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Efficacy of lung ultrasound and chest X-ray in children with cough and fast breathing to search a prognostic diagnostic approach to predict childhood pneumonia

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ABSTRACT

Background. Globally, pneumonia is one of the major cause of mortality and morbidity in children aged below 5 years. Lung ultrasonography (LUS) may become the next line investigation of choice before CXR and CT. Researchers have investigated the idea of employing LUS to diagnose pneumonia.

Aim. To evaluate the findings of LUS in children with pneumonia and to correlate LUS findings with clinical and etiological findings in children.

Methods. Study conducted in 100 children with chronic cough and fast breathing. All children undergone LUS within 24 hrs, and the data was correlated between clinical indicators and ultrasound proven pneumonia. The ROC (receiver operating characteristic curve) was drafted to estimate the cut-off values for respiratory, and laboratory variables.

Results. 44% had positive LUS results. The presence of sensitivity with 88.5%, 77.45%, 95.4%, 81.6%, 79.4%, 70.45%, 84.25%, and 86.25% for the presence of fever, refusal of feeds/fluids, temperature 380C, oxygen saturation 95%, nasal flaring, grunting, chest retractions, and crepitation in children to predict the pneumonia. Leukocytosis appeared in 60% and CRP positive in 24% children. Grunting had the highest specificity of 94.66%. Chest x-ray identified 40% of pneumonia cases, while LUS identified 44% pneumonia cases. LUS had a sensitivity of 0.895 and a specificity of 0.66, and CXR had a sensitivity of 0.855 and a specificity of 0.60 to detect pneumonia.

Conclusions. LUS cannot be used a sole diagnostic tool in childhood pneumonia, but it has role in the detection of complications. LUS has higher diagnostic accuracy than CXR for pneumonia diagnosis.

Keywords: pneumonia, crepitation, lung ultrasonography, crepitations, lower respiratory tract infections

INTRODUCTION

Respiratory tract infections are major cause of death among children globally. They are responsible every year for the deaths of 4.3 million children <5 years of age globally [1]. In India, 1.2 million deaths among children were due to respiratory tract infections [2]. Respiratory tract infections were divided into upper and lower respiratory tract infections. Lower respiratory tract infections (LRTI) are the common cause of death than upper respiratory tract infections [3]. Risk factors were lack of breast-feeding, overcrowding, under nutrition, delayed weaning, and pre-lacteal feeds. The etiological agents of LRTI are viral, bacterial, or both combined together [4]. Pneumonia and bronchiolitis are the most common types of LRTI in children. Pneumonia accounts for most of the deaths in children <5 years [5,6]. Pneumonia, defined as inflammation of the lung parenchyma, is the leading cause of death globally among children younger than 5 years, accounting for an estimated 1.2 million (18%) deaths annually [7]. 150 million episodes of pneumonia in childhood are reported every year worldwide [8].

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The 15 countries account for nearly 75% and 6 countries including India account for 50% [9]. The WHO defines pneumonia as an acute disease episode with cough combined with fast breathing with age-specific cut-values for increased respiratory rate. The chest X-ray remains the diagnostic test of choice; chest x-radiograph has been a major contributor to the diagnosis of pneumonia.

A study showed that 21% of patients clinically diagnosed Community-acquired pneumonia (CAP) had negative chest radiographs at presentation. The Infectious Diseases Society of America (IDSA) guidelines states that routine chest radiographs are not necessary for the confirmation of suspected CAP in patients well enough to be treated in the outpatient setting [10]. Moreover, chest radiographs are not without risk; though exposure to radiation from a chest radiograph is minimal, future cancer risk increases with the decreasing age of the child and the number of chest radiographs and other radiation exposures [11]. Thoracic CT scan is considered the "gold standard" for detection of pneumonia and other pulmonary lesions, but it cannot be used as a first-line radiological examination in all patients with suspected pneumonia. This is due to it is often costly, not available and that it involves a high radiation dose. The interest in lung ultrasound (LUS) has increased during the last few years for the use in diagnosis of pleural effusions, pneumothorax, pneumonia, pulmonary embolism and pulmonary contusions [12]. Current study aimed to determine the clinical parameters associated with Sonologically confirmed pneumonia among the children presenting with cough and fast breathing.

MATERIALS AND METHODS

A descriptive cross sectional observation study conducted at Government General Hospital, Kadapa for the duration of one year. The study protocol had ethical clearance from Institutional ethical committee. Study conducted on children attending the emergency and outpatient department of the institution with cough and fast breathing.

Purposive sampling technique on consecutive cases was used for selecting the patients. Data obtained from the medical record Sheets of the Hospital.

Inclusion Criteria:

On examination, children aged 2 months to 12 years old with cough and rapid breathing.

Exclusion Criteria:

Children with cystic fibrosis or bronchopulmonary dysplasia, congenital heart and lung abnormalities, and children with cleft lip and palate. Children with sickle cell anemia, immunosuppression, or cancer, all of which lead to pneumonia. Children with trauma or foreign body aspiration.

Method: Clinical examination findings, routine blood investigations and urine examination, and Ultrasound data collected from all the patients.

All children who presented with cough and fast breathing to emergency and out-patient departments were examined. After obtaining informed written consent from their parents/guardians in their native language the study was conducted. Coughing, fast breathing, fever, wheezing, vomiting, and refusal of feeding were recorded. The axillary temperature was taken for 3 min with a digital thermometer, the pulse rate was counted for one minute, and the respiration rate was counted for one minute by viewing the chest. Capillary refill time was determined by pushing on the finger for 5 sec at room temperature with moderate pressure, oxygen saturation was determined by pulse oximetry, and additional symptoms such as nasal flaring, grunting, pallor, and cyanosis were recorded. Complete systemic examination including chest retractions, rhonchi, and crepitation were also noted. The vaccination status, food habits, and nutritional condition of the children were recorded. Blood tests including hemoglobin, total count, differential count, and C-reactive protein were performed.

All children underwent ultrasound chest using standard equipment and radiological techniques. All ultrasounds were reviewed independently by two different pediatricians, who were blinded regarding the patient details.

The radiologists were completely unaware of the ultrasound findings. The hemithorax is divided into anterior, lateral, and posterior zones, as well as upper and lower halves. The following anatomical lines were scanned: parasternal, mid-clavicular, anterior axillary, mid-axillary, posterior axillary, midscapular, and paravertebral. Pneumonia is defined by the presence of B-lines, hepatization, and air bronchograms. Children and infants have thinner chest walls, an unossified thorax, and smaller lung volumes. A pediatrician made the final diagnosis of pneumonia based on clinical presentation, signs and symptoms such as cough, dyspnea, tachypnoea, rales or crackles on auscultation and/or decreased breathing sounds, fever with or without chills, chest and/or abdominal pain, abnormal oxygen saturation, laboratory and instrumental tests, and chest x-ray findings. Finally, during the study's preparation, the radiological images that contradicted the ultrasound results were re-evaluated by a senior radiologist.

Scanning protocol: Procedure involves sliding from the apex to diaphragm in 6 zones such as anterior, lateral, and posterior bilaterally-in both sagittal and transverse orientations [13].

Basic definitions of lung ultrasound (LUS) findings

A-lines (A-line artefacts): Repetition of pleural line at a standardized distance equal to the skin–pleural line distance.

B-lines: Comet-tail artefacts arise from pleural line and move simultaneously with the breathing cycle.

Other 4 criteria were: screen-long, well-defined, erasing A-lines, and hyperechoic.

A consolidation has blurred margins:

- The loss of pleural line echogenicity over area of consolidation and absence of A-lines within the area.
- Comet-tail artefacts from deep edge of consolidation.
- B-lines surrounding the area of consolidation

Consolidation: An air bronchogram: observed as multiple hyperechoic specks or branching tree-like structure within the area of consolidation:

a) Dynamic –moving simultaneously with the breathing cycle; or
b) Static.

A fluid bronchogram: an anechoic or hypoechoic branched tubular structure along the airways, within the area of consolidation.

Vascular pattern in color Doppler option- observed as branching tree-like structures with blood flow.

I-lines & Z-lines: Short vertical hyperechoic artefacts from pleural line, not reaching distal edge of the screen.

Interstitial syndrome: ≥3, B-lines visible in longitudinal plane between the two ribs.

The children coming to the hospital with symptoms suggestive of pneumonia according to ARI control programme were admitted.

Statistical analysis: The results were described as percentages, proportions, central distributions, and standard deviations. Chi-square test was used to determine the statistical significance of the proportional differences. The ANOVA test was used to determine whether there was any statistical significance in the difference of means. A p value of less than 0.05 was used to indicate a significant difference in all statistical tests. SPSS version 22.0 (SPSS Inc., USA) Windows software was used to analyze the data.

RESULTS

Study population comprised 65% of males and 35% of females. Majority children are of 1-5 yrs age group accounts 48%, followed by 27% in 2 to 11 months, 17% in 6-10 years and 8% in 11-12 years age group (Table 1). History of fever in 78%, fast-breathing in 76%, refusal of feeds/fluids in 20%, vomiting in 24%, and history of wheeze noted in 43% of children. Majority symptoms including fever, wheeze, vomiting, refusal of feeds/fluids, cough, fast breathing, lethargy, cyanosis, and stridor were seen in age group 1-5 years (Table 2). 40% of children had the temperature of >38°C at the time of the examination and 52% of the children had an oxygen saturation of <95%. Temperature ≥380 C and SpO_2 <95% were present in 38% and 52% of children. Malnutrition, as scored by wasting was noted in 37%. Malnutrition present maximum in age group 1-5 years with 37.5%. Nasal Flaring present in 65% of children. On examination of the respiratory system, rhonchi present in 58%, retractions in 45% and crepitations in 43%, grunting in 35% and nasal flaring present in 77% of children.

Association between sex and pneumonia: 65.9% of the sonologically confirmed pneumonia patients were males. Males made up the majority of the sonologically confirmed pneumonia cases.

Lung ultrasound (LUS) confirmed Pneumonia: 44% of children were confirmed as pneumonia by using Lung ultrasound.

Association between age and pneumonia: Sonologically confirmed pneumonia found to be more common in children aged 1 to 5 years (n=22), and 2 months-11months (n=10). Pneumonia was found in 22.7% of children aged 2 months - 11months, 50% of children aged 1-5 years, 20.4% of children aged 6-10 years, and 6.8% of children aged 11-12 years.

TABLE 1. Association between laboratory variables and age-wise distribution in pneumonia

Laboratory parameters		Age Group								P value
		2 mon-11 mon		1 -5 yr		6 - 10 yr		11 - 12 yr		
		number	%	number	%	number	%	number	%	
Leukocytosis	+ (60%)	14	51.9%	30	62.5%	12	70.6%	4	50.0%	0.45
	- (40%)	13	48.1%	18	37.5%	5	29.4%	4	50.0%	
Anemia	+ (55%)	16	59.3%	32	66.7%	6	35.3%	1	12.5%	0.021
	- (45%)	11	40.7%	16	33.3%	11	64.7%	7	87.5%	
ESR >20mm/hr	+ (75%)	17	69.99%	37	77.08%	15	88.23%	6	75%	0.26
	- (25%)	10	37.03%	11	22.91%	2	11.76%	2	25%	
CRP	+ (24%)	12	44.4%	10	20.8%	2	11.8%	0	0.0%	0.029
	- (76%)	15	55.6%	38	79.2%	15	88.2%	8	100.0%	

TABLE 2. Association between clinical parameters and incidence of pneumonia

Clinical parameters		Pneumonia (LUS confirmed)		Without Pneumonia		p-value
		number	%	number	%	
Refusal of Feeds/ fluids	+	34	77.29%	14	25%	<0.0001
	-	10	22.7%	42	75%	
Fever	+	39	88.55%	39	69.59%	0.03
	-	5	11.45%	17	30.41%	
Vomiting	+	7	15.9%	18	32.1%	0.07
	-	37	84.1%	38	67.9%	
Fast breathing	No	4	9.1%	18	32.15%	0.0042
	Yes	40	90.9%	38	67.85%	
Wheeze	No	38	86.4%	20	35.71%	<0.0001
	Yes	6	13.6%	36	64.35%	
Stridor	+	24	54.5%	20	35.72%	0.105
	-	22	45.4%	36	64.31%	
Cough	No	12	27.28%	46	82.15%	<0.0001
	Yes	32	72.72%	10	17.81%	
Cyanosis	+	12	27.28%	8	14.29%	0.078
	-	33	72.73%	48	85.72%	

Fever was reported in 88.65% of pneumonia patients, which was higher than in non-pneumonia patients (69.59%). 77.29% of pneumonia patients had a history of refusing food or water. History of fever and refusal of feeds/fluids is associated with pneumonia. Cyanosis was observed in 27.28% of pneumonia patients, which was higher than the non-pneumonia patients (72.73%) and history of cyanosis is related with pneumonia. Lethargy appeared in 50% of pneumonia patients. History of Lethargy was present in 17.85% of patients with no pneumonia. Stridor was present in 54.5% of pneumonia patients. History of cough was present in 72.7% of pneumonia patients. No history of cough was seen in 27.28% of pneumonia patients. Presence of history of cough was significantly associated with pneumonia. Presence of history of wheeze was significantly associated with pneumonia. History of fast breathing was present in 90.9% of pneumonia cases and the history of fast breathing was significantly associated with pneumonia (Table 3).

Association between vital signs and respiratory parameters:

Presence of temperature ≥38°C was found in 95.6% of the pneumonia children. Oxygen saturation <95% was found in 81.79% of the children. Both temperature ≥38°C and Oxygen saturation <95% are significantly associated with pneumonia. Malnutri-

TABLE 3. Association of vital signs and respiratory parameters with pneumonia

Vital signs	Presence	Pneumonia (LUS confirmed)		Without Pneumonia		p-value
		number	%	number	%	
Wasting	+	28	63.65	8	14.3%	0.003
	-	16	36.35%	48	85.7%	
Grunting	+	31	70.5%	3	5.4%	0.002
	-	13	29.5%	53	94.6%	
Rhonchi	+	28	63.6%	14	25.0%	0.0002
	-	16	36.4%	42	75.0%	
SpO2 <95%	+	36	81.79%	15	26.8%	0.0035
	-	8	18.21%	41	73.2%	
Retractions	+	37	84.1%	8	14.3%	0.005
	-	7	15.9%	48	85.7%	
Nasal Flaring	+	35	79.5%	29	51.8%	0.004
	-	9	20.5%	27	48.2%	
Crepitations	+	38	86.4%	4	7.1%	0.0031
	-	6	13.6%	52	92.9%	
Temperature ≥38°C	+	42	95.6%	21	37.5%	0.00025
	-	2	4.4%	35	62.5%	

tion as scored by wasting was present in 63.65% of the pneumonia children. The presence of wasting was significantly associated with pneumonia. Presence of nasal flaring, Rhonchi, grunting, Chest retractions, and crepitations were found to be significantly associated with pneumonia (Table 3).

The mean difference in Respiratory rate, Temperature, and WBC count between the patients with Pneumonia showing significantly associated with the patients without pneumonia. Pneumonia patients had significantly higher levels of moderate leukocytosis than children who did not have pneumonia (Table 4).

TABLE 4. Association of parameters in Pneumonia and without Pneumonia

Parameter	Mean + SD		p-value
	Pneumonia	Without Pneumonia	
Respiratory rate	56.1 + 2.2	55.2 + 2.3	0.003
Temperature	38.46 + 0.62	37.05+ 0.69	0.002
TLC	17712 + 1698	14420 + 2459	0.0003
neutrophil count	68.12±1.26	68.11±1.59	0.072

Receiver operating characteristic curve (ROC) plots

Respiratory rate: Area under the curve = 0.68 (95% CI: 0.56-0.80). The best cut off lies at 43.49 with a sensitivity of 80.48% and specificity of 45.49% (p =0.01).

Temperature: Area under the curve = 0.8295 (95% C.I: 0.74-0.93). The best cut off lies at 37.5 with a sensitivity of 92% and specificity of 67.4%.

Leukocytosis: Area under the curve = 0.831 (95% C.I: 0.74-0.89) (p=0.00). The best cut off is 13649, which has a sensitivity of 73.5% and a specificity of 74.5%.

An area of 1 represents a perfect test; an area of 0.5 represents a worthless test.

Outcome: Children with no pneumonia treated with supportive care showed symptomatic improvement in wheeze and respiratory distress in 10 to 14 hrs. With quick response to bronchodilators and in pneumonia within 2-7 days. No deaths were observed in both the study groups (Figure 1).

72.7% of pneumonia children had anemia and Leukocytosis in 61.45%. Anemia was found to be significantly associated with pneumonia. Blood cultures were positive in 72.6% of pneumonia children (Table 5). The difference demonstrates statistical significance. *S. pneumonia* was the most isolated organism (n=39), followed by *S. aureus* (n=10) and Klebsiella (n=6).

Antibiotic administration: First-line antibiotics were given to 84% of patients, second-line antibiotics were given to 16% of patients, and antibiotics were switched from first to second line in 14% of cases. Oral antibiotics administered at the time of discharge in 52% of the cases. Antibiotics were taken for an average of 14.5 ±2.7 days.

The sensitivity of the significant parameters was 88.5%, 77.45%, 95.4%, 81.6%,79.4%, 70.45%, 84.25%, and 86.25% for the presence of fever, refusal of feeds/fluids, temperature 380C, oxygen saturation 95%, nasal flaring, grunting, chest retractions, and crepitations in children to predict Pneumonia . Our study found that grunting (sensitivity of 70.45%, specificity of 94.66%, PPV of 91.25%), retractions (sensitivity of 84.25%, specificity of 85.65%, PPV of 82.3%), and crepitation (sensitivity of 86.25%, specificity of 92.9%, PPV of 90.52%) had both high sensitivity and high specificity with more PPV in predicting pneumonia (Table 6).

Association between Immunization with pneumonia: Up to their chronological age, 57% were immunized and 6% were unimmunized. Pneumonia cases were observed in 19 fully vaccinated children, 43.18% partially vaccinated children, and 13.63% unvaccinated children. This means that

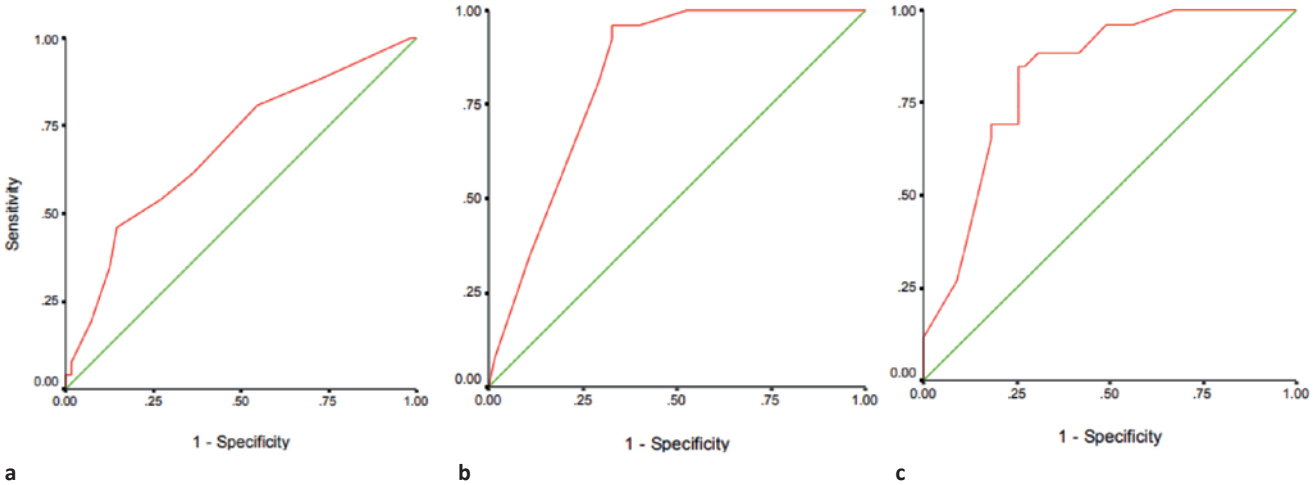

FIGURE 1. a. Receiver operating characteristic curve (ROC) to predict the respiratory rate cut-off value for Pneumonia. b. ROC curve for temperature cut-off value for Pneumonia. c. ROC curve for Leukocytosis for children with Pneumonia

TABLE 5. Association of laboratory parameters with pneumonia

Laboratory variables		Pneumonia (LUS confirmed)		Without Pneumonia		p-value
		number	%	number	%	
Leukocytosis	+	27	61.45%	33	58.90%	0.795
	-	17	38.55%	23	41.10%	
Blood Culture	+ve growth	32	72.65%	23	41.10%	0.0032
	No growth	12	27.35%	33	58.90%	
CRP	+	13	29.50%	11	19.60%	0.195
	-	31	70.50%	45	80.40%	
Anemia	+	32	72.69%	23	41.20%	0.0012
	-	12	27.41%	33	58.90%	

TABLE 6. Sensitivity, specificity, positive predictive value of clinical and laboratory variables

For predicting Pneumonia	Sensitivity	Specificity	Positive Predictive value	Likelihood ratio
Temperature ≥38°C	95.4%	62.6%	66.7%	2.65
Leukocytosis	61.36%	41.07%	45.00%	1.04
History of Wheeze	13.64%	35.71%	14.29%	0.21
Vomiting	15.91%	67.86%	28.00%	0.5
CRP	29.55%	80.36%	54.17%	1.5
History of fever	88.5%	30.5%	50%	1.25
SpO2 < 95%	81.6%	73.3%	70.42%	3.1
Malnutrition	63.64%	85.71%	77.78%	4.45
Crepitations	86.25%	92.9%	90.52%	12.15
Grunting	70.45%	94.66%	91.25%	13.09
Retractions	84.25%	85.65%	82.3%	5.88
Refusal of Feeds/fluids	77.45%	75.2%	70.49%	3.1
Rhonchi	36.41%	25.5%	27.59%	0.48
Anemia	72.73%	58.93%	58.18%	1.77
Nasal Flaring	79.4%	48.1%	54.5%	1.61

67.85% fully vaccinated children and 32.14% partially vaccinated children did not develop Pneumonia. Hence, incomplete and unvaccinated children have a higher incidence of pneumonia. The association between vaccination and pneumonia was found to be significant (P=0.001). Association between the socio-demographic variables and birth-related covariates were demonstrated in Table 7.

ROC analysis of LUS to predict bacterial & viral pneumonia: Current study analyzed the association of LUS characteristics with the etiology of Pneumonia (viral vs. bacterial) using a regression model. The ROC curve analysis found that the optimal cut-off for discriminating between the bacterial and viral pneumonia is a consolidation size of 20 mm, with a sensitivity of 80% and a specificity of 75% for diagnosing the bacterial pneumonia. The AUC was 0.85 (95% CI 0.79–0.92, p<0.001). Regarding the viral pneumonia, the AUC was 0.65 (95%CI:0.5–0.80, p=0.05). Single consolidation, 2 consolidations, three consolidations and four (or more) consolidations were detected with LUS in 15%, 6%, 3% and 2% patients. A weak or negative correlation observed between the number of consolidations and the WBC. A significant agreement was found between the lung ultrasound and chest x-ray regarding the presence of bilateral consolidations (p<0.001). For bacterial pneumonia, the extent of the consolidation remained significant (95%CI: 1.01–1.19).

Pneumonia was diagnosed based on a history and clinical examination, laboratory and instrumental tests, including chest radiography (without LUS findings). Chest radiography identified 40%, while LUS identified 44% of children. LUS was found in four patients who had negative results from CXR. Finally, the sensitivity, specificity, positive and negative likelihood ratios, positive and negative predictive values of chest x-ray and LUS were calculated (Table 8, Table 9).

Continuous variables were represented as the mean and analyzed using the chi-square test. Pleural effusion, perilesional inflammatory edema and lung consolidations were referred as pneumonia. LUS had 0.895 sensitivity and 0.66 specificity for detecting pneumonia, and chest X-ray had 0.855 sensitivity and 0.60 specificity.

TABLE 7. Bivariate associations of socio-demographic and birth-related covariates with pneumonia

		Pneumonia (LUS confirmed)		Without Pneumonia		Odds ratio	Class interval	P value
		Number	%	Number	%			
Residence	Urban-37%	20	45.45%	17	30.35%	R	R	0.09
	Rural-63%	24	54.55%	39	69.65%	1.68	1.01–2.81	
Born term low birth weight	No-79%	37	84.09%	42	75%	R	R	0.089
	Yes-21%	7	15.91%	14	25%	0.36	0.20–0.67	
Born premature	No-78%	34	77.27%	44	78.57%	R	R	0.798
	Yes-22%	10	22.72%	12	21.42%	16.6	7.65–36.38	
Smoking at home	No-55%	5	11.36%	50	89.28%	R	R	0.00004
	Yes-45%	39	88.63%	6	10.71%	0.35	0.18–0.62	
Mother's education	Illiterate-10%	9	20.46%	1	1.78%	R	R	0.006
	Up to secondary-83%	33	75%	50	89.28%	2.62	1.14–5.95	
	Graduate-7%	2	4.55	5	8.93%	2.95	0.85–10.25	
Mother's occupation	Working-12%	5	11.63%	7	12.5%	R	R	0.769
	Non-working-88%	39	88.64%	49	87.5%	0.17	0.07–0.38	
Type of home	Pukka-37	15	33%	22	46%	R	R	0.079
	Kuccha-63	29	67%	34	54%	1.75	1.05–2.92	
Type of family	Nuclear-50	18	40%	32	69%	R	R	0.098
	Joint-50	26	60%	24	31%	3.2	2.1–5.82	
Drinking water source	Underground water-41	18	40%	23	44%	R	R	0.455
	Tap water-59	26	60%	33	56%	1.16	0.70–1.92	
Poor ventilation in living area	No-26	4	8%	22	56%	R	R	0.219
	Yes-74	40	92%	34	44%	14.44	7.33–28.39	
Number of family member	Up to 5(49)	18	40%	31	64%	R	R	0.298
	5–10(43)	22	50%	21	31%	2.6	2.4–5.95	

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–)	0	0	0	4	52	56
Lung ultrasound (LUS+)	40	4	44	0	0	0
Total	40	4	44	4	52	56

TABLE 9. Comparison of accuracy of Lung ultrasound with Chest X-ray to identify pneumonia

Parameter	Chest X-ray		LUS	
	Patient population	P-value	Patient population	P-value
True positive pneumonia	40%	<0.0001	44%	0.0001
True negative pneumonia	60%	<0.0001	56%	0.0020
False positive pneumonia	4	<0.0001	2	0.0001
False negative pneumonia	5	<0.0001	2	0.0001
Sensitivity	0.855	<0.0001	0.895	0.0001
Accuracy	0.559	<0.0001	0.661	0.0001

DISCUSSION

This present study was undertaken to examine the lung ultrasound findings in pneumonia as a useful diagnostic tool for early detection of childhood pneumonia. Upon the laboratory investigations, anemia appeared in 55% of children, Leukocytosis in 60% and CRP was positive in 24% of children. LUS confirmed pneumonia was observed in 44% of children.

In the present study, sonologically confirmed pneumonia was present more in children aged <5 years. The higher prevalence of Pneumonia observed in 50% in the age group of 1-5 yrs, followed by 22.7% in the age group of 2-11 months, and 20.4% in

6-10 years, and 6.8% in the age group 11-15 years. The reduced prevalence in the age group of 2 months to 11months than the elder age groups may be due to the exclusive breastfeeding practices in the infancy. Evidence showed that breastfeeding protects the infants against infection and has a protective factor for reducing the risk of respiratory illness among infants. This implies that the cough and fast breathing which were used to identify pneumonia cases in less than 5 year old children can also be used to identify pneumonia in more than 5 years old children presenting with cough and fast breathing. A study by Abuka et al found that pneumonia was seen more in children of age group 2-11 months, and found that this age group was one of the determinants of pneumonia [14-17].

The presence of temperature ≥ 380C was found in 95.5% of the pneumonia patients and Oxygen saturation <95% was found in 81.8% of the pneumonia. Both temperature ≥38°C and Oxygen saturation <95% are significantly associated with pneumonia.

Binominal logistic regression analysis shows that the independent predictors of pneumonia in our study were temperature ≥38°C, crepitation, and presence of malnutrition. Among them, temperature ≥38°C has the strongest accuracy of predicting pneumonia in our study. When compared to children without pneumonia, children with pneumonia showed substantially greater mild leukocytosis.

In our study, history of wheeze had low sensitivity and specificity of 13.6% and 35.7%. In a study by Mathew et al found that the incidence of pneumonia among children with wheezing was low (4.9%). The routine uses of chest X-ray for children with wheezing but without fever should be discouraged. These findings were similar to our study. The presence of history of wheeze had got a low PPV and Likelihood ratio of having pneumonia. The presence of wheeze in children with cough and fast breathing was associated with no pneumonia [18].

In our study, presence of temperature ≥ 380C had the highest sensitivity of 95.4% and a specificity of 62.6%. The likelihood ratio was 2.65 with a PPV of 66.7%. It was significantly associated with pneumonia and one of the independent predictors of pneumonia. Findings were similar to Al-Najjar et al with sensitivity of 87.4% and specificity 60.9%. It also agrees with the findings of the studies done by Zukin et al., Shamo'ons et al. and Juven et al [19-21].

In our study, oxygen saturation <95% was significantly associated with radiographic pneumonia. It had got sensitivity and specificity of 81.6%, 73.3%, and PPV of 70.42%. It was similar to the study done by Lozano et al, who found a specificity of 83% and sensitivity of 73%. They concluded that presence of hypoxemia is the best predictor when the auscultatory findings are excluded [22].

In the current study, children living in kuccha households had a higher risk of severe pneumonia. Kuccha dwellings are often built by the poor, and they have been associated to pneumonia in other Asian countries [23].

CRP cut-off of 20 mg/L exhibited a high specificity (90%) and positive predictive value (92%) for distinguishing non-severe from severe illness. Hence, CRP levels >20 mg/L may be useful in predicting severe pneumonia in our case, which is comparable to others [24].

In our study, grunting had sensitivity of 70.45% and specificity of 94.66% in predicting pneumonia in children. Al-Najjar et al showed that chest retractions were present in 80% of pneumonic children with sensitivity and specificity of 80% and 88.2%. The presence of chest retraction had got a likelihood ratio of 5.88 in predicting pneumonia in children, which means children with chest retractions were 5 times more likely to have pneumonia than children without chest retractions [25,26].

In our study, we found that presence of rhonchi had got a sensitivity and specificity of 36.41% and 25.5% in predicting pneumonia in children. It was similar to the study done by Silayach et al., where they found that the presence of rhonchi has got a sensitivity and specificity of 32% and 25% [27].

Our study found that grunting (sensitivity of 70.45%, specificity of 94.66%, PPV of 91.25%), retractions (sensitivity of 84.25%, specificity of 85.65%, PPV of 82.3%), and crepitation (sensitivity of 86.25%, specificity of 92.9%, PPV of 90.52%) had both high sensitivity and high specificity with more PPV in predicting pneumonia. With these findings, we conclude that a thorough assessment of the respiratory system, including auscultation, is required to avoid misdiagnosis and overuse of chest radiographs and antibiotics in children.

The 'gold standard' for of pneumonia is a chest CT scan, but it cannot be used routinely in children because they are radiosensitive and have a higher risk of radiation exposure than adults. Hence, an alternate diagnostic technique for detecting pneumonia in children with a lower risk of radiation exposure is required [28].

Hence, the current study employed Ultrasonography, a non-radiative imaging technique that can detect subpleural lung consolidation in pneumonia.

Sonography successfully detected a minimal pleural effusion and perilesional inflammatory edema. The finding of our study is accordance with a recent study [29].

The chest x-ray did not detect four cases of pneumonia in our investigation, which were instead identified by lung ultrasonography. The great variability of interpretation and the limitations of chest x-ray resolution less than 1 cm are two more probable factors.

This study showed that 44% of the study subjects had changes in lung ultrasound, even when the child had clinical findings suggestive of severe disease. The reason for lower incidence of lung ultrasound changes in this study could be attributed to inability of ultrasound is able to pick up changes in lung parenchyma near to the pleural surface and changes deep within the lung parenchyma. In a study by Tirdia et al, found that 93.5% had subpleural consolidation by lung ultrasound and 35.9% had B-lines [30].

When compared to chest CT, lung ultrasound showed 0.895 sensitivity and 0.66 specificity for the identification of pneumonia in the current investigation, while chest X-ray had 0.855 sensitivity and 0.60 specificity. These findings were in line with the findings of other prospective diagnostic accuracy studies [31].

The increased sensitivity may be due to children's smaller thorax size and thinner chest wall, which allows for better visualization of the lung parenchyma by LUS. Overall, the present study findings show that Ultrasonography (LUS) identifies the diagnosis of pneumonia for all cases. Sensitivity and specificity of CUS in detection of pleural effusion were 92.3% (95% CI: 62.1-99.6) and 100% (95% CI: 77.1-100).

In our study, LUS had a higher beneficial score than chest X-ray for pneumonia severity indexes 3 and 4, indicating that lung ultrasound may aid in the clinical decision-making process when putting children on antibiotics in the early stages of pneumonia, when symptoms are not severe.

LUS findings	Bacterial Pneumonia	Viral Pneumonia
Distribution	Posterior	Diffuse
Pleural Line	Irregular near consolidations	Irregular Thickened
Lung Parenchyma	Discrete B-lines air-bronchograms	Scattered B-lines confluent B-lines
Consolidations	Focal consolidations Hepatization	Sub-centimeter consolidations
Pleural Effusion	Common	Rare

The great sensitivity found in this investigation was due to the lung ultrasonography detecting consolidation closer to the pleural surface.

In our study, significant higher association noted between chest X-ray and LUS in identifying bacterial pneumonia.

The area under the ROC curve was 0.65 (95%CI: 0.50–0.85, p=0.012). The AUC for identifying atypical bacterial and viral pneumonia was 0.65 (95% CI 0.50–0.80, p=0.05).

According to a study conducted by Biagi et al., the sensitivity and specificity of LUS for the diagnosis of pneumonia was 100% and 83.9%, with an area under the curve (AUC) of 0.92, while CXR had a sensitivity of 96% and specificity of 87.1 % [32].

LUS is a straightforward and non-invasive approach for diagnosing probable pneumonia in children.

Limitations of this study was that LUS was not compared against any standardized reference diagnostic modality, the study was conducted in a single centre and the study was conducted without prior individualized training.

CONCLUSION

Cough and difficulty in breathing were sensitive indicators, which were strongly associated with sonologically diagnosed pneumonia in <5years and even in children > 5 years of age. The LUS demonstrates high reliability and accuracy in the detection of pneumonia, as well as the possibility of a follow-up until complete resolution of lung injury without ionizing radiation exposure. It does not necessitate sedation and can be performed at any time. Unlike chest X-rays and CT scans, LUS can be performed at the bedside on children without exposing them to ionizing radiation.

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