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Original Research Article

ASSOCIATION OF CLINICAL PARAMETERS OF PNEUMONIA WITH LUNG ULTRASOUND DIAGNOSIS OF CHILDHOOD PNEUMONIA IN AGE GROUP 2 MONTHS-12 YEARS

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ABSTRACT

Background: The objective is to evaluate lung ultrasonography (LUS) findings in children with pneumonia and to correlate these findings with clinical features in children aged 2 months to 12 years.

Materials and Methods: This study included 100 children aged 2 months to 12 years presenting with cough and fast breathing. All participants underwent LUS within 24 hours of admission, and the data were analyzed. Statistical correlations between various clinical indicators and ultrasound-confirmed pneumonia were assessed. Receiver operating characteristic (ROC) curves were generated to determine cut-off values for respiratory, vital, and laboratory parameters.

Results: LUS was positive in 44 (44%) of the 100 children. LUS findings showed strong correlations with clinical features of pneumonia. The sensitivity of key clinical parameters in predicting pneumonia was: fever (88.64%), refusal of feeds/fluids (77.27%), temperature ≥38°C (95.45%), oxygen saturation ≤95% (1.82%), nasal flaring (79.55%), grunting (70.45%), chest retractions (84.09%), and crepitations (86.36%). Temperature ≥38°C had the highest sensitivity, while grunting had the highest specificity (94.64%). Fast breathing was the most common symptom, present in 90.9% of pneumonia cases, and was significantly associated with pneumonia (P<0.001). Both cough and rapid breathing were reliable clinical indicators across all pediatric age groups. Overall, respiratory features were strongly associated with pneumonia (p<0.05). LUS demonstrated higher diagnostic accuracy than chest X-ray, with a sensitivity of 90.6% and specificity of 66.1%, compared to 79.3% sensitivity and 55.9% specificity for chest X-ray.

Conclusion: Low-grade fever (<38°C), malnutrition, and crepitations were independent predictors of radiologically confirmed pneumonia. No pneumonia was strongly associated with a history of wheezing and the presence of bronchial sounds. While LUS cannot serve as the sole diagnostic tool for pediatric pneumonia, it is valuable for detecting complications such as pleural effusion, showing higher accuracy than chest X-ray. Proper training is essential for clinicians to detect early signs of pneumonia using LUS.

Keywords: lung ultrasonography, Cough, diagnostic accuracy, chest X-ray, pneumonia.

INTRODUCTION

Respiratory tract infections (RTIs) are among the most common human ailments. While they often cause discomfort, disability, and loss of productivity in adults, they are significant causes of morbidity and mortality in young children. Globally, of the 5.9 million deaths in children under five, 1.2 million were due to RTIs, with India accounting for a substantial proportion.[1-3]

RTIs are classified into upper and lower respiratory tract infections (LRTIs), with LRTIs being a more common cause of childhood mortality. Modifiable risk factors for LRTIs include lack of breastfeeding, malnutrition, overcrowding, delayed weaning, and pre-lacteal feeding.[4,5] The etiological agents of LRTIs can be viral, bacterial, or a combination of both. Pneumonia and bronchiolitis are the most common types of LRTIs in children, with pneumonia being responsible for the majority of deaths in children under five years of age. Pneumonia has been a challenge to medical science since antiquity and remains the leading cause of under-five mortality in developing countries, accounting for an estimated 1.2 million deaths annually (approximately 18% of global under-five mortality).[6,7]

Worldwide, approximately 150 million episodes of childhood pneumonia are reported each year. Fifteen countries account for nearly 75% of cases, with six countries, including India, accounting for 50%. India bears 25% of the global disease burden, with an estimated 45 million episodes annually, 6.6 million hospitalizations, and 0.37 million deaths.[8,9]

The World Health Organization (WHO) defines pneumonia as an acute episode of illness with cough and age-specific fast breathing. Accurate diagnosis in children remains challenging. Clinical features such as cough, fever, wheezing, difficulty breathing, chest pain, and abdominal pain are considered important indicators, but their relative contribution to diagnosis is debated.[10-14]

Chest X-ray has traditionally been the diagnostic test of choice for pneumonia. However, its utility is limited by variability in interpretation and inability to reliably distinguish between bacterial and viral etiologies. Studies have shown that a notable proportion of children clinically diagnosed with community-acquired pneumonia (CAP) may have negative chest radiographs.[15,16] The Infectious Diseases Society of America (IDSA) guidelines suggest that routine chest radiographs are unnecessary for outpatient management of suspected CAP in otherwise well children. Additionally, repeated exposure to radiation from chest imaging increases long-term cancer risk, particularly in young children. Thoracic CT scans, although considered the gold standard for detecting pneumonia and other pulmonary lesions, are costly, not widely available, and involve high radiation doses, making them unsuitable as first-line investigations.[17]

In recent years, lung ultrasound (LUS) has emerged as a promising tool for the diagnosis of pneumonia, pleural effusion, pneumothorax, pulmonary embolism, and pulmonary contusions. LUS is non-invasive, radiation-free, and increasingly accessible.

The present study was designed to determine clinical parameters associated with sonologically confirmed pneumonia in children aged 2 months to 12 years presenting with cough and fast breathing. Specifically, this study aimed to investigate the relationship between clinical features and LUS-confirmed pneumonia in this pediatric population.

MATERIALS AND METHODS

Study Design: Descriptive cross-sectional study

Study Period: 18 months

Study Setting: Department of Pediatrics and Department of Radiology, Nimra Hospital, Jupudi

Ethical Approval: Institutional ethical clearance was obtained prior to the commencement of the study. Written informed consent was obtained from parents or caregivers in their native language before enrollment.

Source of Information: Data were collected from hospital patient record sheets, laboratory registers, and treatment cards.

Study Population: Children aged 2 months to 12 years presenting to the emergency or outpatient departments with cough and fast breathing.

Sample size=100.

Inclusion Criteria:

Children aged 2 months to 12 years presenting with cough and rapid breathing

Exclusion Criteria:

- Children with chronic respiratory diseases such as cystic fibrosis, bronchopulmonary dysplasia, congenital heart or lung abnormalities, and morphological deformities (e.g., cleft lip/palate)
- Children with sickle cell anemia, immunosuppression, or cancer that could predispose to pneumonia
- Children undergoing chest X-ray for reasons other than pneumonia (e.g., trauma, foreign body aspiration)
- Children whose parents/caregivers declined participation

Data Collection:

For each child, the following data were recorded:

1. Demographic information
2. Clinical examination findings
3. Routine blood and urine investigations
4. Lung ultrasound (LUS) findings

Clinical Assessment:

- Comprehensive history included cough, fast breathing, fever, wheezing, vomiting, and refusal of feeds
- Vital signs: axillary temperature (digital thermometer, 3 minutes), pulse rate (1 minute), respiratory rate (1 minute), oxygen saturation (pulse oximetry), capillary refill time (5 seconds)
- Clinical signs such as nasal flaring, grunting, pallor, cyanosis, chest retractions, rhonchi, and crepitations were noted
- Vaccination status, nutritional status, and feeding habits were recorded
- Laboratory investigations: hemoglobin, total leukocyte count, differential count, and C-reactive protein (CRP)

Lung Ultrasound (LUS):

- Performed using standard pediatric ultrasound equipment and techniques
- Chest was divided into anterior, lateral, and posterior zones, further split into upper and lower halves

- Anatomical lines scanned: parasternal, mid-clavicular, anterior axillary, mid-axillary, posterior axillary, mid-scapular, paravertebral
- Pneumonia was defined by the presence of B-lines, lung hepatization, and air bronchograms
- Consolidation was identified by blurred margins, loss of pleural line echogenicity, absence of A-lines, comet-tail artifacts, and presence of dynamic or static air or fluid bronchograms; vascular patterns were assessed using color Doppler
- LUS images were independently reviewed by two pediatricians blinded to patient details; radiologists were blinded to LUS findings
- Final diagnosis of pneumonia was based on clinical presentation, physical signs, laboratory tests, and imaging (chest X-ray or ultrasound). Radiological discrepancies were reviewed by a senior radiologist

Definitions of LUS Findings:

- A-lines: Horizontal repetitions of the pleural line at a distance equal to the skin-pleural line distance
- B-lines: Vertical comet-tail artifacts moving with respiration; ≥3 B-lines indicate interstitial syndrome
- I-lines / Z-lines: Short vertical hyperechoic artifacts from pleural line not reaching the distal screen edge
- Consolidation: Loss of pleural line echogenicity, absence of A-lines, air or fluid bronchograms
- Air bronchogram: Hyperechoic specks or branching structures within consolidation (dynamic or static)
- Fluid bronchogram: Anechoic or hypoechoic tubular structures along airways

Patient Management: Children presenting with pneumonia symptoms per the ARI control program were admitted and managed according to standard pediatric protocols.

Statistical Analysis:

- Descriptive statistics: percentages, proportions, means, standard deviations
- Inferential statistics: Chi-square test for categorical variables, ANOVA for differences in means
- Statistical significance: $p < 0.05$
- Data analysis performed using SPSS version 22 (SPSS Inc., Chicago, IL, USA).

RESULTS

Demographics

- Gender: 64% male, 36% female.
- Age distribution:
  - 2–11 months: 27%
  - 1–5 years: 48% (majority)
  - 6–10 years: 17%
  - 11–12 years: 8%

Clinical Features

- Most common symptoms: Fever (78%), refusal of feeds/fluids (48%), wheezing (42%), vomiting (25%).
- Age-wise symptom distribution:
  - Fever most common in all age groups.
  - History of refusal of feeds/fluids highest in 2–11 months (66.7%) and 1–5 years (50%).
  - Wheezing more frequent in 1–5 years (58.3%) and 11–12 years (62.5%).
- Vital signs:
  - Temperature ≥38°C in 63% of children.
  - Oxygen saturation <95% in 51% of children.
  - Mean respiratory rate: 55 ± 2 (no pneumonia) vs. 56 ± 2 (pneumonia).
  - Mean temperature: 37.1 ± 0.7 (no pneumonia) vs. 38.2 ± 0.5 (pneumonia).
  - Nutritional Status
- Wasting (malnutrition): 36% overall.
- Highest in age group 1–5 years (37.5%).

Respiratory Examination

- Findings in study population:
  - Nasal flaring: 64%
  - Rhonchi: 58%
  - Retractions: 45%
  - Crepitations: 42%
  - Grunting: 34%
- Age-wise trends: All respiratory signs were most frequent in 1–5 years.

Laboratory Investigations

- Anemia: 55% overall, significantly associated with pneumonia ($p = 0.002$).
- Leucocytosis: 60%, no significant association with pneumonia.
- CRP positive: 24%, highest in 2–11 months (44.4%), not significantly associated with pneumonia.
- Blood cultures: Positive in 72.7% of pneumonia patients; S. pneumoniae most common (39 cases).

Clinical Outcomes

- Children without pneumonia improved in 10–14 hrs with supportive care.
- Pneumonia patients improved in 2–7 days with antibiotics.
- No deaths were reported.

Diagnostic Accuracy

Clinical parameters:

- Temperature ≥38°C: highest sensitivity (95.45%).
- Grunting: highest specificity (94.64%) and highest positive predictive value (91.18%).
- Refusal of feeds, SpO2 <95%, grunting, retractions, crepitations: high sensitivity and specificity for pneumonia.

Lung Ultrasound (LUS) vs. Chest X-ray (CXR):

- LUS sensitivity: 90.6%, specificity: 66.1%
- CXR sensitivity: 79.3%, specificity: 55.9%
- LUS identified pneumonia in 44% of patients, including 4 cases missed on CXR.

LUS findings for bacterial vs viral pneumonia:

- Optimal consolidation size to distinguish bacterial pneumonia: 21 mm
  - Sensitivity: 80%
  - Specificity: 75%
  - AUC: 0.85 ($p < 0.001$)
- Viral pneumonia: AUC 0.65 ($p = 0.051$)

Number of consolidations detected by LUS:

- Single: 15%
- Two: 6%
- Three: 3%
- Four or more: 2%
- Weak negative correlation between number of consolidations and WBC count ($\rho = -0.35$, $p < 0.001$).
- Agreement between LUS and CXR for bilateral consolidations: $\kappa = 0.45$ ($p < 0.001$).

Statistical Findings

- Fever, refusal of feeds, SpO2 <95%, malnutrition, nasal flaring, grunting, retractions, crepitations, and anemia were significantly associated with pneumonia ($p < 0.05$).
- Mean TLC higher in pneumonia (17,708 ± 1,750) than in non-pneumonia (14,418 ± 2,568), $p < 0.001$.
- Neutrophil count difference not statistically significant ($p = 0.051$).
- Logistic regression model incorporating clinical factors: accuracy 93.3%, $p < 0.001$.

Treatment

- Antibiotics used in all patients:
  - First-line: 85.5%
  - Second-line: 14%
  - Duration: average 14.08 ± 2.2 days
  - Oral antibiotics on discharge: 52%

Key Takeaways

1. LUS is more sensitive than CXR in detecting pneumonia in children.
2. Clinical signs such as fever, grunting, retractions, and refusal of feeds are strong predictors of pneumonia.
3. Anemia is significantly associated with pneumonia, while leucocytosis and CRP are less predictive.
4. Bacterial pneumonia can be distinguished by consolidation size (>21 mm) on LUS.
5. Early supportive care and appropriate antibiotic therapy lead to recovery, with no mortality observed.

Table 1: Age & sex distribution in study population

Age-Category	Sex		Total	P value
	Male	Female		
2 months – 11months	17 (17%)	10 (10%)	27 (27%)	0.7072
1 - 5 years	33 (33%)	15 (15%)	48 (48%)	
6 - 10 years	9 (9%)	8 (8%)	17 (17%)	
11 - 12 years	5 (5%)	3 (3%)	8 (8%)	
Total	64 (64%)	36 (36%)	100 (100%)	

Table 2: Age wise distribution of respiratory parameters in the study population

Respiratory parameters		Age Categories								P value
		2 months – 11months		1 - 5 years		6 - 10 years		11 - 12 years		
		N	%	N	%	N	%	N	%	
Nasal Flaring	Present	19	70.4%	37	77.1%	6	35.3%	2	25.0%	0.0015
	Absent	8	29.6%	11	22.9%	11	64.7%	6	75.0%	
Grunting	Present	11	40.7%	18	37.5%	4	23.5%	1	12.5%	0.3494
	Absent	16	59.3%	30	62.5%	13	76.5%	7	87.5%	
Retractions	Present	13	48.1%	24	50.0%	6	35.3%	2	25.0%	0.4693
	Absent	14	51.9%	24	50.0%	11	64.7%	6	75.0%	
Crepitations	Present	10	37.0%	22	45.8%	8	47.1%	2	25.0%	0.6391
	Absent	17	63.0%	26	54.2%	9	52.9%	6	75.0%	
Rhonchi	Present	20	74.1%	28	58.3%	6	35.3%	4	50.0%	0.0830
	Absent	7	25.9%	20	41.7%	11	64.7%	4	50.0%	

Table 3: Age wise distribution of laboratory parameters in the study population

Laboratory parameters		Age Group								P value
		2 months – 11 months		1 - 5 years		6 - 10 years		11 - 12 years		
		N	%	N	%	N	%	N	%	
Anemia	Present(55%)	16	59.3%	32	66.7%	6	35.3%	1	12.5%	0.010
	Absent(45%)	11	40.7%	16	33.3%	11	64.7%	7	87.5%	
Leukocytosis	Present(60%)	14	51.9%	30	62.5%	12	70.6%	4	50.0%	0.572
	Absent(40%)	13	48.1%	18	37.5%	5	29.4%	4	50.0%	
CRP	Present(24%)	12	44.4%	10	20.8%	2	11.8%	0	0.0%	0.0374
	Absent(76%)	15	55.6%	38	79.2%	15	88.2%	8	100.0%	
ESR >20mm/hr	Present(75%)	17	69.99%	37	77.08%	15	88.23%	6	75%	0.285
	Absent(25%)	10	37.03%	11	22.91%	2	11.76%	2	25%	

Table 4: Age distribution in Ultrasound chest (Lung ultrasound) confirmed Pneumonia

Age group	Pneumonia (N = 44)
2m-11 months	10 (22.7%)
1y-5y	22 (50%)
6y-10y	9 (20.45%)
11y-12y	3 (6.8%)

Table 5: Association of vital signs and respiratory parameters with pneumonia

Vital signs		Pneumonia (sonologically confirmed)		No Pneumonia		P value
		N	%	N	%	
Temperature ≥ 380 C	Present	42	95.5%	21	37.5%	<0.001(sig)
	Absent	2	4.5%	35	62.5%	
SpO2 < 95%	Present	36	81.8%	15	26.8%	<0.001(sig)
	Absent	8	18.2%	41	73.2%	
Wasting	Present	28	63.65	8	14.3%	<0.001(sig)
	Absent	16	36.4%	48	85.7%	
Nasal Flaring	Present	35	79.5%	29	51.8%	0.004(sig)
	Absent	9	20.5%	27	48.2%	
Grunting	Present	31	70.5%	3	5.4%	<0.001(sig)
	Absent	13	29.5%	53	94.6%	
Retractions	Present	37	84.1%	8	14.3%	<0.001(sig)
	Absent	7	15.9%	48	85.7%	
Crepitations	Present	38	86.4%	4	7.1%	<0.001(sig)
	Absent	6	13.6%	52	92.9%	
Rhonchi	Absent	28	63.6%	14	25.0%	<0.001(sig)
	Present	16	36.4%	42	75.0%	

Table 6: Association of laboratory parameters with pneumonia

Laboratory parameters		Pneumonia (sonologically confirmed)		No Pneumonia		P value
		N	%	N	%	
Anemia	Present	32	72.7%	23	41.1%	0.002*(sig)
	Absent	12	27.3%	33	58.9%	
Leukocytosis	Present	27	61.4%	33	58.9%	0.805(no sig)
	Absent	17	38.6%	23	41.1%	
CRP	Present	13	29.5%	11	19.6%	0.25(no sig)
	Absent	31	70.5%	45	80.4%	
Blood Culture	Positive	32	72.7%	23	41.1%	0.002*(sig)
	No growth	12	27.3%	33	58.9%	

Table 7: Sensitivity, specificity, positive predictive value and Likelihood ratio of the variables.

For predicting Pneumonia	Sensitivity	Specificity	Positive Predictive value	Likelihood ratio
H/o fever	88.64%	30.36%	50.00%	1.27
H/o Wheeze	13.64%	35.71%	14.29%	0.21
Vomiting	15.91%	67.86%	28.00%	0.5
Refusal of Feeds/fluids	77.27%	75.00%	70.83%	3.09
Temperature ≥ 380 C	95.45%	62.50%	66.67%	2.55
SpO2 < 95%	81.82%	73.21%	70.59%	3.05
Malnutrition	63.64%	85.71%	77.78%	4.45
Nasal Flaring	79.55%	48.21%	54.69%	1.54
Grunting	70.45%	94.64%	91.18%	13.14
Retractions	84.09%	85.71%	82.22%	5.88
Crepitations	86.36%	92.86%	90.48%	12.1
Rhonchi	36.36%	25.00%	27.59%	0.48
Anemia	72.73%	58.93%	58.18%	1.77
Leukocytosis	61.36%	41.07%	45.00%	1.04
CRP	29.55%	80.36%	54.17%	1.5

Table 8: Comparison of chest radiography and lung ultrasonography results

	Pneumonia +			Pneumonia −		
	Chest radiography (CR+)	Chest radiography (CR-)	Total	Chest radiography (CR+)	Chest radiography (CR-)	Total
Lung ultrasound (LUS+)	40	4	44	0	0	0
Lung ultrasound (LUS−)	0	0	0	4	52	56
Total	40	4	44	4	52	56

Table 9: Comparison of accuracy of Lung ultrasound with X-ray Chest to identify pneumonia

	Lung ultrasound		X-ray Chest	
Parameter	Patient population	P-value	Patient population	P-value
True positive pneumonia	44%	<0.0001	40%	<0.0001
True negative pneumonia	56%	0.0020	60%	<0.0001
False positive pneumonia	2	<0.0001	4	<0.0001
False negative pneumonia	2	<0.0001	5	<0.0001
Sensitivity	0.906	<0.0001	0.793	<0.0001
Accuracy	0.661	<0.0001	0.559	<0.0001

DISCUSSION

In the present study, fever was the most common symptom, observed in 78% of children, followed by refusal of feeds/fluids (48%), wheeze (42%), and vomiting (25%). The mean temperature was ≥38°C in 63% of children, and 51% had oxygen saturation below 95%. Malnutrition, assessed by wasting, was most prevalent in the 1–5 years age group (37.5%).[18] Laboratory findings revealed anemia in 55% of children, leukocytosis in 60%, and positive CRP in 24%. Notably, elevated CRP levels were most frequent in the 2–11 months age group, with a prevalence of 44.4%.[19]

Sonographically confirmed pneumonia was observed in 44% of children, with a higher proportion in males (65.9%) compared to females (34.1%). This prevalence is higher than reported by Shetty et al., who documented positive lung ultrasound (LUS) findings in 19.5% of children.[20]

Clinical indicators of pneumonia were significantly associated with the disease: a temperature ≥38°C was observed in 95.5% of pneumonia patients, and oxygen saturation <95% in 81.8%. Both indicators were statistically significant predictors of pneumonia ($p < 0.001$). Children with pneumonia also exhibited significantly higher total leukocyte counts (TLC 17,708 ± 1,750 vs. 14,418 ± 2,568; $p < 0.001$) and neutrophil counts (68 ± 1.27; $p = 0.05$) compared to children without pneumonia.[21]

Among clinical parameters, temperature ≥38°C demonstrated the highest sensitivity (95.4%) and a specificity of 62.5%, with a positive likelihood ratio of 2.55 and a positive predictive value (PPV) of 66.7%. These results are consistent with prior studies by Al-Najjar et al., Zukin et al., Shamo'ons et al., and Juven et al., indicating fever as a strong independent predictor of pneumonia.[22

The study also highlights the impact of malnutrition and post-measles infections on pneumonia risk, reinforcing the importance of growth monitoring and timely immunization in reducing pneumonia-related morbidity and mortality.[23]

Imaging and Diagnostic Findings

Although chest CT remains the gold standard for pneumonia diagnosis, its routine use in children is limited due to ionizing radiation exposure. MRI offers high soft-tissue contrast without radiation but is technically challenging for lung imaging because of low proton content and motion artifacts.

Therefore, this study employed lung ultrasonography (LUS) as a non-radiative alternative. LUS detected subpleural consolidations, minimal pleural effusions, and perilesional edema, including consolidations missed by chest X-ray (CXR), particularly in retrocardiac and juxta-diaphragmatic regions. This highlights the higher sensitivity of LUS compared to CXR, which is operator-dependent and may fail to detect small or deep lung lesions.[24,25]

Sonographic features of pneumonia in this study included:

- Subpleural hypoechoic zones with variable hyperechoic patches (air bronchograms)
- Fluid bronchograms
- Confluent B-lines
- Superficial fluid alveolograms
- Vascular tree-shaped patterns

In bacterial pneumonia, LUS findings ranged from subpleural consolidations to lobar consolidation with hepatization, whereas viral pneumonia often presented as discrete or confluent B-lines without discrete consolidation. LUS also facilitated detection of concomitant diseases, including bacterial co-infections, which occur in 9.7–42% of severe bronchiolitis cases.

Diagnostic Accuracy: In the study, LUS showed a sensitivity of 0.906 and specificity of 0.661, compared to CXR sensitivity of 0.793 and specificity of 0.559. When evaluating bacterial pneumonia with consolidations >1 cm, LUS specificity increased to 98.4%, demonstrating that consolidation size is a critical factor for diagnostic accuracy. A ROC analysis identified a consolidation size of 21 mm as the optimal cutoff to differentiate bacterial from viral pneumonia, with 80% sensitivity and 75% specificity (AUC = 0.85, 95% CI: 0.79–0.92, $p < 0.001$).

LUS has additional advantages over CXR, including:

- No radiation exposure
- Shorter examination time (2–8 minutes)
- Lower cost
- Bedside applicability with immediate results

These features make LUS a practical and highly sensitive tool for pneumonia diagnosis in pediatric patients, particularly for detecting consolidations near the pleural surface.

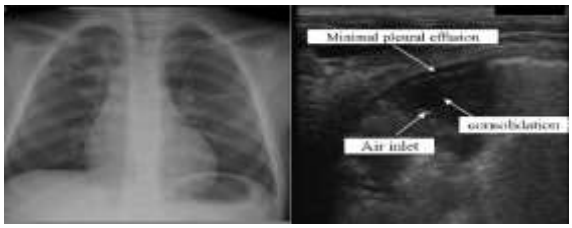

Figure 1: A case of Negative chest X-ray result for a 6 year old female and evidence of pneumonia of left lung [by lung ultrasound]

Figure 2. CXR showed a right lung consolidation consistent with pneumonia, associated with hyperinflation and a mediastinal herniation of the left lung. LUS revealed a large hypoechoic consolidated area with sonographic air bronchograms with branching pattern, compatible with pneumonia.

In the present study, ultrasonography (CUS) successfully identified pneumonia in all but one case (false positive). CUS detected 12 cases (40%) with only one false negative, while chest X-ray (CXR) detected 8 cases (26.7%) but had 4 false positives and 4 false negatives. Sensitivity and specificity of CUS for pleural effusion were 92.3% (95% CI: 62.1–99.6) and 100% (95% CI: 77.1–100.0), respectively. These findings align with previous prospective diagnostic accuracy studies but contrast with some observational studies in children and adolescents.

Unlike CXR, which blends tissue images, LUS enables dynamic evaluation of each intercostal space during respiration. Artefacts are generated even by small amounts of fluid or air, particularly in the left lower chest, enhancing the detection of pleural effusions. In this study, LUS produced significantly fewer false negatives than CXR (31 vs. 82; $P < 0.0001$). CXR sensitivity is limited for small subpleural consolidations, detecting only lesions ≥1.5 cm, whereas LUS can identify smaller lesions and consolidate imaging by using intercostal, cardiac, and subdiaphragmatic views.

Additionally, LUS demonstrated a higher clinical utility score than CXR for pneumonia severity indices 3 and 4, suggesting that it may aid early antibiotic decision-making even when symptoms are mild. LUS also offers the advantage of repeatability, allowing follow-up imaging to monitor response to treatment. For instance, a segmental consolidation in the axillary basal right lung was identified by LUS three days after a negative CXR, highlighting its utility for dynamic reassessment.

The study also examined correlations between positive LUS findings (consolidations with bronchograms) and clinical/laboratory parameters such as fever >38°C, oxygen saturation ≤92%, WBC >15,000/mm³, and CRP >4 mg/dL. No definitive association was found, reflecting the difficulty in distinguishing bacterial from viral pneumonia based solely on clinical or laboratory markers. However, a modest positive correlation emerged when all consolidations with bronchograms were considered. The high sensitivity of LUS in this study is largely due to its ability to detect subpleural consolidations.

Overall, LUS is a non-invasive, bedside diagnostic tool for pediatric pneumonia that avoids ionizing radiation, is rapid, and allows dynamic and follow-up assessment. This study supports its use over CXR or CT in diagnosing pneumonia in children aged 2 months to 15 years.

Limitations of the study include:

- Lack of comparison with a standardized reference diagnostic modality (e.g., CT)
- Single-center study design
- LUS was performed without prior individualized operator training

Despite these limitations, the study demonstrates that lung ultrasonography is an effective and practical tool for the early diagnosis and management of pediatric pneumonia, especially in resource-limited settings.

CONCLUSION

Chest ultrasonography (CUS) demonstrated a 44% detection rate for pneumonia in children presenting with cough, rapid breathing, and fever. Independent predictors of pneumonia included temperature ≥38°C, crepitations, and malnutrition.

Lung ultrasound proved to be highly reliable and accurate in diagnosing pediatric pneumonia, with the added advantage of enabling follow-up until complete resolution of lung injury without ionizing radiation exposure. It is non-invasive, does not require sedation, and can be performed at the bedside at any time.

Unlike chest X-rays and CT scans, lung ultrasound provides a safe, repeatable, and practical diagnostic alternative for pediatric pneumonia. Clinical symptoms such as cough and difficulty in breathing were sensitive indicators and were strongly associated with sonologically confirmed pneumonia in both children under 5 years and those older than 5 years.

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