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Assessment of Pneumonia in Children with Acute Bronchiolitis Using Lung Ultrasound

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ABSTRACT

Background: Bronchiolitis is a lower respiratory tract infection (LRTI), resulting from the inhalation of virus-containing droplets. Chest ultrasound is not considered in the diagnostic algorithm for assessment of pneumonia in children with acute bronchiolitis even though its usefulness has been tested in several studies in the last years as an emerging diagnostic tool. **Objective:** The aim of the present study was to assess the diagnostic accuracy of lung ultrasound (LUS) for the detection of pneumonia in children with acute bronchiolitis.

Patients and methods: This cross-sectional study included children from birth to 24 months of age admitted to Pulmonology and Allergy Unit, Pediatric Hospital of Zagazig University. Children were diagnosed with bronchiolitis according to the American Academy of Pediatrics guideline. All patients underwent posteroanterior chest X-ray (CXR) because of clinical suspicion of concomitant bacterial pneumonia, persistent oxygen saturation ($SatO_2$) < 90%, and asymmetric breath sounds on auscultation.

Results: The mean age of the studied cases was 4.19 months and 86.7% of them were from 1 to 6 months. The most common clinical findings among the studied group was wheezes (96.7%) followed by fever (60%). 63.3% of the studied group had moderate respiratory distress, 26.7% had mild and 10% had severe. Abnormal findings of X-ray were peri-bronchial thickening, lung consolidation and hyperinflation (13.3%, 13.3% and 10% respectively). Abnormal findings of ultrasound were compact B line, subpleural lung consolidation and irregular pleural lines (53.3%, 26.7% and 3.3% respectively).

Conclusion: Lung ultrasonography is more accurate and sensitive than chest X-ray to diagnose suspected cases of pneumonia in the pediatric age group. LUS is a sensitive and highly specific diagnostic tool in children with community-acquired pneumonia (CAP).

Keywords: Acute Bronchiolitis, CXR, Lung Ultrasound, Pneumonia.

INTRODUCTION

Bronchiolitis is a viral lower respiratory tract infection (LRTI) that affects children less than 24 months and represents the leading cause of hospitalization in infants [(1)]. The main responsible pathogen is Respiratory Syncytial Virus (RSV), with infection typically occurring as recurrent seasonal epidemics [(2)]. There is evidence that RSV is the predominant virus associated with bronchiolitis and pneumonia in young children. However, in older age groups the role of other viruses, especially rhinoviruses becomes more pronounced [(3)].

Nevertheless, there is high variation in the use of diagnostic tests across hospitals and chest X-ray (CXR) is still performed in about 50% of bronchiolitis, mainly to diagnose or rule out bacterial pneumonia. It has been shown that children with clinical bronchiolitis are more likely to receive antibiotics when radiography is performed owing to similar radiographic appearance of infiltrate and atelectasis [(4)].

Despite these attempts, no significant enhancement into clinical practice has been reached. Lung Ultrasound (LUS) is a feasible, portable, easy to learn, and nonionizing radiation technique. In the last decades, it has become an emerging diagnostic tool for diagnosing pneumonia in children and adults, with remarkable sensitivity and specificity [(5)].

At present LUS is not included in the diagnostic work-up of bronchiolitis. In fact, although few studies describe the sonographic characteristics of bronchiolitis, none have investigated the role of LUS in children with clinical bronchiolitis and suspected pulmonary bacterial co-infection [(6)].

To date, the limited number of studies included in meta-analyses did not allow for subgroup analyses comparing the diagnostic accuracy of LUS for childhood pneumonia performed by novice versus advanced sonographers. It is currently unknown whether LUS's accuracy is significantly dependent on sonographer experience [(3)].

Therefore, this study aimed to assess the diagnostic accuracy of LUS for the detection of pneumonia in children with acute bronchiolitis.

PATIENTS AND METHODS

A cross sectional study was conducted in Pulmonology and Allergy Unit, Pediatric Department, Zagazig University Hospital (ZUH) during the period from May 2021 to October 2021. We have chosen 30 cases of patients with acute bronchiolitis admitted to ZUH within 6 months, 15 cases female and 15 cases males (5 cases/month), which fulfill inclusion criteria with mean age = 4.19±3.32 months.

Inclusion criteria: (1) Children from birth to 24 months of age, both sexes, admitted to Pediatric Hospital of Zagazig University. (2) Children diagnosed with bronchiolitis according to the American Academy of Pediatrics guideline[(7)] and undergone posteroanterior CXR because of clinical suspicion of concomitant bacterial pneumonia. (3) Bacterial pneumonia was

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suspected in patients with at least one of: fever >= 38.5 °C or > 38 °C for 2 or more days, persistent oxygen saturation ($SatO_2$) < 90%, asymmetric breath sounds on auscultation, - White Blood Cells (WBC) > 15,000/mmc and/or C-Reactive Protein (CRP) > 6 mg/dl. (4) The diagnostic gold standard for the study was according to the basis of clinical presentation, laboratory tests, CXR and clinical course following British Thoracic Society Guidelines recommendations [(8)]. (5) The criterion to define pneumonia on LUS was the finding of an hypoechogenic area with poorly defined borders and compact underlying artifacts perpendicular to the pleural line, called B lines[(9)]. The pleural line is less echogenic in the area interested by consolidation and lung sliding is reduced or absent, similar to prior studies [(10)].

Exclusion criteria: (1) Chronic respiratory disease (i.e. bronchopulmonary dysplasia). (2) Congenital heart diseases. (3) Hospitalized patients with congenital or acquired immunodeficiency. (4) Severe neuromuscular disease. (5) Patients whose parents refused to participate in the study.

Operative Assessment:

All children enrolled were subjected to complete history taking from their relatives including name, age, sex, date of hospital admission, residence, socioeconomic state, and number of days of admission. Clinical examination included heart rate, respiratory rate, temperature, oxygen saturation. Local respiratory examination as wheezes, crepitation, air entry and subcostal retractions and grading of respiratory distress.

Severity of respiratory distress by Downes' Score [(11)]: (1) Mild bronchiolitis: score 0–3. (2) Moderate bronchiolitis: score 4–6. (3) Severe bronchiolitis: score 7–10.

Laboratory investigation:

Complete blood count performed using 1 cm of blood was taken by IV. Blood was collected in a test tube containing 20 µl of EDETA and analyzed as soon as possible using Sysmexxf 500 cell counter for RBC count, hemoglobin level, hematocrit value, WBC count (Total and differential) and platelet count.

C-reactive protein (CRP): was done by latex agglutination, on Siemens machine. Skin was rubbed with antiseptic and 3 cm of blood was taken by IV, blood was collected in a plain test tube, left to clot, then centrifuged for 10 minutes at 1500 rpm, serum was separated and analyzed using Turbox plus. Results were considered positive above 10 mg/l.

Chest X-ray: X ray was performed in the Radiology Unit of the hospital.

Chest Ultrasound: Chest US was performed in the Pulmonology and Allergy Unit of the hospital Using LOGIQ V5 device chest US was performed. The anterior points are called upper BLUE points and the anteromedial points lower BLUE points, after the protocol. The posterior points are called the 'posterolateral alveolar and/or pleural syndrome point', or PLAPS point. In addition, the protocol includes optional identification of the 'lung point'.

Upper anterior point: This corresponds to the base of the middle and ring fingers on the upper hand. It lies over the upper lobe.

Lower anterior point: This is the middle of the palm on the lower hand (close to the nipple in a man). It lies over the middle or lingular lobe. These points will miss the heart on the left.

Posterolateral point: From the lower anterior point move laterally and posteriorly as far as possible behind the posterior axillary line (limited by the bed). It lies over the lower lobe. With a curvilinear probe rib shadows can then be minimized by rotating the probe slightly to lie between the ribs (cephalad will still be on the left of the image).

Probe selection:

Linear probe: Linear probe was used for examination of superficial structures as pleura to detect pleural effusion, pneumothorax and irregular pleural lines.

Curvilinear probe: Curvilinear probe was used for examination of deep structure as lung parenchyma, interstitial tissue and diaphragm because of the good penetration and large sector width to detect lung consolidation, B-lines and diaphragmatic movement. More comprehensive scanning techniques have also been described and are recommended for advanced practitioners.

Ethical consent:

An approval of the study was obtained from Zagazig University Academic and Ethical Committee. Parent of every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

Data were imported into Statistical Package for the Social Sciences (SPSS version 20.0) software for analysis. According to the type of data; qualitative were represented as number and percentage, and quantitative continues group were represented by mean ± SD, median, and range. Validity test was used. P value was set at <0.05 for significant results and <0.001 for high significant result.

RESULTS

The present study showed the mean age of the studied cases was 4.19±3.32 months and 86.7% of them were from 1 to 6 months. Regarding sex half of them were males and half were females. Urban residence was more predominant (53.3%) and more than three quarters of them were of low social class (76.7%). Finally, only 6.7% had positive family history of asthma **(Table 1).**

Table (1): Sociodemographic data of the studied group

Variable	N=30	
Age:(months) **mean ± SD** **(Range) median**	 4.19±3.32 4 (0.83-18)	
Variable	**No**	**%**
Age distribution: **1-6 months** **7-12 months** **13-18 months**	 26 3 1	 86.7 10 3.3
Sex: **Male** **Female**	 15 15	 50 50
Residence: **Rural** **Urban**	 14 16	 46.7 53.3
Socioeconomic class: **Low** **Moderate**	 23 7	 76.7 23.3
Family history of asthma: **Positive** **Negative**	 2 28	 6.7 93.3

The most common clinical findings among the studied group was wheezes (96.7%) followed by fever (60%) **(Figure 1)**.

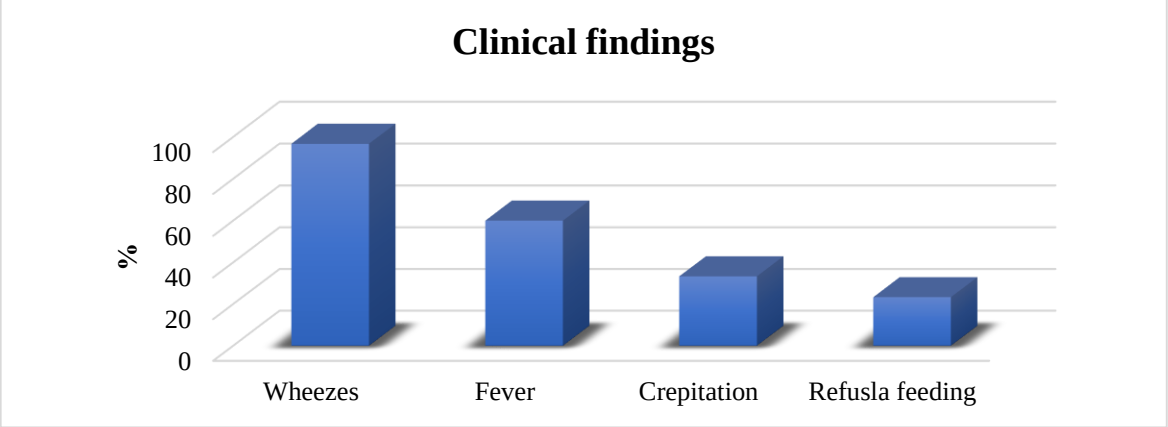

Figure (1): Bar chart for clinical data among the studied group.

About 63.3% of the studied group had moderate respiratory distress **(Figure 2)**.

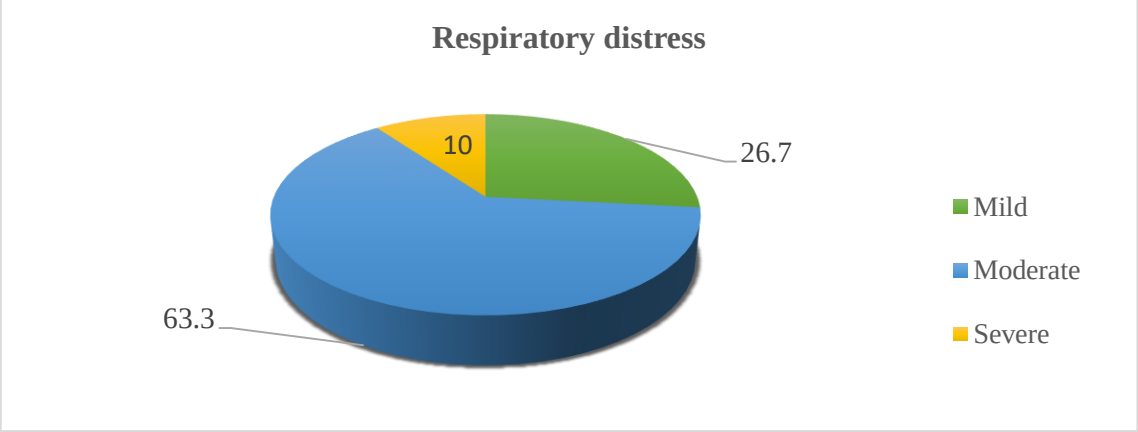

Figure (2): Pie chart for grading of respiratory distress among the studied group

Results of the laboratory investigations are shown in table 2. CRP was 13.86 ±35.28 mg/dl **(Table 2)**.

Table (2): Laboratory investigations among the studied group

Variable	(N=30) Mean± SD
Hb: (gm/dl)	10.07±1.43
WBCs: ($x10^3/mm^3$)	11.81±2.35
Neutrophils: ($x10^3/mm^3$)	3.37±0.28
Lymphocytes: ($x10^3/mm^3$)	7.4±1.77
Platelets: ($x10^3/mm^3$)	357±19.3
CRP: (mg/dl)	13.86±3.28

About 21 cases had normal X ray. Abnormal findings of X ray were Peri-bronchial thickening, lung consolidation and hyperinflation **(Table 3)**.

Table (3): X-ray findings among the studied group

X-ray findings	(N=30)	
	No	%
Normal:	21	70
Peri-bronchial thickening:		
Positive	4	13.3
Negative	26	86.7
Lung Consolidation:		
Positive	4	13.3
Negative	26	86.7
Hyperinflation:		
Positive	3	10
Negative	27	90

About 10 cases had normal US. Abnormal findings of ultrasound were compact B line, subpleural lung consolidation and irregular pleural lines. No cases had pleural effusion, occult pneumothorax or focal multiple B-Lines **(Table 4)**.

Table (4): Ultrasound findings among the studied group

Ultrasound findings	(n=30)	
	No	%
Normal Pattern	10	33.3
Compact B Lines:		
Positive	16	53.3
Negative	14	46.7
Subpleural lung Consolidation:		
Positive	8	26.7
Negative	22	73.3
Irregular Pleural Lines:		
Positive	1	3.3
Negative	29	96.7
Pleural Effusion:		
Positive	0	0
Negative	30	100
Occult Pneumothorax:		
Positive	0	0
Negative	30	100
Focal Multiple B-Lines:		
Positive	0	0
Negative	30	100

There was a statistical significant agreement between clinical and X ray in diagnosis of non-pneumonia cases (specificity 95.7%) while sensitivity of pneumonia diagnosis by X ray was only 42.9% **(Table 5)**.

Table (5): validity of X ray in diagnosis of pneumonia in comparison to clinical as gold standard

X ray	Clinical		Total	Kappa	P
	+ve	-ve			
+ve	3	1	4	**0.45**	**0.009***
-ve	4	22	26		
Total	7	23	30		
Validity	**Sensitivity: 42.9% Specificity: 95.7% PPV: 75% NPV: 84.6% Accuracy: 83.3%**				

Kappa: Test of agreement PPV: +ve predicted value NPV:-ve predicted value, *: Significant

There was a highly statistical significant agreement between clinical and ultrasound in diagnosis of pneumonia cases (sensitivity 100%) and non-pneumonia cases (sensitivity 95.7%) **(Table 6)**.

Table (6): validity of ultrasound in diagnosis of pneumonia in comparison to clinical as gold standard

US	Clinical		Total	Kappa	P
	+ve	-ve			
+ve	7	1	8	**0.91**	**<0.001****
-ve	0	22	22		
Total	7	23	30		
Validity	**Sensitivity: 100% Specificity: 95.7% PPV: 87.5% NPV: 100% Accuracy: 96.7%**				

Kappa: Test of agreement PPV: +ve predicted value NPV:-ve predicted value, *: Highly significant

DISCUSSION

Bronchiolitis is a lower respiratory tract infection that affects children younger than 2 years mostly caused by viruses. It represents the leading cause of hospitalization in infants [(1)]. The main responsible pathogen is Respiratory Syncytial Virus (RSV), which typically occurs as recurrent seasonal epidemics [(2)]**.** Its management is mainly supportive and no specific etiological therapy is routinely used to reduce the viral infection and decrease the severity of clinical course [(7)]**.**

According to the most recent American Academy of Pediatrics guidelines, the diagnosis of bronchiolitis is clinical and chest X-ray (CXR) should be reserved for severe cases with pulmonary complications or where there is clinical deterioration that leads to Intensive Care Unit (ICU) admission [(7)].

Nowadays, chest ultrasound is not included in the management of infant pulmonary disease. However, many papers have demonstrated that chest ultrasound may be useful in some pulmonary diseases. **Biagi *et al.*[(9)]** demonstrated that chest ultrasound is a reliable tool to evaluate patients with respiratory distress syndrome, since all of them show a chest ultrasound findings of bilateral white lung, diffuse B-lines, small subpleural lung consolidation, occult pneumothorax, minimal pleural effusion and areas with a normal pattern**.**

This study included 30 infant with bronchiolitis to assess the diagnostic accuracy of LUS for the detection of pneumonia in children with acute bronchiolitis.

The current study showed that the mean age of the studied cases was 4.19±3.32 months and 86.7% of them were from 1 to 6 months. **Fujiogi *et al.*[(12)]** reported that 57% of cases were under age of 6 months. Regarding sex half of them were male and half were female with M:F ratio 1:1. These results disagreed with **Green *et al.*[(13),]** which was conducted on 2087 cases with M:F ratio of 1.4: This difference in results may be due to different demographic variability and different sample size.

Urban residence was more predominant (53.3%) and more than three quarters of them were of low social class (76.7%). These results almost agree with **Ramagopal *et al.*[(14)]** who stated that (50%) of cases were of low socioeconomic level. Finally only 6.7% had +ve family history of asthma.

In this study wheezes were the commonest presentation (96.7%) of the studied group followed by fever (60%) while crepitation was found in 33.3% of them. This comes in agreement with **Raita *et al.*[(15)]** who reported that most of the cases presented with wheezes and some more severe cases had asthma with crepitations.

The current study showed that 63.3% of the studied group had moderate, 26.7% had mild and 10% had severe respiratory distress. Also, **Biagi *et al.*[(9)]** found that 15% of the studied group had mild respiratory distress, 47.1% had moderate and 37.9% had severe respiratory distress.

The current study showed the laboratory investigations of the studied group. Mean Hb level was 10.07±1.43 gm/dl. Mean WBCs, neutrophil and lymphocyte were 11.81±4.35, 3.37±3.28, 7.4±2.77 ($x10^3/mm^3$) respectively. Mean platelets was 357±119.3

($x10^3/mm^3$) and mean CRP was 13.86 ±35.28 mg/dl. These results almost agree with **Ramagopal *et al.* (14)** who reported their results of mean hemoglobin concentration (10.7±0.92), mean total leucocytic count of (11.8±4.1), mean DC-N of (41.5), mean DC-L of (57.5), mean platelet count of (579.1±100.9).

The current study showed that 10 cases had normal US. Abnormal findings of ultrasound were compact B line, subpleural lung consolidation and irregular pleural lines (53.3%, 26.7% and 3.3% respectively). No cases had pleural effusion, occult pneumothorax or focal multiple B-Lines.

In study by **Caiulo *et al.* (16)** they reported that chest ultrasound findings in infants with bronchiolitis were the following: subpleural lung consolidations were found in 84.6% of infants ($p<0.001$ vs control group). Lung consolidations were observed mainly in the anterior and lateral scans. Vertical reverberation comet-tail artifacts were often seen in the areas adjacent to the consolidation. In 65.3% of infants, there were numerous compact B-lines (areas of white lung; $p<0.001$ vs control group). In 44.2 % of infants, there were pleural line abnormalities ($p<0.001$ vs control group). In 5.8% of infants, minimal pleural effusion, not revealed by CXR, was found. In 1.9% of infants, a small pneumothorax, not revealed by CXR, was found. 9.6 % of infants with bronchiolitis had a few isolated B-lines**.**

Karkar *et al.* (17) reported that in LUS, 114 patients (95.6%) were positive for consolidation, 104 patients (86.7%) were positive for air bronchogram, fluid bronchogram were detected in 37 patients (31.1%), multiple B-lines were detected in 68 patients (56.7%), and pleural effusion was detected in 29 patients (24.4%)

Biagi *et al.* (9) found that LUS was able to identify all the cases of bronchiolitis with concomitant bacterial pneumonia, of which 5/25 were subcentimetric pneumonia.

According to **Milner and Tsung (18)**, the majority of patients with pneumonia (16/25, 64%) had a sonographic consolidation in the posterior lung zones. In 6 patients LUS was able to identify 2 concomitant consolidations associated with bronchograms, thus the total number of ultrasound consolidations consistent with pneumonia was 31, of which 21 (67.8%) were in the posterior lung zones. LUS showed false-positive findings in 10 cases, all but one consisting in subcentimetric pneumonia. In the only patient with a false-positive consolidation > 1 cm on ultrasound, the final diagnosis was respiratory syncytial virus pneumonia.

CONCLUSION

Lung ultrasonography is more accurate and sensitive than chest X-ray to diagnose suspected cases of pneumonia in the pediatric age group. LUS is a sensitive and highly specific diagnostic tool in children with CAP. Therefore, we hypothesize that LUS may be considered as the first imaging test in children with suspicion of CAP.

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Author contribution: Authors contributed equally in the study.

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