ORIGINAL RESEARCH

An evaluation of the efficacy of lung ultrasound contrary to chest x-ray in children with community acquired pneumonia

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ABSTRACT
Lung ultrasound (US) is a simple and inexpensive technique for assessing community-acquired pneumonia (CAP). It has no radiation hazards and is easy to use. The aim of this study is to evaluate the efficacy of lung ultrasound in the diagnosis and follow-up of CAP. Also, the effectiveness of LUS is compared to that of CXR in patients.
100 patients aged from 1 month to less than 18 years were admitted to J.K. Lon Hospital, Jaipur with pictures of CAP. Lung US was performed for all patients initially, then a plain chest X-ray (CXR) was performed. Another lung ultrasound was performed on the 3rd and 5th day after admission.
In our study a significant correlation between PRESS score and USG was found on admission (r=0.42), and on final day (r=0.43) which were significant at 0.001 level. A significant correlation between CXR and PRESS score was found on admission (r=0.23) and on final day (r=0.27), which were significant. A significant correlation was also found between CXR and USG on day1 (r=0.77), and on final day (r=0.66) which were significant at 0.001 level. These results showed that all three PRESS score, LUS, CXR were helpful in follow-up of CAP patients. Correlation between USG and CXR were more significant and helpful in diagnosis and follow-up of CAP patients.
This study concluded that LUS is a better modility than CXR in identifying pneumonia in children. It is a promising tool for the follow up of patients with pneumonia.
Keywords: Paediatric Pneumonia, LUS, CXR, PRESS score

INTRODUCTION

Community acquired pneumonia (CAP) is a leading cause of morbidity and mortality, in paediatric age group and accounts for 16% of all deaths in patients under 5 years of age worldwide, estimated at 0.9 million in 2015.[1] Developed countries had an annual incidence of CAP in children less than 5 years of age of 34-40 per 1000 child years.[2] Pneumonia is an infection that affects the alveoli and involves variable proportion of pulmonary parenchyma. The air from the alveoli is replaced by fluid or pus. Community-acquired pneumonia is defined as the presence of signs and symptoms of pneumonia in a previously healthy child due to an infection, which has been acquired outside hospital.[3] Early diagnosis of CAP is essential to reduce the total burden of the disease. CAP can be diagnosed by history and physical examinations and clinical findings. However, in a significant number of children, CAP remains a diagnostic challenge mainly because a number of viral respiratory diseases, which require a different therapeutic approach, mimic the clinical manifestations of CAP.[4] Chest radiography has historically been employed to determine authentic CAP. Chest x-rays (CXR) are not the only diagnostic tool for CAP, though. It requires at least two projections to examine the entire lung anatomy. If only the posterio-anterior/antero-posterior projection is utilized, the heart, mediastinum, and diaphragm may hide some lung sections.[5] The two projections technique exposes patients significantly to ionising radiation, thereby raising their chance of developing

cancer and gene mutations, especially in the youngest children. Furthermore, there can frequently be delays in the acquisition and processing of images, and observers' interpretations of an image might vary widely. Finally, CXR has low image quality and is frequently not available in environments with inadequate resources.[6,7]

Due to all of these disadvantages, medical professionals and scientific bodies do not frequently recommend using CXR to diagnose CAP. Only in few circumstances, especially those with severe clinical symptoms pointing to consequences, is CXR advised. Additionally, just one projection—the poster-anterior/antero-posterior projection—is advised by the majority of experts in order to minimise radiation exposure, despite the fact that doing so increases the chance of missing CAP diagnosis. To confirm a cure, CXR must be avoided at the end of treatment. Currently, due to its low sensitivity and specificity, chest X-rays are not advised for routine screening of children receiving home therapy for CAP pneumonia.[8-10]

Computed tomogram imaging is regarded as the gold standard for diagnosis of pneumonia with higher sensitivity and specificity[11]. However, CT scan may not always be available and the high cost and higher radiation dose precludes its routine use in diagnosis of pneumonia.[12-13]

Acute respiratory illnesses caused by multiple virus impact children. The severity of a respiratory condition may be reflected by a number of symptoms, including breathing rapidly, wheezing, cyanosis, and usage of the supplementary respiratory muscles. These clinical findings may be crucial for an early diagnosis and course of therapy. Additionally, it's critical to properly treat acute respiratory infections to reduce the risk of respiratory failure, which can be fatal in children. In order to properly triage and treat severe instances, the respiratory state should be evaluated at the time of first encounter, similarly to how the APGAR rating system evaluates infants.

To address this issue, a new scoring system of the severity of respiratory infections in children is established, and named the Paediatric Respiratory Severity Score (PRESS) (Five components included in PRESS, namely, respiratory rate, wheezing, accessory muscle use, SpO2, and feeding difficulties), and evaluated its utility for assessing the severity of infection caused by various pathogens and for deciding the necessity of further clinical examinations and the treatment to start.[14]

The use of lung ultrasonography (LUS) has been suggested to be able to overcome these limitations of CXR and CT scan and increase the feasibility and accuracy of CAP diagnosis [15,16]. LUS is fast, radiationfree, repeatable, inexpensive and easily performed at the bedside [17-18]. In last few years Chest ultrasonography has shown a growing interest and has been used in diagnosis of pneumothorax, pneumonia and other lung pathology[19]. However not much of information is available regarding use of ultrasound in diagnosis and prognosis of pneumonia in children. Hence this study is planned to assess the utility of ultrasound in diagnostic and prognostic evaluation of patients with pneumonia.

MATERIAL AND METHODS

A prospective and observational Study was carried out among patients hospitalized with clinical suspicion of CAP pneumonia admitted in J.K. Lon Hospital Jaipur. Duration of study was from June 2018 to October 2019. Patients were considered for enrolment in the study after applying exclusion & inclusion criteria. Sample size calculated at 95% confidence level at alpha error of 0.05 assuming correlation coefficient(r) as 0.43 between USG and Chest X-ray on day 1st, 3rd, and 5th day as further reference article. As the study power of 80% an expecting at least 0.03 correlation coefficient between USG and chest X ray and the required sample size were 100 subjects hospitalized with diagnosis of CAP pneumonia.

INCLUSION CRITERIA: Children of age more than 1 month and less than 18 years with diagnosis of Community acquired pneumonia. Parent's prior informed consent.

EXCLUSION CRITERIA: Patients with co-morbid diseases like cardiac and renal disorders, chronic pulmonary diseases like tuberculosis, and Immunosuppression diseases like HIV. Children requiring ICU care, mechanical ventilation during hospitalization. Patients having less than 3 days hospital stay.

METHODOLOGY: 100 children with CAP pneumonia diagnoses were enrolled in the trial.Parent's informed written consent was obtained. A detailed clinical history was recorded, including symptoms, co-morbidities, and risk factors. Clinical testing was completed. Paediatric respiratory severity scores were used on patients who had been hospitalised and whose medical history and physical examination had suggested CAP pneumonia. For all patients, the PRESS Score (consisting of five components, including respiratory rate, wheezing, auxiliary muscle use, SpO2, and eating difficulties) was repeated on the 3rd and 5th days.

Chest radiograph was taken at the time of presentation and was reported by the radiologist (Dr. Rajkumar Yadav, Co- guide). Patients were treated as per protocol and in same admitted unit. Chest radiograph was repeated when required. All patients who were able to maintain orthostatic position underwent posterior-anterior (PA) radiograph, and patients which could not maintain the position underwent anterior-posterior radiograph on day of admission with a fixed machine (DR machine - Definium 6000/CR, machine Wipro GE DX-525, 500mA). Ultrasonographic examination were done with help of 3-7 MHz

frequency linear probe (machine Hitachi preirus) on day of admission and day 3rd and day 5th.

OBSERVATION AND RESULTS

This study was conducted in Department of Paediatrics, SMS Medical College Jaipur (Raj.), a tertiary level hospital. In this study a total of 100 children who were hospitalized for with the diagnosis of CAP were enrolled, out of 100 cases 65% male and 35% were female. Children belong to rural background 64%, urban 28%, and slum background 8%. We observed that 53% were fully immunized, 38% were partially immunized and 9% were unimmunized.

Table 1: Cohort characteristics of the 100 patients enrolled

Gender	Male	65
	Female	35
Residential status	Rural	64
	Urban	28
	Slum	8
Immunization status	Fully immunized	53
	Not immunized	9
	Partially immunized	38

Table 2: Paediatric Respiratory Severity Score (Severity)

PRESS score severity		
	Ad.	Final
Mild (1-2)	4	84
Moderate (3-4)	46	11
Severe (4-5)	50	5

Paediatric Respiratory Severity Score shows severity of illness and according to this score 4, 46, and 50 patients are classified mild, moderate and severe on admission day. On final day 84, 11, and 5 patients were classified as mild, moderate and severe categories.

Table 3: Distribution of Ultrasonography features

	At the time of admission (%)		**At the time of final outcome (%)**	
	No.	%	No.	%
Hypoechoic area	90	90.00	37	37.00
Irregular margin	51	51.00	16	16.00
Heterogenous area	40	40.00	11	11.00
Air bronchogram	90	90.00	37	37.00
Fluid bronchogram	26	26.00	8	8.00
Pleural effusion	20	20.00	18	18.00
Hepatization of lung tissue	43	43.00	7	7.00
Confluent B lines	24	24.00	6	6.00

This table shows USG findings. Out of 100 patients, 90% patients had hypoechoic area of consolidation and dynamic air bronchogram, hepatization of lung tissue detected in 43% and irregular and serrated margins in 51% 0f patients. Heterogenous area were evident in 40%, fluid bronchogram in 26%, pleural effusion was evident in 20% and confluent b lines in 24% patients.

Table 4: Follow up of lung consolidation findings as reported by LUS

Maximum thickness of consolidation(mm)	**No. of patients**	
	Day-1	**Day-2**
Group A(<15mm)	40	53
Group B (15-29mm)	47	26
Group C (>30mm)	10	7
Total	97	86

Consolidation was reported in 97% patients out of 100 patients. LUS done on day 1of presentation, and follow-up studies done on day 3rd and day 5th. This consolidation findings were reduced to 63% patients on follow-up on day 5th. Patients were divided into three groups according to maximum thickness of consolidation.

Table 5: Comparison between lung ultrasound and chest X-ray for the suggestive findings of pneumonia.

	USG Positive	USG negative	Total
CXR Positive	90	0	90
CXR Negative	7	3	10
Total	97	3	100

Among 100 patients having pneumonia, CXR was suggestive of pneumonia in 90 (90%) patients while LUS was suggestive of pneumonia in 97 (97%). This difference was statistically significant (p=<0.001).

Sensitivity =92.78% (Confidence Interval = 0.9590-1)
Specificity = 100% (Confidence Interval = 0.1077-0.6032)

Table 6: Comparison between LUS and Chest X-ray findings suggestive of pneumonia

Characteristics	LUS	CXR	P-value
Consolidation	97	90	0.001
Pleural Effusion	22	15	0.506

Two characteristic findings common in CXR and LUS are consolidation and pleural effusion. Consolidation was reported in LUS findings of 97% patients and CXR findings of 90% patients. The difference was statistically significant (p<0.001).

LUS reported pleural effusion in 22% patients while CXR reported pleural effusion in 15% patients. The difference was statistically not significant (p=0.50).

Table 7: Correlation between Paediatric Respiratory Severity Score (PRESS), chest ultrasonography (USG) and chest radiograph (CXR) scores

	Press and USG		CXR and Press		CXR and USG	
Findings	Correlation Coefficient 'r'	Pvalue	Correlation Coefficient 'r'	Pvalue	Correlation Coefficient 'r'	Pvalue
Admission	0.420	0.30	0.231	0.020	0.770	0.001
Final	0.439	0.001	0.276	0.005	0.668	0.001

A significant correlation between PRESS score and USG was found on admission (r=0.42), and on final day (r=0.43) which were significant at 0.001 level. A significant correlation between CXR and PRESS score was found on admission (r=0.23) and on final day (r=0.27), which were significant. A significant correlation was also found between CXR and USG on day1 (r=0.77), and on final day (r=0.66) which were significant at 0.001 level.

DISCUSSION

A significant number of individuals employ chest radiography to diagnose pneumonia because it is convenient and easy to perform. The risk of exposure to radiation in gestation and the interpretation of chest radiographs, however, have been found in certain investigations to be highly variable. Despite not being a good ultrasound target, the lung can more easily be seen on an ultrasound scan once fluid or solid material has accumulated there. The delays that are often associated with CXR and avoiding radiation exposure can be greatly reduced with chest ultrasonography. While the interpretation of the echographic image is unquestionably less operator dependent than the execution of the USG examination, the ultrasound pattern of a lung consolidation is in fact very different from an alveolar-interstitial syndrome or a normal pattern. The use of LUS in the diagnosis and treatment of community-acquired pneumonia in adults has been the subject of certain investigations.

This study was conducted in Department of Paediatrics, SMS Medical College Jaipur (Raj.), a tertiary level hospital. In this study a total of 100 children who were hospitalized for with the diagnosis of CAP were enrolled, out of 100 cases 65% male and 35% were female. Children belong to rural background 64%, urban 28%, and slum background 8%. We observed that 53% were fully immunized, 38% were partially immunized and 9% were unimmunized.

In our study LUS characteristic findings on right side lung in 62%, left lung side in 21%, and bilateral lung fields in 17%. On comparison between right and left lung involvement observed in LUS, the difference is statistically significant (p<0.001). This study result showed that right side of lung was more involved in CAP patients.

Meng chie ho Ho *et al*. (2014) in a retrospective study showed usefulness of lung ultrasound in diagnosis of CAP in children, they observed that characteristic location on right side in 59.5%, left side in 30.2% and on both side in 10.1%.[20] our findings suggest that 62% of patients had right lung involvement in CAP patients.

In our study among 100 patients having pneumonia, CXR was suggestive of pneumonia in 90 (90%) patients while LUS was suggestive of pneumonia in 97 (97%) patients with sensitivity 92.78% and specificity 100%. Positive predictive value (PPV) was

100% and negative predictive value (NPV) was 80%. This difference was statistically significant (p=0.001).

Esposito *et al.* (2014) studied "Performance of lung ultrasonography in children with community-acquired pneumonia" found that 48 cases out of total 103, radiographically confirmed CAP patients, the sensitivity, specificity, and positive and negative predictive values of LUS in comparison with CXR were respectively 97.7%, 98.1%, 94.0% and 98.1%.[21]

Bourcier JD *et al.* (2013) in their study "Performance comparison of lung ultrasound and CXR for the diagnosis of pneumonia in Emergency department" found that out of 166 patients included in this study, 123 were finally diagnosed with pneumonia. In this study the sensitivity, specificity, and positive and negative predictive values of LUS in comparison of CXR were respectively 95%, 57%, 93% and 67%. This study reveals a significantly higher sensitivity of lung ultrasound for the diagnosis of acute pneumonia compared to chest X-ray (95% vs 60%, $p<.01$).[22]

Cortellaro *et al.* (2010) in this study "Lung ultrasound is an accurate diagnostic tool for the diagnosis of pneumonia in the emergency department" found that 81 cases were diagnosed with CAP. The CXR was positive in 54/81 patients' sensitivity 67% and specificity 85%, whereas lung ultrasound was positive in 80/81; sensitivity 98% and specificity 95%.[23]

Reissing *et al*. (2012) reported first prospective study in adults for the diagnosis of community acquired pneumonia using LUS and revealed a sensitivity of 93.4%, specificity of 97.7%.[24] USG studies showed higher sensitivity and specificity in diagnosis of CAP as compared to CXR and these results are similar to our study.

In our study LUS characteristic findings suggest that predominantly posterior region on both right and left side 49% and 24% involved in pneumonia patients. And in lower lateral region on both side 35% and 23% also significantly involved.

D'Amato *et al.* (2017) Assessment of thoracic ultrasound in complementary diagnosis and in follow up of community-acquired pneumonia detect involvement of posterior region in 54% cases on LUS.[25] This study showed similar results to our study.

In our study consolidation was reported in 97% patients out of 100 patients. LUS done on day 1 of presentation, and follow-up studies done on day 3rd and day 5th. This consolidation findings were reported to 86% patients on follow-up on day 5th. Observations are further analysed and divided into three groups according to maximum thickness of consolidation in Group A, Group B, and Group C as 30 mm respectively.

Group A included patients having consolidation of 15 mm. In this group, on day 1, LUS reported 40 patients, which were increased to 53(this increase in number is due to fall in group B and group C patients after 4,5-day treatment) patients on follow-up.

Group B included patients having consolidation of 15-29 mm. In this group, there were 47 patients, which were decreased to 26 on follow-up.

Group C included patients having consolidation of >30 mm. Number of patients in this group steadily declined on subsequent follow-up LUS. On day 1 LUS 10 patients were reported in this group and on follow-up decreased to 7 patients.

Meng- Chiegh Ho *et al*. (2014) studied "Usefulness of LUS in the diagnosis of CAP in children". LUS follow-up was also performed on 23 patients on day 1, day 3 to 5, and day 7 to 14. The results showed the decreasing size of the pneumonia patch from 10.9±8.7 cm2 to 5.5±4.8 cm2, and finally to 2±1.9 cm2.[20]

According to their LUS characteristics out of 97 patients' consolidation thickness <15mm in 40, between 15-29mm in 47 patients while >30mm only in 10 as reported on day. The size of consolidation ranges from 7-45mm with the average 16.33mm.

Caiulo *et al.* (2012) studied LUS characteristics of CAP in hospitalized children found a decrease in size or even complete resolution of pneumonia consolidations in 91.6% of patients in days 3 to 6 of follow-up in LUS examination. Mean size of Consolidation 18mm (range 6-48mm)[26]. Our study findings also were similar.

In our study 9 patients initially showed increase in size of consolidation probably due to poor response and progression of disease on LUS then gradual decrease in size of consolidation due change in antibiotics.

All the above studies showed gradual decline in the size of consolidation on follow-up at 4-5 th day. Hence these results are helpful in follow up of CAP patients. These studies are similar to our results.

In our study the two characteristic findings common in chest X-ray and LUS were consolidation and pleural effusion. Consolidation was reported in LUS findings of 97% patients and chest X-ray findings of 90% patients. This difference was statistically significant (p 0.001).LUS reported pleural effusion in 22% patients while chest X-ray reported pleural effusion in 15% patients. This difference was also statistically significant (p=0.005). Meng chie ho *et al*. (2014) studied the usefulness of lung ultrasound in the diagnosis of CAP in children, and found pleural effusion in 28.5% in LUS.

Saied Moghawri *et al.* (2019) results showed that there was a highly significant difference (p 0.001) between LUS and CXR in detecting consolidation, consolidation was detected in 116 patients (96.7%) with LUS, where as in 101 patients (84.6%) with CXR. There was a significant difference (p 0.001) between CXR and LUS in the detection of pleural effusion, 5(4.2%) with CXR in comparison with 19 (15.8%) with LUS.[27]

Bhimwal *et al.* (2017) studied Comparative study of x-ray chest and lung ultrasonography characteristics among community acquired pneumonia in children in 139 patients and found consolidation in LUS findings

in 130(93.5%) patients and CXR findings of 107(76.97%) patients. LUS reported pleural effusion (P.E) in 22(15.83%) patients while CXR reported P.E 15(5.03%) patients.[28]

LUS were better in diagnosis of consolidation in CAP patients as compare to CXR and used as a diagnostic tool in place of CXR where ultrasonography is available so avoid the excessive radiation exposure. LUS was also more helpful in diagnosis of pleural effusion in comparison of chest X ray. These above study results are similar to our study. In our study USG findings suggest that out of 100 patients on hospitalization, 90% patients had hypoechoic area of consolidation and 90% dynamic air bronchogram which was reduced to 37% on follow up, hepatization of lung tissue detected in 43% and reduced to 7% and irregular and serrated margins in 51% 0f patients which was reduced to 16%. Heterogenous area were evident in 40% and on follow-up reduced to 11%, fluid bronchogram in 26% and on follow-up reduced to 8%, pleural effusion was evident in 20% and on follow-up 18% and confluent b lines in 24% patients which showed improvement and on follow-up present in only 6% patients.

Disappearance or a change in these patterns showed sign of lung reaeration, and improvement in CAP. These follow-up results helped in prognosis of CAP. Reissing *et al*. (2012) in their study Lung Ultrasound in the Diagnosis and Follow-up of Community-Acquired Pneumonia suggest hypoechoic area of consolidation in 97.6% at hospitalization and showed improvement to 61% on follow up, air bronchogram in 86.7% and on follow-up 71.2%, and fluid bronchogram only in 8.1% and on follow-up 6.1%, and pleural effusion in 54.4% reduced to 23.5%, and irregular margin in 76.5% to 48.4% on follow-up.[24] These results are also similar to our study and helpful in prognosis on CAP.

Cortellaro *et al*. (2010) came to similar results hypoechoic area of consolidation in 73(91%) cases on hospitalization and showed improvement on follow-up in 38(47.5%), Dynamic air bronchograms were almost always present within the consolidation in 71(90.1%) and on follow-up 38(47.5%), fluid bronchogram in 28(39%) and on follow-up in 17(21.25%), pleural effusion in 31(42%) and on follow-up in 18(22.5%), irregular and serrated margins in 42(57%) patients and showed improvement in 20(25%) patients.[23] This study results are similar to our study.

Parlamento *et al*. (2009) studied Evaluation of lung ultrasound for the diagnosis of pneumonia in the emergency department found that out of 48 cases showed hypoechoic area of consolidation in 31(96.9%) on hospitalization and on follow up, alveolar interstitial syndrome in 22(68.8%), air bronchogram in 16(50.0%) and pleural effusion in 3% cases.[29] This study results are also similar to our study. These follow-up results of above studies are similar to our study and helped in prognosis of CAP.

In our study Paediatric Respiratory Severity Score shows severity of illness and according to this score 4, 46, and 50 patients are classified into mild, moderate and severe on admission day. On final day 84, 11, and 5 patients were classified as mild, moderate and severe categories. Results showed that PRESS score is helpful in assessment of severity of illness.

PRESS score was compared with USG and CXR on follow-up and showed similar result in improvement in clinical status of CAP patients. So, PRESS Score can be used as a tool for assessment of CAP patients. Still No study is available regarding this scoring system and for comparison.

In our study a significant correlation between PRESS score and USG was found on admission (r=0.42), and on final day (r=0.43) which were significant at 0.001 level. A significant correlation between CXR and PRESS score was found on admission (r=0.23) and on final day (r=0.27), which were significant. A significant correlation was also found between CXR and USG on day1 (r=0.77), and on final day (r=0.66) which were significant at 0.001 level.

On correlating USG with CXR, USG proves to be a better diagnostic tool in diagnosis and follow up of CAP patients, and also helpful in eliminating the exposure to X-ray radiation.

SUMMARY AND CONCLUSION

This was a hospital based prospective observational study, conducted between June 2018 to October 2019 in Sir Padampat Mother and Child Health Institute (SPMCHI), Department of Paediatric Medicine, SMS Medical College, Jaipur.

In our study there were 65% male and 35% female out of 100 patients and presented male sex predominance. LUS findings suggested involvement of lungs according to localization 62%, 21% and 17% on right, left and bilaterally. Also proposed that posterior region predominantly involved on both side in 49% and 24% cases. USG findings displayed hypoechoic area of consolidation, irregular margin, heterogenous area, air bronchogram, fluid bronchogram, pleural effusion, hepatization of lung tissues, and confluent B lines in 90%, 51%, 40%, 90%, 26%, 20%, 43%, and 24% patients on hospitalization and 37%, 16%, 11%, 37%, 8%, 18%, 7%, and 6% on follow-up and exhibited improvement in all areas of consolidation. In our study LUS findings were used in prognosis of hospitalized CAP patients according to consolidation size; three groups 30 mm, showed 40%, 47%, 10% patients and on follow up in 53%, 26%, and 7% patients. This shows improvement on follow-up can be assess better by LUS.

In our study USG showed more sensitivity and specificity in diagnosis of pneumonia in comparison of CXR and used as a diagnostic tool for pneumonia. In our study a significant correlation between PRESS score and USG was found on admission (r=0.42), and on final day (r=0.43) which were significant at 0.001 level. A significant correlation between CXR and

PRESS score was found on admission (r=0.23) and on final day (r=0.27), which were significant. A significant correlation was also found between CXR and USG on day1 (r=0.77), and on final day (r=0.66) which were significant at 0.001 level. These results showed that all three PRESS score, LUS, CXR were helpful in follow-up of CAP patients. Correlation between USG and CXR were more significant and helpful in diagnosis and follow-up of CAP patients.

CONCLUSION

This study found that LUS is a superior modality for detecting pneumonia in children than CXR. It is a potential technique to monitor pneumonia patients. Using LUS, patients can be followed up on more frequently during therapy, and more information can be made available to paediatricians for decision-making. We propose that LUS can be used as a supplemental tool to chest radiography in the diagnosis and follow-up of pneumonia in children, thereby reducing ionizing radiation exposure.

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