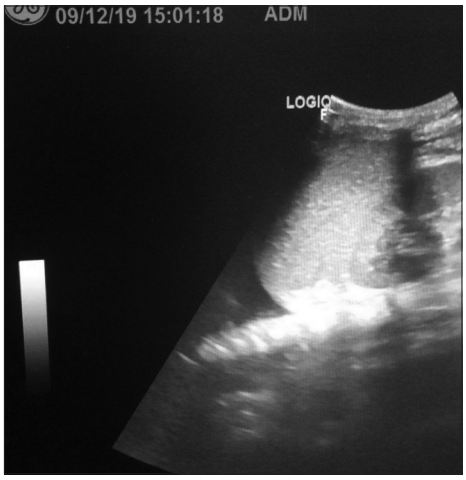

Figure 7: Lung ultrasound scan showing right-sided pleural effusion.

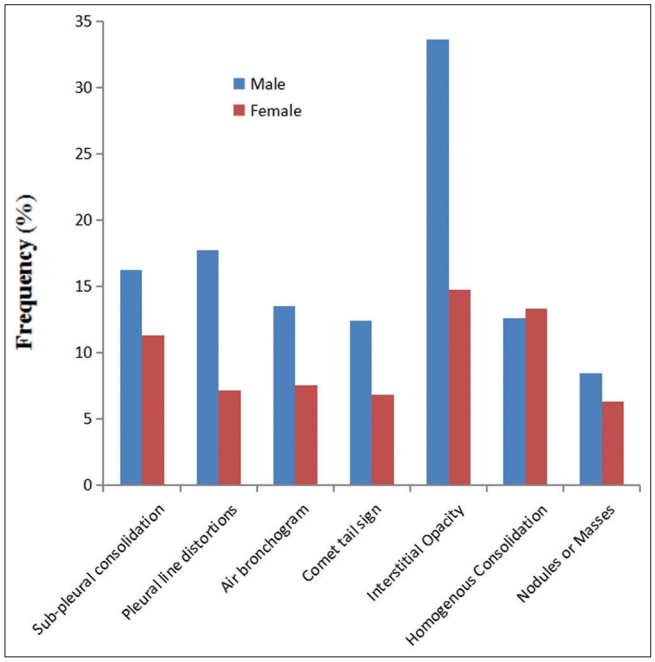

Figure 8: Spectrum of lung ultrasound findings of participants

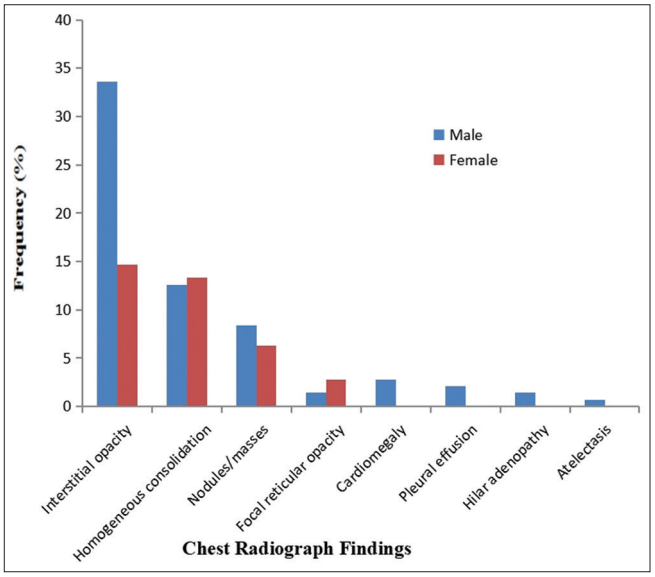

Figure 9: Spectrum of chest radiographic (CXR) findings of participants

values (NPVs) of LUS in this study were 96.2%, 18.2%, 80.6%, and 57.1%, respectively. The accuracy, false-positive error rate, and false-negative error rate are, respectively, 79.0%, 81.8%, and 3.8%.

CXR was used as the gold standard in this study and LUS was compared against it. Therefore, children who had positive findings on both CXR and LUS were considered true positives and were 75 in number. Children with positive findings on LUS and negative on CXR were considered false positives and were 18 in number. Children with no

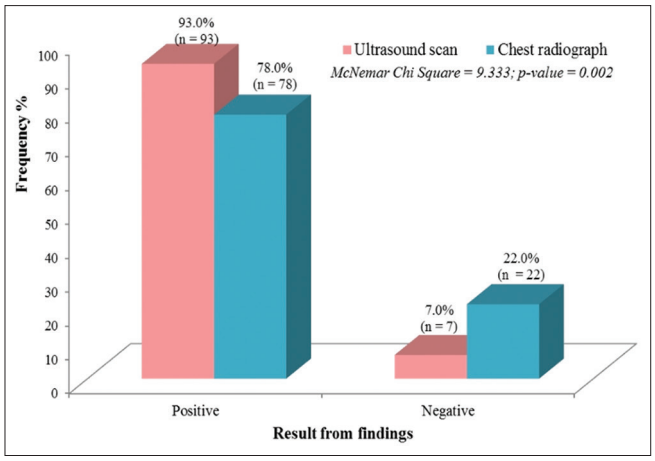

Figure 10: Grouped bar charts showing distribution of result from ultrasound scan and chest radiograph findings among children with pneumonia

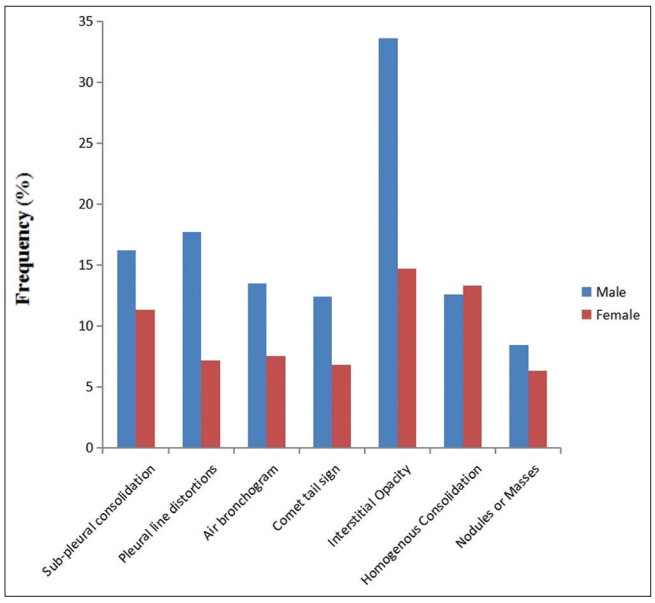

Figure 11: Commonest findings on lung ultrasound scan and chest radiograph among children with pneumonia

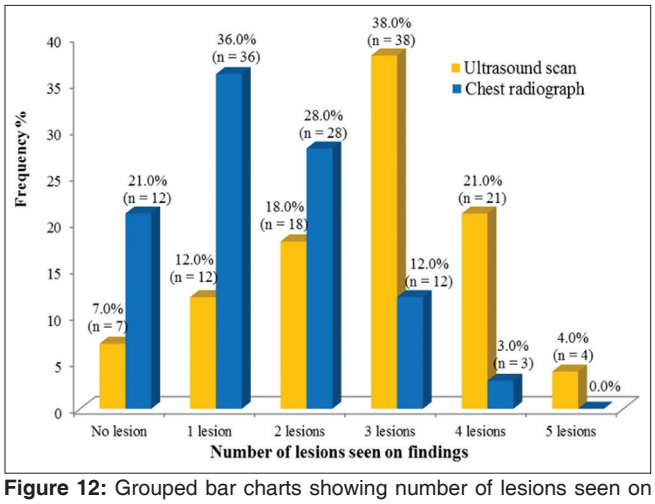

Figure 12: Grouped bar charts showing number of lesions seen on lung ultrasound scan and chest radiography (CXR) per individual child with pneumonia

Table 3: Comparison of result from findings between lung ultrasound and chest radiograph

Lung ultrasound	Chest radiograph		Total
	Positive	Negative	
Positive	75 (true positive)	18 (false positive)	93
Negative	3 (false negative)	4 (true negative)	7
Total	78	22	100

identifiable lesion on both CXR and LUS were classified as true negatives and were 4 in number. Children with positive findings on CXR and negative findings on LUS were considered false negatives and were 3 in number.

$$\text{Accuracy} = \frac{\text{True Positive} + \text{True Negative}}{\text{Total}} \times 100$$

$$= \frac{75+4}{100} \times 100 = 79.0\%$$

$$\text{Sensitivity} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}} \times 100$$

$$= \frac{75}{75+3} \times 100 = 96.2\%$$

$$\text{Sensitivity} = \frac{\text{True Negative}}{\text{True Negative} + \text{False Positive}} \times 100$$

$$= \frac{4}{4+18} \times 100 = 18.2\%$$

Positive Predictive Value (PPV)

$$= \frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}} \times 100$$

$$= \frac{75}{75+18} \times 100 = 80.6\%$$

Negative Predictive Value (NPV)

$$= \frac{\text{True Negative}}{\text{True Negative} + \text{False Negative}} \times 100$$

$$= \frac{4}{4+3} = 57.1\%$$

False Positive Error Rate

$$= \frac{\text{False Positive}}{\text{False Positive} + \text{True Negative}} \times 100$$

$$= \frac{18}{18+4} \times 100 = 81.8\%$$

False Negative Error Rate

$$= \frac{\text{False Negative}}{\text{False Negative} + \text{True Positive}} \times 100$$

$$= \frac{3}{3+75} \times 100 = 3.8\%$$

DISCUSSION

Pneumonia is an acute inflammatory condition affecting the alveoli and characterized by symptoms such as cough, fever, chest pain, and dyspnea as well as evidence of pulmonary parenchymal involvement either by physical examination or the presence of infiltrates on chest radiograph.[1] Globally, pneumonia is a leading cause of morbidity and mortality among children <5 years of age, accounting for more than 90% of acute lower respiratory tract-related deaths.[6] The World Health Organization (WHO) estimates that there are 156 million new cases of pneumonia each year, worldwide.[6] Pneumonia accounts for 20% of childhood mortality in Nigerian children[2,3] causing more deaths than Malaria, Measles, and AIDS.[4,5]

Pneumonia is commoner in male children. In a study conducted by Mustaphar MG,[19] at the University of Maiduguri Teaching Hospital, childhood pneumonia was found to be more common in males with a male-to-female ratio of 1.5:1.0. Oyejide and Osinusi.,[20] also had similar findings in a study conducted in a community in Ibadan Nigeria. Nonetheless, these findings corroborate the findings of Jokinen *et al*.,[7] who demonstrated a strong male prevalence of pneumonia below the age of 5 years (11.2 out of 1000 among males and 5.7 out of 1000 among females). In the index study, the ratio of male to female children diagnosed with pneumonia is 1.5:1.0 which agrees with the aforementioned studies.

Both chest CXR and LUS findings in this study show increased incidence of pneumonia in children below the age of 2 years accounting for 79% (79) of the cases with progressive reduction in incidence with increasing age up to 5 years. This is in agreement to the findings of Oyejide and Osinusi,[20] in a longitudinal community-based study carried out in Idikan community, in Ibadan, Nigeria. They found out that the incidence of childhood pneumonia was highest in the first 2 years of life and decreased with increasing age. Teep *et al*.,[21] in another study titled risk factors of pneumonia in children, demonstrated that lower age is an independent determinant of pneumonia in the pediatric population. Radiological changes were also more frequently seen in children who were malnourished or immune compromised due to prolonged periods of illness in this study. This finding is corroborated by findings in a study by Lim *et al*.,[22] in which they demonstrated an increased incidence of pneumonia in both immunocompromised and malnourished children. Overall, this study showed that most children with detectable abnormal findings on both LUS and CXR had more abnormalities detectable on LUS than on CXR. For instance, for a case with only patchy interstitial opacities on CXR, LUS could detect pleural line distortion and thickening as well as sub-pleural consolidation and B-lines.

The spectrum of abnormal CXR findings in this study includes interstitial opacities 69 (69%), homogenous consolidation 37 (37%), nodularities 21 (21%), focal reticular opacities 6 (6%), pleural effusion 3 (3%), hilar adenopathy 2 (2%), and atelectasis 1 (1%). Four (4%) children had cardiomegaly (incidental finding). On the other hand, the spectrum of abnormal LUS findings include, subpleural consolidation 73 (73%), pleural line distortion 66 (66%), air bronchograms 76.7%, B-lines 51 (51%), pleural line thickening 15 (15%), and pleural effusion 5 (5%). Caiulo *et al*.[10] and Copetti and Cattarossi[11] in two different studies, both reported a higher percentage of children with lung consolidation detected by LUS than CXR. This study had a corroborated the above findings with a positive rate of detection of subpleural consolidation on LUS and CXR being, respectively, 73% and 37%. It must be stressed, however, that lung consolidation may have a variety of causes including infections, pulmonary embolism, compression atelectasis, and lung contusion.[23]

In the index study, air-bronchograms which appear as hyperechoic round shadows when air is trapped in the bronchioles were present in about 76.7% of cases. This is close to the findings in previous studies which range from 78% to 97%.[10,11,24] Fluid-bronchograms represent exudate-packed conducting airways. They occur less frequently than the air-bronchograms with a positive detection rate ranging from 0% to 8.1% in previous studies.[24] In this study, fluid-bronchograms were not identified. This maybe because children below 12 months formed the bulk of the study population as already stated above. Such children have smaller conducting airways and the exudate obstructs the airways more easily, sometimes even collapsing the lungs.[15]

Caiulo *et al*.,[10] found the positive rate of pleural line distortion of 20.2%. In this study, the positive rate of pleural line distortion was 66% which is relatively high. This maybe because of high level of atmospheric pollution in our environment which have been implicated in rising incidence of acute respiratory tract infections.[17,25]

Diffuse comet tail sign (B-lines) in LUS are a sign of alveolar interstitial syndrome. However, these artifacts are

also present around an isolated alveolar consolidation.[23] In the index study, the positive rate of B-lines around the consolidation is 51% which is close to previously reported data in children. Ho *et al*.,[15] reported a positive rate of B-lines of 50.9% while Caiulo *et al*.,[10] reported a positive rate of 59%. In the diagnosis of pneumonia by LUS, consolidation is accompanied by air-bronchograms within the lesion and B-lines around this consolidation can increase the specificity of a diagnosis of pneumonia.[26] Nonetheless, the disappearance of B-lines or change in pattern of multiple lines in the follow-up by LUS is a sign of re-aeration.[27]

Radiological modalities available for diagnosis and confirmation of pneumonia include chest magnetic resonance imaging (CMRI), chest computerized tomography (CCT) scan, chest radiography (CXR), and lung ultrasonography (LUS).[28] Of these, CCT remains the most sensitive and accurate tool for definitive diagnosis.[29,30] However, the limitations of CCT scanning include high ionizing radiation dose, high cost and absence in some areas as well as frequent need for sedation.[30,31] Reduction of ionizing radiation is of particular importance in children as they are more susceptible to the risk of ionizing radiation.[32] CMRI provides both functional and morphological information and is an attractive nonionizing radiation-emitting alternative diagnostic tool in children with pneumonia.[33] It can measure clearer than CXR in segmental and bronchopneumonia.[34] However, access to magnetic resonance imaging facility is limited and a significant proportion of young children develop dorsal atelectasis, associated with sedation, which may mask pathological processes.[35]

Jain *et al*.,[36] in their study found out that CXR, though widely recognized as a crucial step in the diagnosis of pneumonia, has several shortcomings and is not 100% sensitive or 100% specific. One of the major setbacks is the emission of ionizing radiation associated with CXR.

Ionizing radiations like X-rays have been officially classified as "carcinogen" by the WHO's International Agency for Research on Cancer, the Agency for Toxic Substances and Disease Registry of the Centers for Disease Control and Prevention, and the National Institute of Environmental Health Sciences.[37] Aside that limitation, intra and inter observer variations among radiologists during the interpretation of the same chest radiographs was a major setback.[38]

Previous articles have demonstrated that LUS is a reliable diagnostic instrument in both childhood and adult Pneumonia.[11,39,40] Copetti and Cattarossi[11] showed that LUS is more sensitive than CXR in the diagnosis of childhood pneumonia. Accordingly, LUS is suggested as a "clinically useful diagnostic tool in pediatric patients suspected pneumonia" in the recent "international evidence-based recommendations for point of care lung ultrasound[23]" Esposito *et al*.[41] showed a very high diagnostic performance of LUS (as compared to CXR) in children with suspected pneumonia with sensitivity, specificity, positive predictive, and NPVs of 97.9%, 95.4%, 94.0%, and 98.1% respectively. Reali *et al*.,[42] also showed similar high sensitivity and specificity of 94% and 96%, respectively. In the index study, the high sensitivity values of LUS (96.2%) in children agree with previous studies. However, its specificity and positive predictive value (PPV) are relatively low, being, respectively, 18.2% and 80.6%. The explanation could be found in a study by Ho *et al*.,[15] where they noted that CXR-negative and LUS-positive findings (classified as false positive), adversely affect the results of specificity and PPV calculations. This study had high false-positive LUS findings (false positive because CXR against which it is compared is the gold standard). In addition, 57% (57) of the children were infants while 79% were <2 years. Infants are more likely to have bronchiolitis with negative CXR and positive LUS findings. This agrees with a study by Caiulo *et al*.[10] comparing LUS and CXR findings in bronchiolitis. They found that 17.3% of children (with bronchiolitis) with abnormal LUS findings had normal CXR. This agrees with the finding in the index study where 18% of children with abnormal LUS findings had normal CXR. It is important to stress that in studies where sensitivity and specificity of LUS in children with suspected pneumonia are high, older children form the bulk of the population. In the study by Esposito *et al*.,[41] the mean age and standard deviation were 5.6 (±4.6) years while it was 4.0 (±3.0) years with a range of 1–16 years in the study conducted by Reali *et al*.[42] The clinical implication of the findings in this index study could be very noteworthy, possibly implying that the younger the population of children with suspected pneumonia (and abnormal LUS findings) the more the likelihood of bronchiolitis as a differential diagnosis.

This study confirms that LUS is a simple, noninvasive and reliable tool, not inferior to CXR in identifying pleural and pulmonary parenchymal irregularities in children with suspected pneumonia. LUS has the potential of reducing practical delays associated with plain CXR when used as a bedside tool in pediatric wards. Currently, LUS is not the gold standard for the radiological diagnosis of pneumonia and is not included in its diagnostic workup. CXR is the gold standard at present.[1,10]

CONCLUSION

The index study shows that the most common LUS findings were subpleural consolidation, pleural line distortions, and comet-tail sign (B-lines), while the most common findings on CXR were interstitial opacities, homogeneous consolidations, and nodular opacities. It also shows that LUS has a high sensitivity and is not inferior to CXR in detecting pulmonary and pleural irregularities in children with suspected pneumonia. It is reliable, noninvasive, rapid, and repeatable without the risk of exposure to ionizing radiation. The high sensitivity of LUS and the portability of the ultrasound machine suggest that the device can be used as a first hand tool in the pediatric wards for the diagnosis and management of pneumonia. CXR which is the current gold standard can be reserved for cases that are either equivocal or require further assessment.

Recommendation

The study recommends that LUC instead of CXR should be requested by pediatricians while investigation patients for pneumonia to minimize the exposure of children to ionizing radiation.

Limitations of the study

There are a few identified limitations in this study. First, CXR was used as the gold standard in confirmation or exclusion of true positive cases of pneumonia although it is well known that chest computerized tomography (CCT) is a more sensitive and specific imaging method.[18] The high number of false-positive LUS findings could be traced to this fact. However, CCT could not have been used due to obvious ethical reasons related to radiation exposure.

Second, majority of the children who formed the bulk of the study population were <12 months, with some on oxygen, unlike many previous studies where older children formed the bulk of the study population.[42,43] LUS cannot reliably differentiate between pneumonia and bronchiolitis in this age; the differentiation is more clinical and radiographical[7,8,42] than sonographical. In addition, LUS can miss consolidations that do not reach the pleura.[23]

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Conflicts of interest

There are no conflicts of interest.

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