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The Role of Lung Ultrasonography as a Diagnostic Tool in Different Pediatric Lung Diseases in Benha University Hospital

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ABSTRACT
Background: Lung illnesses account for the majority of problems that affect newborns and children, as well as the main cause of death for children under the age of five. Thus, prompt and precise diagnosis is critical to effective therapy and better patient outcomes for those suffering from lung conditions. This study aimed to assess the role of lung ultrasonography as a diagnostic tool in different pediatric lung diseases.
Patients and Methods: This case-control study was conducted at Pediatric Department, Benha University Hospital during the period from December 2022 to December 2023. It included 120 participants presenting with symptoms and signs suggesting lung diseases, the average age of the participants was 5.27 years with a standard deviation of 2.21.
Results: Chest X-ray was (100%) diagnostic in different studied lung diseases, except for bronchitis where it was diagnostic in 69.7% of cases. Chest ultrasound was diagnostic in 84.8% of patients with bronchitis and (75%) of patients with pneumonia, while it was 100% diagnostic in cases with pneumonia complicated with effusion, collapse, and pneumothorax. In diagnosis of bronchitis, based on chest radiography (CXR), as a reference standard, US had overall sensitivity, specificity, and diagnostic accuracy of 100%, 50% and 84.8% respectively. Kappa statistics revealed significant moderate agreement between LUS and X-ray (kappa =0.582, p<0.001). In diagnosis of pneumonia, US had overall sensitivity, and diagnostic accuracy of 75% and 75% respectively.
Conclusion: LUS has good sensitivity and specificity in diagnosing and following up common pediatric lung diseases at least as accurate as chest X-ray.
Keywords: Lung Ultrasonography, Pediatrics, Lung Diseases, Benha.

INTRODUCTION
Pediatricians still face a global issue in the form of lung disorders. Not only in developing nations but also in the West, pulmonary infections are a leading cause of illness and mortality [(1)].

The mainstay of pediatric chest imaging remains to be plain chest X-rays. For the imaging diagnosis of all disorders, a chest computed tomography scan is regarded as the gold standard. It is neither cheap nor accessible in the critical care unit, therefore it must be transported to the radiology department, which could be hazardous. Furthermore, it subjected the patient to significant ionizing radiation doses [(2)].

When it comes to diagnosing some diseases, most notably pneumothorax, where ultrasound has a sensitivity of 92% compared to computed tomography, it compares favorably with the scan. Furthermore, it is easier and faster than a chest X-ray or CT because it is easily accessible at the bedside and reasonably priced [(2)].

When it comes to the diagnosis and identification of infant respiratory disorders, particularly respiratory distress syndrome and transient tachypnea, lung ultrasonography seems to be a more successful method. Additionally, lung ultrasonography can distinguish between the causes of premature newborns who have long-term oxygen requirement, which is a useful practical feature. Lung ultrasonography examinations on a regular basis are crucial for managing pulmonary illness in the NICU [(3)].

AIM OF THE WORK
The aim of our study was to assess the role of lung ultrasonography as a diagnostic tool in different pediatrics lung diseases.

PATIENTS AND METHODS
This cross-sectional study included 120 participants presenting with symptoms and signs suggesting lung diseases, collected from Pediatric Department, Benha University Hospital during the period from December 2022 to December 2023.

Ethical approval
Before participating in the study, all patients' guardians gave their written informed consent. This consent was approved from the Institutional Review Board (IRB), Faculty of Medicine, Benha University. The work has been completed in compliance with the Declaration of Helsinki, the World Medical Association's code of ethics for human subjects' research.

Both sexes, ages between two and twelve, suggestive histories (fever, cough, sputum production, dyspnea, and/or pleuritic chest discomfort), and general and local physical symptoms suggestive of lung illnesses were the inclusion criteria. Exclusion criteria were; patients or their guardian refused to share in the study, comorbidities other than lung diseases, obese patients with thick chest wall, patients with subcutaneous emphysema.

All patients were subjected to:

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- Comprehensive history taking, encompassing name, age, gender, hospital admission date, place of residence, and socioeconomic status, smoking habits in the family, past history of RD**.**
- Symptoms of any respiratory tract infection including the onset and duration of each, e.g., fever, dyspnea, apnea and rhinorrhea and tachypnea**.**
- Anthropometric measurements including weight, height, BMI**.**
- Vital sign measurement: Respiratory rate, heart rate, oxygen saturation, and temperature.
- Chest examination; air entry, wheezes, subcostal retractions, and crepitation.

Laboratory investigations all blood samples were taken in the morning after an overnight fast including:

Complete blood count (CBC): After applying antiseptic to the skin, a puncture was made to extract 1 cm of blood. It was then gathered and placed in a test tube with 20µl of EDETA. The sample was quickly examined with a Sysmexxf 500 cell counter to ascertain the platelet count, total and differential WBC count, hemoglobin level, hematocrit value, and RBC count.

C-reactive protein (CRP): On a Siemens machine, latex agglutination was used to do it. After applying antiseptic to the skin, a puncture was made to extract 3 cm of blood. Following the collection of blood in a plain test tube, the serum was separated and examined using Turbox Plus after the blood was centrifuged for ten minutes at 1500 rpm and given time to clot. Results exceeding 10 mg/l were deemed positive.
Erythrocyte sedimentation rate (ESR) and renal and liver function tests were also made.

Radiological investigations:

- Posteroanterior X-ray was done by experienced physician. Lung ultrasonography examination was done by experienced physician who was blinded to the chest X-ray. CT chest was done for some selected patients.
- Then, four groups according to the radiological finding were present:
- Cases with plain chest X-ray positive and US positive for lung disease diagnosis.
- Cases with plain chest X-ray negative and US positive for lung disease diagnosis.
- Cases with plain chest X-ray positive and US negative for lung disease diagnosis.
- Cases with plain chest X-ray negative and US negative for lung disease diagnosis.

Lung ultrasonography (chest ultrasound): Using LOGIQ V5 device, chest US was performed according to Lichtenstein BLUE protocol.

Statistical Analysis

Data were entered, checked, and processed using Epi-Info version 6 and SPSS for Windows version 8 (Dean, 2006). The 5% level was the set threshold of significance (p-value). When the error probability was smaller than 0.1% ($p < 0.001$), the result was considered highly significant. Chi square, Standard Deviation (SD), were used. It was used when comparing two means.

RESULTS

Table 1 shows that the average age of the participants was 5.27 years, 80 participants (66.67%) were males, and 69 patients (57.5%) reside in rural areas. A total of 54 (45%) participants reported passive smoking habits and (12.5%) of patients had positive family history of lung diseases.

Table (1): Demographic data in the studied group

	Studied patients (N =120)
Age (years)	
mean±SD	5.27 ± 2.21
median (range)	5 (2-12)
Gender *(N. %)*	
Male	80 (66.67%)
Female	40 (33.33%)
Residence *(N. %)*	
Urban	51 (42.5%)
Rural	69 (57.5%)
Passive smoking *(N. %)*	
Absent	66 (55%)
Present	54 (45%)
Family history *(N. %)*	
Absent	105 (87.5%)
Present	15 (12.5%)

Table 2 shows that (66.7%) of patients with pneumonia had hepatic consolidation, all patients (100%) in effusion group had para pneumonic effusion, and all patients (100%) with pneumothorax had absent lung sliding, absent B lines, absent lung pulse sign and absent A line.

Table (2): Distribution of CUS findings frequency among pneumonia group

Chest US findings	Studied patients (N =45), *(N. %)*
Hepatic consolidation	16 (66.7%)
Dynamic air bronchogram	11 (45.8%)
Fluid bronchogram	6 (25 %)
Pleural line irregularities	4 (16.7%)
Numerous compact B lines	9 (37.5%)
Vasculature by colored doppler	4 (16.7%)
Effusion group	
Hepatization/consolidation	26 (89.7%)
Dynamic air bronchogram	20 (69%)
Fluid bronchogram	18 (62.1%)
Multiple B lines	28 (96.6%)
Para pneumonic effusion	29 (100%)
Pneumothorax group	
Absent lung sliding	16 (100%)
Absent B lines	16 (100%)
Lung point sign	6 (37.5%)
Absent lung pulse sign	16 (100%)
Absent A lines	16 (100%)

Table 3 shows that all cases (100%) with lung collapse had consolidation with irregular borders and static air bronchogram with absence of vasculature by colored doppler.

Table (3): Distribution of CUS findings frequency among collapse group

Chest US findings	Studied patients (N =18) *(N. %)*
Presence of consolidation with irregular borders	18 (100%)
Presence of static air bronchogram	18 (100%)
Absence of vasculature by colored doppler	18 (100%)

Table 4 shows that there was highly statistically significant difference between cases with different diagnosis as regards chest X-ray diagnostic role.

Table (4): Distribution of cases in each studied group as regards chest X-ray role

Clinical diagnosis	Chest X-ray		P-value
	Diagnostic *(N. %)*	Non-diagnostic *(N. %)*	
Bronchitis (n=33)	23 (69.7%)	10 (30.3%)	**<0.001**
Pneumonia (n=24)	24 (100%)	0 (0%)	
Pneumonia with effusion (n=29)	29 (100%)	0 (0%)	
Collapse (n=18)	18 (100%)	0 (0%)	
Pneumothorax (n=16)	16 (100%)	0 (0%)	

Table 5 shows that there was highly statistically significant difference between cases with different diagnosis as regards chest US diagnostic role.

Table (5): Distribution of cases in each studied group as regards chest ultrasound role

Clinical diagnosis	Chest ultrasound		P-value
	Diagnostic *(N. %)*	Non-diagnostic *(N. %)*	
Bronchitis (n=33)	28 (84.8%)	5 (15.2%)	**<0.001**
Pneumonia (n=24)	18 (75%)	6 (25%)	
Pneumonia with effusion (n=29)	29 (100%)	0 (0%)	
Collapse (n=18)	18 (100%)	0 (0%)	
Pneumothorax (n=16)	16 (100%)	0 (0%)	

Based on CXR, as a reference standard, US had overall sensitivity, specificity, and diagnostic accuracy of 100%, 50% and 84.8% respectively. Kappa statistics revealed significant moderate agreement between LUS and X-ray (Kappa =0.582, p<0.001) as showed in table 6.

Table (6): Comparison between LUS and X-ray in diagnosis of bronchitis

		Chest X-ray		Total	Kappa	P-value
		Positive	Negative			
Chest US	Positive	23	5	28	0.582	<0.001
	Negative	0	5	5		
Total		23	10	33		

Based on CXR, as a reference standard, US had overall sensitivity, and diagnostic accuracy of 75% and 75% respectively as showed in table 7. Based on CXR, as a reference standard, US had overall sensitivity, and diagnostic accuracy of 100% each as showed in table 8. Based on CXR, as a reference standard, US had overall sensitivity, and diagnostic accuracy of 100% each as showed in table 7. Based on CXR, as a reference standard, US had overall sensitivity, and diagnostic accuracy of 100% each as showed in table 7.

Table (7): Comparison between LUS and X-ray

		Chest X-ray		Total
		Positive	Negative	
Diagnosis of pneumonia				
Chest US	Positive	18	0	18
	Negative	6	0	6
Total		24	0	24
Diagnosis of pneumonia with effusion				
Chest US	Positive	29	0	29
	Negative	0	0	0
Total		29	0	29
Diagnosis of collapse				
Chest US	Positive	18	0	18
	Negative	0	0	0
Total		18	0	18
Diagnosis of pneumothorax				
Chest US	Positive	16	0	16
	Negative	0	0	0
	Total	16	0	16

DISCUSSION

As regards gender distribution; 80 patients (66.67%) were male, and 40 (33.33%) were female. While as regards residency, 51 (42.5%) resided in urban areas, while 69 (57.5%) resided in rural areas. A total of 54 (45%) participants reported passive smoking habits and (12.5%) of patients had positive family history of lung diseases.

Karkar *et al.* [(4)] studied 120 cases of pneumonia, of whom 77 (64.4%) were male and 43 (35.6%) were female. The ages of the subjects varied, with the mean being 24.11± 7.42 months.

Of the patients, 85 (71.1%) lived in cities, but 35 (28.9%) lived in rural areas. Also, **Mohamed *et al.*** [(5)] **(2018)** studied the accuracy of LUS as compared to chest X-ray (CXR) in diagnosing community-acquired pneumonia (CAP) in 139 children. They reported that the mean age was 3.28 ± 0.62 year, they were 91 (65.5%) males and 48 (34.5%) females, 72 (51.79%) were rural, 57 (41.00%) were urban and 10 (7.19%) were slum, 22 (15.82%) had positive family history of respiratory distress and 117 (84.17%) were negative.

In the current study, in pneumonia group, 66.7% of patients with pneumonia had hepatic consolidation, 45.8% had dynamic air bronchogram, 25% had fluid bronchogram, 16.7% had pleural line irregularities, 37.5% had numerous compact B lines and 16.7% had vasculature by color Doppler. In pneumonia with effusion group, 89.7% of patients with pneumonia complicated with pneumonia had hepatization/consolidation, 69% of patients had dynamic air bronchogram, 62.1% had fluid bronchogram, 96.6% had multiple B lines and all patients (100%) had parapneumonic effusion.

Elmashad *et al.* [(6)] found that LUS could detect more obvious findings in pneumonia cases compared with nonpneumonia cases, as seen in 43/45 (95.6%) patients with consolidation and 39/45 (86.7%) patients with air bronchogram, whereas multiple B-lines in 22/45 (48.9%) patients. In addition, fluid bronchogram finding was positive in 14/45 (31.1%) patients, pleural effusion in 11/45 (24.4%) patients, but pleural line abnormalities in only 8/45 (17.8%) patients. In contrast, LUS detected one case each with subpleural hepatization and pleural line irregularity in nonpneumonia cases. **Basanti *et al.*** [(7)] investigated the diagnostic accuracy of lung ultrasonography for pediatric community-acquired pneumonia (CAP). Pleural effusion, lung consolidation, air-bronchogram, and pleurisy were all evident.

In our study, in pneumothorax group, all patients (100%) with pneumothorax had absence of B lines, lung sliding, and lung pulse sign and absent A line, while 37.5% of patients with collapse had lung point sign. **Scialanga *et al.*** [(8)] assessed children experiencing acute chest discomfort to determine how accurate LUS was in identifying PNX. Thirty of the seventy-seven children (or 39%) suffered thoracic trauma; twenty of the seventy-seven children (or 26%) had pneumonia, with or without pleural effusions; and thirty of the seventy-seven children (or 39%) had interstitial lung disease, such as viral bronchitis. Myocarditis/pericarditis was the final diagnosis made in 7 out of 77 children, or 9.1%.; and 13 out of 77 children (16.9%) had a pneumothorax (PNX).

Scialanga *et al.* [(8)] revealed the "barcode sign" in 13 patients, and a lung point, indicative of PNX, was present in 12 (92.3%) of the patients. In five (38.5%) patients with a small PNX, Between the anterior axillary and parasternal lines on the anterior chest surface was the lung point. In two of these patients, the lung point was located in the right hemithorax; in three other cases, it was located in the left hemithorax. In eight cases (61.5%), the PNX was found to be large. The lung point was located in the left hemithorax in four cases, the right hemithorax in three, and the lateral surface of the thorax following the midaxillary line in seven cases.

In our study, chest X-ray was (100%) diagnostic in different studied lung diseases, except for bronchitis where it was diagnostic in 69.7% of cases. Regarding the diagnostic value of chest X-rays, there was a highly statistically significant difference between cases with different diagnoses role (P <0.001).

Chest ultrasound was diagnostic in 84.8% of patients with bronchitis and (75%) of patients with pneumonia, while it was 100% diagnostic in cases with pneumonia complicated with effusion, collapse, and pneumothorax. Regarding the chest US diagnostic role, there was a highly statistically significant difference between cases with different diagnoses (P <0.001).

Karkar *et al.* [4] revealed that 114 patients (95.6%) with LUS tested positive for consolidation, 104 patients (86.7%) positive for air bronchograms, 37 patients (31.1%) positive for fluid bronchograms, 68 patients (56.7%) positive for multiple B-lines, and 29 patients positive for pleural effusion (24.4%)

Biagi *et al.* [9] discovered that all cases of concurrent bacterial pneumonia with bronchiolitis, of which 5/25 were subcentimetric pneumonia, could be identified by LUS. As stated by **Milliner and Tsung**[10], Sixty-four percent (16/25) of the pneumonia patients showed sonographic consolidation in the posterior lung zones. Six patients had two concurrent consolidations identified by LUS that were linked to bronchograms; as a result, there were 31 ultrasound consolidations compatible with pneumonia, 21 of which (67.8%) were located in the posterior lung zones. Ten instances had false-positive results from LUS, with subcentimetric pneumonia accounting for all but one of them. Respiratory syncytial virus pneumonia was the final diagnosis made in the lone patient whose ultrasonography showed a false-positive consolidation greater than 1 cm.

Elmashad *et al.* [6] when diagnosing pneumonia in children, chest radiography (CXR) and chest ultrasound (CHUS) were compared. 95.6% of pneumonia cases had LUS; a statistically significant percentage. **Talwar *et al.*** [11] contrasted the community-acquired pneumonia (CAP) diagnosis accuracy of PLUS and CXR in hospitalized children. In 141 cases, or 95.27 percent, a PLUS diagnosis was made. Lung ultrasonography (LUS) in these clinically and radiologically diagnosed patients suggested pneumonia in 123 (123/128; 96.09%). In 20 (13.51%) clinically diagnosed patients, CXR was unable to detect pneumonia; however, in 18 (90%) of these patients, PLUS was able to detect pneumonia, which was verified by CT chest imaging.

US demonstrated overall sensitivity, specificity, and diagnostic accuracy of 100%, 50%, and 84.8% in the diagnosis of bronchitis using CXR as the reference standard. The results of Kappa statistics indicated a moderate but significant agreement between LUS and X-ray (kappa = 0.582, p<0.001). US demonstrated an overall sensitivity and diagnostic accuracy of 75% and 75%, respectively, in the diagnosis of pneumonia. In the diagnosis of effusion, collapse, and pneumothorax related to pneumonia, US exhibited 100% diagnostic accuracy and overall sensitivity.

Karkar *et al.* [4] revealed that, when it came to the diagnosis of the cases under study, LUS and CXR had a statistically significant good agreement.

Yan *et al.* [12] found that 65 (7%) false-positive findings from lung ultrasonography and 89 (9%) false-positive results (P=0.053) from chest X-rays, were obtained for the diagnosis of pneumonia.

Mohamed *et al.* [5] found that, out of 139 patients who received a clinical diagnosis of pneumonia, 126 (90.64%) had CXR suggestive of the illness, and 136 (97.84%) had LUS suggestive of the illness (p=0.01). Eleven patients with negative CXR showed LUS findings suggestive of pneumonia with a clinical history consistent with pneumonia (p <0.01), compared to one patient with negative LUS and abnormal CXR. In three patients with a clinical course compatible with pneumonia, LUS was negative, and in thirteen patients, CXR was unable to identify any abnormalities. There was a noticeable difference.

Biagi *et al.* [9] found that LUS in their investigation that CXR and LUS had a good connection (rs 0.64) for the diagnosis of bacterial pneumonia. Similar results were found in other recent investigations, demonstrating a high degree of agreement between the two approaches with kappa values ranging from 0.64 to 0.89.

Shetty and Sabapathy[13] stated that lung ultrasonography was performed on the patients to ascertain the alterations observed in pediatric pneumonia. Of these, 19.5% (n=41) had abnormal lung ultrasonography results. Only one (4.8%) of the 21 pneumonia cases revealed abnormalities on ultrasonography. Twenty individuals (14.4%) with severe pneumonia revealed abnormalities on ultrasonography. Twenty (40%) patients of extremely severe pneumonia revealed abnormalities on ultrasonography.

Basanti *et al.* [7] 48 patients (sensitivity 96% by CXR), 49 patients (sensitivity 98% by LUS), and all 50 patients (100%) by CT chest showed evidence of lung consolidation. They came to the conclusion that chest ultrasonography is a less demanding method for interpreting, safe, readily available, portable, sensitive, and specific for early CAP diagnosis. In order to lessen the prevalence of CAP in underdeveloped nations, community-based screening programs may include chest ultrasonography, which appears to be extremely promising in the screening of CAP.

Scialanga *et al.* [8] discovered that the lung point had a 98.4% negative predictive value, a 100% positive predictive value, a 100% specificity, and a

92.3 sensitivity for the detection of PNX. For the identification of PNX, the "barcode sign" had 100% negative predictive value, 100% positive predictive value, 100% specificity, and 100% sensitivity. They demonstrated how LUS might identify and rule out PNX in kids who were assessed in the pED for sudden chest pain.

Talwar *et al.*[11] discovered that five patients who did not have a positive PLUS result for pneumonia also had a positive CXR and a positive CT chest scan. An area of opacity in the right upper lobe was observed on CXR in two of these patients (area of consolidation in the anterior region of the right upper lobe on CT chest). On a CT scan of the chest, two patients had left upper zone opacity and posterior left upper lobe involvement. They came to the conclusion that PLUS is a sensitive, targeted test that should be done on children who are hospitalized with CAP before CXR.

Several advantages of LUS were observed throughout our study and from the literatures; it is non – invasive, safe, non- ionizing, easy to learn and perform, bedside with no need for sedation or transportation, no or low cost if the machine is available, simple to interpret with no time delay and dynamic with real –time evaluation. These advantages make this procedure ideal. LUS has good sensitivity and specificity in diagnosis and follow up of several pediatric lung diseases at least as accurate as chest radiography.

Limitations of the study

This study represents our first experience in using LUS for diagnosis of pediatric lung disorders. Our passion to cover all areas was associated with relatively small number of cases for each particular illness. More precise, larger number will be our next step in this field. False negative cases missed by LUS, despite clinical and radiological findings, decreased our trust in the modalities to less than 100%. Further larger, wider scale studies are still needed before clear recommendation to replace chest X-ray can be released.

CONCLUSION

LUS has good sensitivity and specificity in diagnosing and following up common pediatric lung diseases at least as accurate as chest X-ray. It reduces radiation exposure in this age group by providing improved detection of consolidations and other lung abnormalities associated with pneumonia. It may also replace X-ray chest imaging as the preferred next step of investigation. Concomitant use of clinical findings, laboratory investigations with LUS may reduce the need for frequent repeat of CXR. LUS is a reliable, accurate, safe modality for repeated monitoring of lung diseases in pediatrics.

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