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Role of Lung Ultrasound in Evaluation And Monitoring of Community Acquired Pneumonia in Pediatric Population.

Dr Alka Agrawal[1] ,Dr P.S. Tripathi[2], Dr Mona[3], Dr Hema Dhakad[4], Dr Selexi Verma[5]*

1. Professor ,Department of Radiodiagnosis MGMMC MYH Indore (M.P.)
2. Associate Professor, Department of RadiodiagnosisMGMMC MYH Indore (M.P.)
3. Junior Resident, Department of Radiodiagnosis MGMMC MYH Indore (M.P.)
4. Junior Resident, Department of RadiodiagnosisMGMMC MYH Indore (M.P.)
5. Junior Resident, Department of Radiodiagnosis MGMMC MYH Indore (M.P.)

***Corresponding Author:Dr Hema Dhakad**
Junior Resident,
Department of Radiodiagnosis
MGMMC MYH Indore (M.P.)
hemadhakad05@gmail.com

ABSTRACT

Background-Community-acquired pneumonia (CAP) is a significant health concern in children, leading to high morbidity and mortality worldwide. Lung ultrasound (LUS) is a non-invasive, cost-effective, and non-ionizing imaging modality that has the potential to diagnose and monitor CAP, differentiating between bacterial and non-bacterial pneumonia. This study evaluates the role of LUS in the evaluation and monitoring of CAP in the pediatric population.

Methods- This prospective observational study was conducted in the Department of Radiodiagnosis at M.G.M. Medical College, Indore, from September 2022 to September 2023. A total of 108 pediatric patients clinically diagnosed with CAP were included. LUS was performed on the day of admission and follow-up scans were conducted between the 5th and 7th day, and between the 10th and 14th day post-admission. Ultrasound findings, such as echo-poor non-aerated lesions, air bronchograms, pleural effusion, B lines, collapse, pleural thickening, and specific vascular patterns, were documented and analyzed.

Results - The study included 108 patients aged 1 month to 16 years, with a slight male predominance (50.9%). The most common symptoms were cold (70.37%), cough (69.44%), and fever (59.25%). LUS findings indicated that bacterial CAP often presented with larger, unilateral, and solitary pneumonic lesions with air or fluid bronchograms and pleural effusion. Non-bacterial CAP was characterized by sub-centimetric, multifocal, and bilateral lesions with diffuse B lines and pleural thickening. LUS showed a diagnostic sensitivity of 87% and an accuracy of 85% for identifying the etiology of CAP. Follow-up scans demonstrated significant regression of lesions, particularly in bacterial CAP cases.

Conclusion- Lung ultrasound is a highly sensitive and accurate imaging modality for diagnosing, characterizing, and monitoring community-acquired pneumonia in pediatric patients. It effectively differentiates between bacterial and non-bacterial pneumonia, improving diagnostic accuracy and guiding appropriate management. LUS should be included in diagnostic protocols for CAP alongside clinical and laboratory data.

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Keywords : Community-acquired pneumonia; Lung ultrasound ; Bacterial pneumonia; Non-bacterial pneumonia

BACKGROUND- Community-acquired pneumonia (CAP) is a major health concern for children. It is a leading cause of morbidity and mortality worldwide, with 151.8 million new cases annually. Among these, 8.7% (13.1 million) are severe enough to require hospitalization. Based on the magnitude of CAP, India ranks among the top five countries. India accounts for nearly 23% of global cases. In India, childhood pneumonia accounts for 14% of under-five mortality, with a current mortality rate of 33 per 1,000 live births.The World Health Organization (WHO) classifies community-acquired pneumonia into two categories: i)Pneumonia, which is characterized by rapid breathing with or without chest indrawing. ii) Severe pneumonia, where one or more danger signs are present, such as the inability to drink, persistent vomiting, convulsions, lethargy or unconsciousness, stridor in a calm child, or severe malnutrition.Clinical symptoms such as fever, cough, breathing difficulty, poor feeding, and irritability are considered while diagnosing pneumonia. Physical examination includes assessing for tachypnea, tachycardia, nasal flaring, chest retractions, crackles and wheezes on auscultation bronchial breathing, and reduced oxygen saturation levels. However, diagnosing pneumonia in children can be challenging due to the overlapping of the signs and symptoms and pathological investigations with other respiratory illnesses.Therefore relying solely on clinical examination and laboratory investigations can lead to antibiotic overuse and resistance, hence chest imaging is required to address this issue.Lung ultrasound (LUS) is readily available, non-invasive, cost-effective, and non-ionizing. The clinical interpretation of findings based on ultrasound images has the potential to diagnose and characterize community-acquired pneumonia. Therefore, this study was opted to evaluate community-acquired pneumonia using lung ultrasound to determine its utility in CAP, to analyze the regression of lesions, and to evaluate the role of lung ultrasound and laboratory parameters to differentiate between bacterial and non-bacterial pneumonia.

METHODS- This is a time-bound, prospective observational study, conductedin the Department of Radio-diagnosis, M.G.M. Medical College Indore, MadhyaPradesh, India after receiving approval from the Institutional Scientific and Ethical Committee. The duration of thestudy was from September 2022 to September 2023. A total of 108 patients who werereferred to the Department of Radiodiagnosis for lung ultrasound by the other departments in M.Y hospital and MGMMC and associated hospitals who are clinically diagnosed with Community-Acquired Pneumonia were includedinthestudy. Lung ultrasound was performed on the day of admission, the reference point is the ribs in an oblique, parallel, and perpendicular configuration. The thorax was divided into an anterior part that covers regions from parasternal to the anterior axillary line; a lateral part that covers regions between anterior and posterior axillary lines; posterior part covering regions from the posterior axillary line to the paravertebral line. Each region is divided into superior and inferior zones.
Look for any echo poor non aerated lesion, air bronchogram ,pleural effusion, B lines, collapse, pleural thickening and specific vascular pattern.Follow-up scans was done between 5th and 7th day after admission and between 10th and 14th day after admission to look for regression of lesions.

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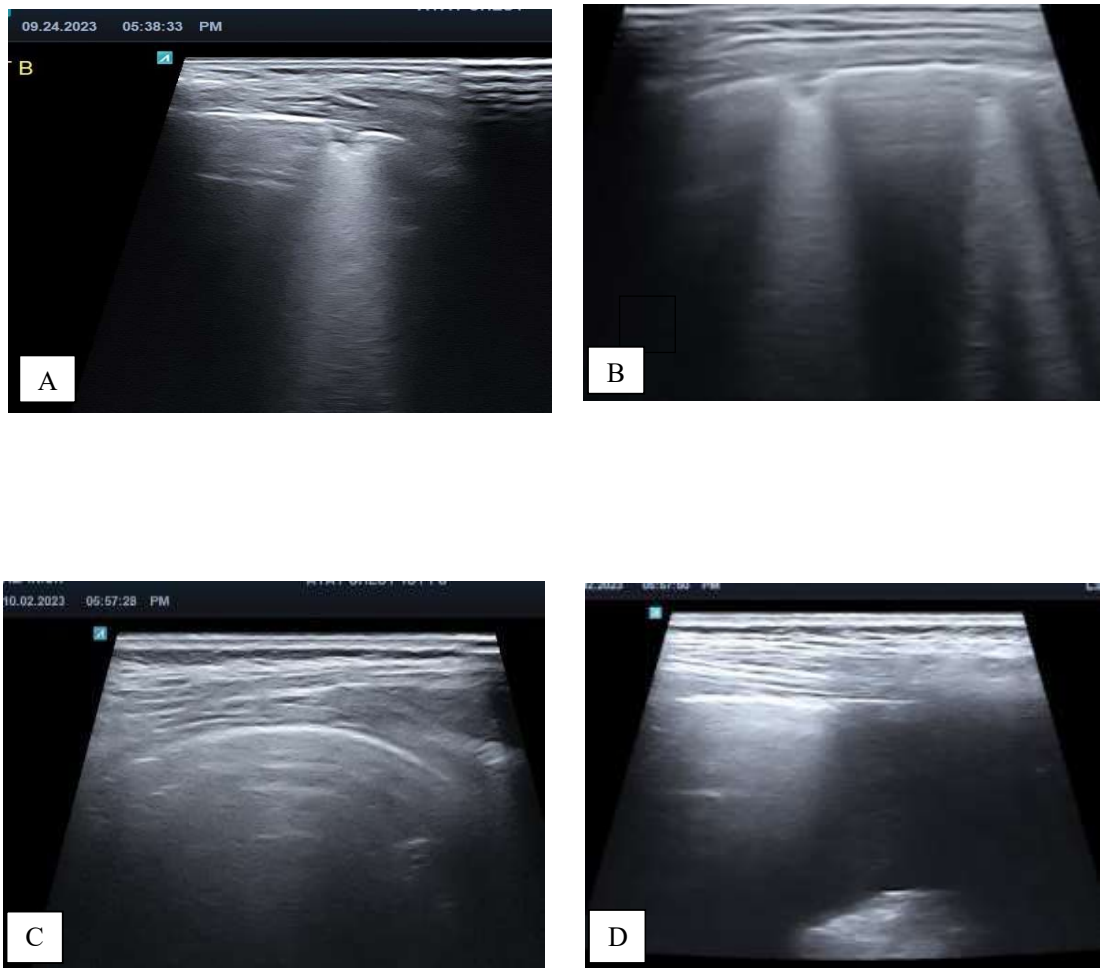
Figure 1
ON DAY 0



A 5-month-old girl presented with symptoms of fever, cough, and cold

(A)– On day 0, Grey scale lung ultrasound shows an Irregular pleural line with sub centimetric subpleural hypoechogenic lesion (consolidation) with few B lines seen in the leftposterior upper zone.

(B)– Irregular pleural line with sub centimetric subpleural hypoechogenic lesion (consolidation) with B lines seen in right posterior basal zone.

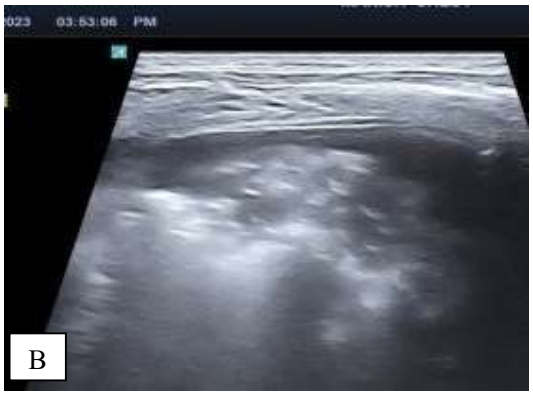
(C)– On follow-up, on 6th day, Grey scale lung ultrasound shows normal visceral pleural interface with A lines indicating normal lung surface in left posterior upper zone.

(D)– On follow-up, on 6th day, Grey scale lung ultrasound shows normal curtain sign indicating normal aerated lung in the right posterior basal zone.

ISSN: 0975-3583, 0976-2833 VOL 15, ISSUE 07, 2024

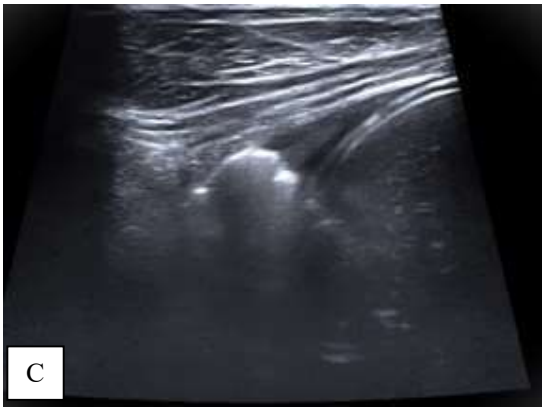
Figure 2

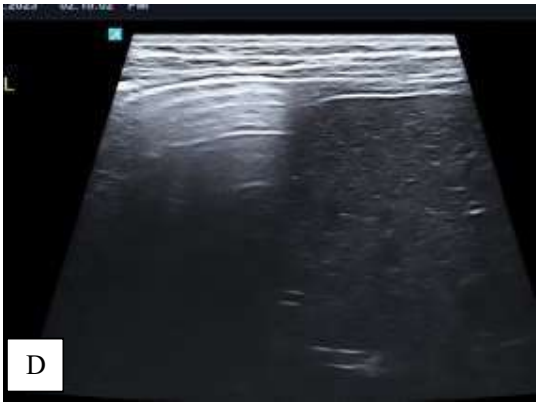
ON DAY 0



ON 7TH DAY

ON 11TH DAY





A 8 year old boy presented with symptoms of cough, fever and abdominal pain-

(A)– on day 0, Greyscale lung ultrasound shows mild pleural effusion and the lung lobe represented as a parenchymatous organ similar to liver parenchyma (lung hepatization) with hyperechoic lines within it representing static air bronchogram seen in the leftposterior basal zone.

(B)– Mild pleural effusion and basal lung consolidation with static air bronchogram seen in the left anterior basal zone.

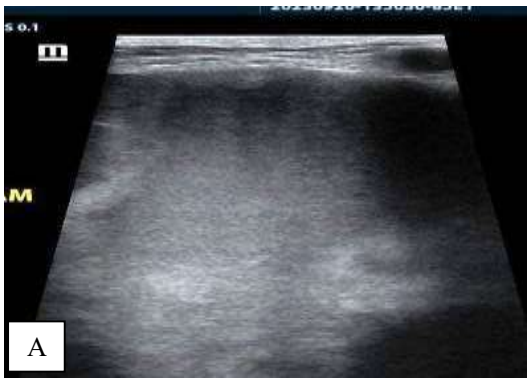
(C)– On follow-up, on 7th day, Greyscale lung ultrasound shows minimal pleural effusion with basal lung collapse and consolidation in left basal zone.

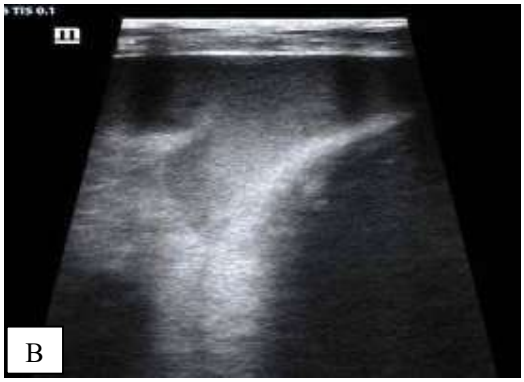
(D)– On follow-up, on 11th day, normal curtain sign with A lines indicating normal aerated lung.

ISSN: 0975-3583, 0976-2833 VOL 15, ISSUE 07, 2024

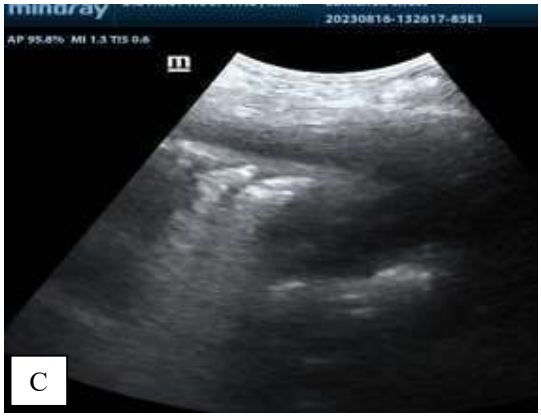
Figure 3

ON DAY 0

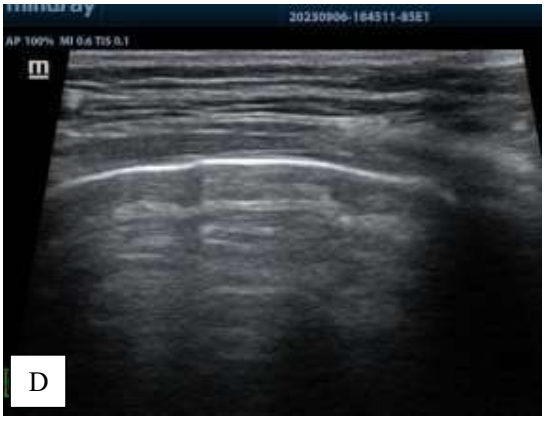




ON 6TH DAY



ON 11TH DAY



A 11 year old boy presented with fever, cough and diffculty in breathing-

(A)– On day 0, Grey scale lung ultrasound shows gross pleural effusion with homogenous echoes with right basal lung collapse in right posterior basal zone.

(B)–Gross pleural effusion with homogenous echoes with right basal lung consolidation with collapse in right posterior basal zone

(C)– On follow up, on 6th day, Grey scale lung ultrasound shows mild pleural effusion with basal lung consolidation in right posterior basal zone.

(D)– On follow up, on 11th day, normal visceral parietal pleura interface with A-lines indicating normal aerated lung.

ISSN: 0975-3583, 0976-2833 VOL 15, ISSUE 07, 2024

RESULTS

The study included 108 patients with clinical suspicion of CAP aged 1m to 16 years, majority lying in the age group of 1-5years (46%). The study comprised of 55 (50.9%) males and 53 (49.1%) females with a male predominance.

In our study, the most common symptoms were cold (70.37%), cough (69.44%), and fever (59.25%), with tachypnea (17.59%) and abdominal pain (11.11%) being less common. Tachypnea (70.3%) and bronchial breathing (59.25%) were the most frequent examination findings.

In the study, 55.6% of patients had normal WBC counts, while 43.5% had increased counts. Elevated CRP levels were observed in 82% of patients. The mean WBC count was 11.21±3.51, and the mean CRP level was 13.74±16.86.

Based on the blood culture report, among 108 patients, 32 % of patients were of bacterial etiology and remaining (68%) were categorized as non-bacterial in etiology which could be viral or atypical etiology.

In bacterial CAP, 71% had increased WBC counts and 91% had elevated CRP levels, with 97.1% having pneumonic lesions, predominantly large, unilateral, and solitary. Air bronchograms were common (91.4%), along with fluid bronchograms (62.8%), vascular patterns (97.1%), pleural thickening (71.4%), and effusion (62%).

In non-bacterial CAP, 70% had normal WBC counts and 77% had elevated CRP levels, with 82.1% having pneumonic lesions, mostly sub centimetric and multifocal/bilateral. Air bronchograms were present in 72.6%, fluid bronchograms in 13.6%, vascular patterns in 71.2%, pleural thickening in 63%, and effusion in 8.2% of patients.

In our study, ultrasound scans of bacterial pneumonia often showed unilateral, solitary pneumonic lesions larger than 1 cm with air or fluid bronchograms or hepatization and specific vascular patterns. Common findings included focal B lines, pleural irregularity, and pleural effusion. Most cases had elevated WBC and CRP levels, though normal or decreased levels did not rule out bacterial pneumonia.

LUS has a diagnostic sensitivity of 87%. The diagnostic accuracy for identifying etiological agents was 85% sensitivity and 83% specificity.

On days 5-7 follow-up, 79% had normal WBC counts, 91% had normal CRP levels. 88.5% of bacterial CAP patients showed reduced lesion size. 40% had B-lines, 31% pleural thickening, 14% pleural effusion, 3% lung collapse on ultrasound. On days 10-14, 93.5% had normal WBC,96.3% normal CRP. 88.5% of bacterial CAP patients had decreased lesion size, 28.7% complete regression. Only 5.7% had B-lines and pleural effusion remaining.

ISSN: 0975-3583, 0976-2833 VOL 15, ISSUE 07, 2024

1) Distribution of patients based on site of lung involvement on lung ultrasound**.**

Lung Involvement	**Frequency(N)**	**Percentage(%)**
Anterior superior	16	14.8
Anterior inferior	50	46.9
Lateral superior	34	32
Lateral inferior	16	14.8
Posterior superior	10	9.2
Posterior inferior	53	49.07
Entire lung	14	13

2) Distribution of the patients based on abnormal lung ultrasound findings, done at thetime of admission

Ultrasound findings	**Frequency(N)**	**Percentage(%)**
Echo-poor, non-aerated lesion	94	87
With air bronchogram	85	90.4
Without air bronchogram	9	9.6
Fluid bronchogram	32	34
Hepatization of lung	25	26.5
Vascular pattern	86	91.4
Interstitial pattern (B lines)	69	63.9

ISSN: 0975-3583, 0976-2833 VOL 15, ISSUE 07, 2024

3) Gross comparison of ultrasound and laboratory findings in bacterial vs non-bacterialetiology of CAP.

Characteristics	Bacterial CAP	Non-Bacterial CAP
1)Ultrasound findings		
Pneumonic lesions sub centimetric or >1cmsize	>1cm sized pneumonic lesions (84.8%)	Sub centimetric sized pneumonic lesions (91.7%)
Unilateral or Bilateral involvement	Unilateral (85.7%)	Bilateral (54%)
Solitary or Multifocal	Solitary (80%)	Multifocal (67%)
Air bronchogram and Hepatization	Common (91.4%)	Less common (72.6%)
Pleural thickening (>2mm)	Less common (In 25 patients)	More common(In 46 patients)
Vascular pattern in consolidation	More common (97.1%)	Less common (71.2%)
Focal or diffuse B lines	Focal B lines (40%)	Diffuse B lines (60%)
Pleural effusion	Common (62.8%)	Rare (8%)
Lung involvement	Posterior basal (80%)	Diffuse (50%)
2) Laboratory findings	Increased (71%)	Normal (70%)
WBC Count		
CRP level	Increased (91.4%)	Increased (76.7%)

ISSN: 0975-3583, 0976-2833 VOL 15, ISSUE 07, 2024

4) Correlation of changes in ultrasound findings with etiology of CAP, on the day 5-7offollow-up

Ultrasound findings	**Bacterial CAP (n=35)**		**Non-bacterial CAP (n=73)**	
Size of pneumonic lesion(Total=94)	(N)	(%)	(N)	(%)
Increase	2	5.7	9	12.3
Same	1	2.8	4	5.3
Decrease	31	88.5	47	64.2
Presence of B lines(Total=69)	14	40	15	20.5
Presence of pleuralthickening (Total=25)	5	14	10	13.6
Presence of pleural effusion(Total=28)	11	31	3	4.1
Presence of collapse(Total=8)	3	8	0	0

5) Correlation of changes in ultrasound findings with etiology of CAP, on days 10-14 of follow-up

Ultrasound findings	**Bacterial CAP (n=35)**		**Non-bacterial CAP (n=73)**	
Size of pneumonic lesion (Total=16)	(N)	(%)	(N)	(%)
Increase	0	0	0	0
Same	0	0	4	5.4
Decrease	2	5.7	10	13.6
Presence of B lines (Total=29)	2	5.7	3	4.1
Presence of pleural thickening (Total=15)	0	0	3	4.1
Presence of pleural effusion(Total=14)	2	5.7	0	0
Presence of collapse (Total=3)	0	0	0	0

ISSN: 0975-3583, 0976-2833 VOL 15, ISSUE 07, 2024

DISCUSSION

The study recruited 108 individuals of various age groups, highlighting the diversity of the CAP. The prevalence of patients aged 1month to 5 years implies that this age group is particularly vulnerable to CAP, which could be attributable to a variety of variables such as immature immune system and undernutrition.

Due to the unavailability of PCR tests in our institute, we were unable to perform PCR tests to detect viral causes of pneumonia. So we divided our patients etiologically into bacterial and nonbacterial pneumonia.35 patients were found of bacterial pneumonia and the remaining 73 patients were categorizedas having non-bacterial pneumonia, which could be viral or atypical in etiology.

We found thatecho-poor non-aerated lesion (pneumonic lesion) with air bronchogram (90.4%) was the most common ultrasound finding at the time of admission followed by B lines (64%). Most of the cases hadsubcentimetric pneumonic lesions (64%), and resthad pneumonic lesions of sizelarger than 1 cm (36 %). on 5^{th} -7^{th} day follow-up examination, it was found that most of the patients (83%) showed a decrease in the size of their pneumonic lesions.During the second follow-up on the 10th - 14th day,of 16 patients most cases (75%) showed a decrease in pneumonic lesion size. We found that certain findings aid in distinguishing bacterial and non-bacterial pneumonia with quite high sensitivity (85%) and specificity (83%) rates. The most common findings in bacterial pneumonia were large echo-poor non-aerated lesions with an air bronchogram, pleural effusion (simple or complicated), and high regression rates. On the other hand, in non-bacterial pneumonia, sub-centimetric echo-poor non-aerated lesions, diffuse B lines, and pleural thickening were common findings. Therefore, incorporating these findings into ultrasound protocols aids in differentiating bacterial and non-bacterial pneumonia and guiding appropriate management. However, integrating ultrasound findings with clinical presentation and laboratory investigations ensures accurate diagnosis and treatment.

The study showed that there is a high sensitivity (87%) of lung ultrasound in diagnosing CAP. Not only in diagnosing but also in the characterization of pneumonic lesions, and also has the potential to differentiate between bacterial and non-bacterial pneumonia. The study has also proved that LUS is an excellent tool in the follow-up of CAP.

CONCLUSION

In conclusion, this study proves lung ultrasound is a highly sensitive imaging modality for diagnosing, characterizing, monitoring, and etiological diagnosis of community-acquired pneumonia.Therefore, Lung Ultrasound (LUS) should be mandatorily included in diagnostic protocols for community-acquired pneumonia, along with clinical and laboratory data, as it improves diagnostic accuracy, patient safety, and clinical efficiency.

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