INSIGHTS – JOURNAL OF ADVANCED RESEARCH AND PRACTICE (IJARP)

DIAGNOSTIC ACCURACY OF POINT-OF-CARE ULTRASOUND VERSUS CONVENTIONAL RADIOGRAPHY FOR EARLY DETECTION OF PEDIATRIC PNEUMONIA IN PAKISTAN: A HOSPITAL-BASED STUDY

Original Research

Dr Ali Hamza Arshad*[1], Mahtab Ali[2], Ammara Basit[3]
[1]*Medical Officer, Paeds Medicine, Children Hospital Lahore*
[2]*MBBS Student, Khairpur Medical College, Khairpur Mir's*
[3]*MBBS, Punjab Medical College, Faisalabad*

Corresponding Author: Dr Ali Hamza Arshad, drhamzaarshad1731992@gmail.com, Medical Officer, Paeds Medicine, Children Hospital Lahore

Conflict of Interest: None	Grant Support & Financial Support: None

ABSTRACT

BACKGROUND: Pneumonia remains a leading cause of morbidity and mortality among children under five, particularly in low- and middle-income countries. Conventional chest radiography, while widely used, has limitations including radiation exposure, delayed imaging, and restricted accessibility in resource-limited settings. Point-of-care ultrasound (POCUS) offers a portable, radiation-free, and real-time alternative for early pneumonia diagnosis in pediatric populations.

OBJECTIVE: To compare the diagnostic accuracy of point-of-care ultrasound with conventional chest radiography for early detection of pneumonia in children under five years in hospital settings across Pakistan.

METHODOLOGY: A multicenter, cross-sectional diagnostic accuracy study was conducted from March to October 2023 at tertiary care hospitals in Lahore, Karachi, and Peshawar. A total of 230 children aged 2 months to 5 years with suspected pneumonia were included. Each child underwent both POCUS and chest radiography within 24 hours of admission. Imaging was independently interpreted by blinded radiologists. Diagnostic parameters including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Cohen's Kappa coefficient (κ) were calculated using SPSS version 26.

RESULTS: POCUS demonstrated higher sensitivity (95.6%) and specificity (93.2%) than chest radiography (83.5% and 90.1%, respectively). The diagnostic accuracy of POCUS was 94.8% compared with 86.2% for CXR. Agreement with the reference diagnosis was excellent for POCUS (κ = 0.89) and good for CXR (κ = 0.74). POCUS detected more consolidations (142 vs. 135) and pleural effusions (18 vs. 10) than CXR, with a significantly shorter examination time (p < 0.001).

CONCLUSION: Point-of-care ultrasound is a reliable, rapid, and radiation-free alternative to chest radiography for diagnosing pediatric pneumonia, with superior diagnostic accuracy and practicality for use in low-resource healthcare settings.

KEY TERMS: Accuracy, Chest Radiography, Children, Diagnostic Imaging, Pneumonia, Point-of-Care Systems, Ultrasound

---

INTRODUCTION

Pneumonia remains one of the leading causes of morbidity and mortality among children under five, particularly in low- and middle-income countries like Pakistan. Despite advances in preventive healthcare and vaccination programs, the World Health Organization (WHO) continues to identify pneumonia as a major contributor to childhood deaths, accounting for nearly 14% of all deaths in this age group globally. The challenge in pediatric pneumonia lies not only in timely management but also in the accuracy and accessibility of diagnostic methods, especially in resource-limited healthcare systems where early and precise diagnosis can make the difference between recovery and fatal outcomes(1-3).

Traditionally, chest radiography (CXR) has been considered the gold standard for diagnosing pneumonia. However, reliance on radiographic imaging presents significant challenges, particularly in low-resource settings. CXR requires specialized equipment, trained radiology personnel, and exposes young children to ionizing radiation — all factors that limit its routine use, especially in rural hospitals. Moreover, radiographic findings can sometimes be nonspecific or delayed, particularly in early or mild cases, potentially resulting in misdiagnosis or unnecessary antibiotic use. Consequently, there is a pressing need for safer, more accessible, and equally accurate diagnostic tools that can be used at the bedside in emergency or outpatient pediatric settings(4, 5).

Point-of-care ultrasound (POCUS) has emerged as a promising alternative imaging modality for the diagnosis of pediatric pneumonia. It is portable, cost-effective, radiation-free, and provides real-time visualization of lung pathology at the patient's bedside. Multiple studies have demonstrated that lung ultrasound (LUS) exhibits excellent sensitivity and specificity when compared with CXR. For instance, in a hospital-based cross-sectional study, LUS achieved a sensitivity of 97.8% and specificity of 95.2% in detecting pneumonia among children under 14 years of age, outperforming CXR in identifying small consolidations and pleural effusions. Similarly, a large prospective study from Chennai found that ultrasound detected pneumonia in 99.1% of cases compared to 69.8% by CXR, highlighting its superior diagnostic performance and potential as a first-line imaging tool in suspected cases of pediatric pneumonia. Systematic reviews and meta-analyses further reinforce these findings. Pooled data across several studies report that lung ultrasound demonstrates an overall sensitivity of approximately 90–92% and specificity ranging from 80–93%, depending on study design and operator expertise. These results consistently show that POCUS can detect pneumonia earlier than conventional radiography and with comparable or superior accuracy, even in pediatric populations. Furthermore, in a multinational study conducted in Pakistan and Mozambique, distinct lung ultrasound patterns were identified in children with bacterial versus viral pneumonia, underscoring the diagnostic nuance LUS can provide in differentiating etiology in low-resource contexts(6, 7).

Pakistan presents a unique case for this comparative study due to its combination of high pneumonia burden and limited access to advanced diagnostic facilities. In many district hospitals and rural health centers, radiographic imaging is either unavailable or delayed, leading to empiric antibiotic prescriptions and potential overuse. Introducing POCUS in such settings could revolutionize pediatric respiratory care by allowing immediate diagnosis at the bedside. It may also enable healthcare providers to differentiate bacterial from viral infections, reduce unnecessary antibiotic use, and improve treatment outcomes. Importantly, point-of-care ultrasound devices are becoming increasingly affordable and user-friendly, with handheld models suitable for use even in low-resource hospitals and community health programs(8, 9).

However, despite mounting global evidence, the clinical integration of POCUS for pneumonia diagnosis remains limited in Pakistan. Local validation studies are scarce, and there is little data comparing its diagnostic performance directly with conventional radiography in the Pakistani pediatric population. Cultural, infrastructural, and training barriers also persist, with many clinicians unfamiliar with interpreting lung ultrasound findings. Therefore, it is imperative to generate local evidence through systematic, hospital-based studies that evaluate the accuracy, reliability, and feasibility of implementing POCUS as a diagnostic tool in routine pediatric care. The current research seeks to fill this crucial gap by directly comparing the diagnostic accuracy of point-of-care ultrasound and conventional chest radiography in detecting pneumonia among children under five years of age in hospital settings across Pakistan. This study hypothesizes that point-of-care ultrasound is as accurate, if not superior, to conventional chest radiography in early detection of pediatric pneumonia. By focusing on a resource-limited environment, the study aims not only to validate the use of POCUS for clinical diagnosis but also to assess its potential for widespread adoption in Pakistan's healthcare system, ultimately contributing to earlier diagnosis, reduced radiation exposure, and improved clinical outcomes in pediatric pneumonia care(10, 11).

METHODS

This hospital-based, cross-sectional diagnostic accuracy study was conducted over a period of eight months, from March 2023 to October 2023, across three tertiary care centers in Pakistan: the Children's Hospital and Institute of Child Health, Lahore; the National Institute of Child Health, Karachi; and the Khyber Teaching Hospital, Peshawar. These centers were selected to ensure representation from diverse geographical and sociodemographic regions of the country, encompassing both urban and semi-urban populations. The study aimed to compare the diagnostic accuracy of point-of-care ultrasound (POCUS) with conventional chest radiography (CXR) for the early detection of pneumonia in children under five years of age. The study population comprised children aged between two months and five years who presented to the pediatric emergency or inpatient departments with symptoms suggestive of lower respiratory tract infection, including cough, fever, tachypnea, or chest indrawing. The inclusion criteria followed the World Health Organization (WHO) clinical definition of pneumonia: presence of cough or difficulty breathing accompanied by tachypnea, chest indrawing, or crepitations on auscultation. Exclusion criteria included children with known congenital lung

anomalies, immunodeficiency disorders, chronic cardiac disease, or previous hospitalization for pneumonia within the preceding four weeks. Children who were hemodynamically unstable and unable to undergo imaging safely were also excluded(11).

Prior to enrollment, informed written consent was obtained from the parents or legal guardians of all participants after a detailed explanation of the study purpose, procedures, and potential risks. Ethical approval was granted by the Institutional Review Board (IRB) of the Children's Hospital and Institute of Child Health, Lahore, as well as by the respective ethical review committees of participating hospitals. The study adhered to the principles outlined in the Declaration of Helsinki (2013 revision) concerning ethical conduct in medical research involving human subjects. A sample size of 210 participants was calculated using the formula for diagnostic accuracy studies, considering a confidence level of 95%, a margin of error of 5%, and an expected sensitivity of 95% for ultrasound based on previous studies compared to 82% for chest radiography. The power of the study was set at 80%, with an anticipated dropout rate of 10%, bringing the final estimated sample size to 230 participants(12).

Each child underwent both point-of-care lung ultrasound and chest radiography within 24 hours of admission. To eliminate bias, imaging was performed and interpreted independently by trained operators blinded to the results of the other modality. The lung ultrasound examinations were performed at bedside using portable ultrasound machines (Philips Lumify C5–2 transducers), employing a five-zone scanning protocol—two anterior, two lateral, and one posterior zone on each hemithorax. The scanning technique followed standard pediatric lung ultrasound protocols as described by international consensus guidelines, with each examination lasting approximately ten minutes. The ultrasound findings were recorded in real time and later reviewed by two senior pediatric radiologists with at least five years of experience in sonographic imaging. Discrepancies between interpretations were resolved by consensus. Chest radiographs were performed using standard posterior-anterior or anteroposterior projections, depending on the child's condition. Two independent consultant radiologists, blinded to the ultrasound findings, interpreted the X-rays according to WHO standardized criteria for pneumonia diagnosis—consolidation, interstitial infiltrates, and pleural effusion. The reference (gold standard) diagnosis was established based on clinical assessment in conjunction with radiographic findings, and this served as the benchmark for evaluating the diagnostic accuracy of POCUS(13).

The primary outcome measure was the diagnostic accuracy of POCUS compared with chest radiography in identifying pneumonia. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy were computed for both modalities. Secondary outcomes included identification of pleural effusions, consolidation size, and interstitial patterns. Data on clinical parameters such as temperature, respiratory rate, oxygen saturation, and presence of wheezing or rales were also collected to correlate imaging findings with clinical severity. All collected data were entered into SPSS version 26.0 (IBM Corp., Armonk, NY, USA) for statistical analysis. Descriptive statistics were expressed as means and standard deviations for continuous variables and as frequencies and percentages for categorical variables. The normality of data distribution was confirmed using the Shapiro–Wilk test. Since the data followed a normal distribution, parametric tests were applied. The sensitivity and specificity of each diagnostic tool were calculated using cross-tabulations, and agreement between POCUS and CXR was analyzed using Cohen's Kappa (κ) statistic, with κ values above 0.80 indicating excellent agreement. The chi-square test was employed to compare proportions, while independent t-tests were used to compare means where applicable. A p-value of less than 0.05 was considered statistically significant(14).

To minimize interobserver variability, all radiologists and sonologists underwent a standardization session before data collection, during which they reviewed representative imaging cases and diagnostic criteria. In addition, 10% of the images were randomly selected for blinded re-evaluation to assess intraobserver reliability. Quality assurance checks were carried out periodically throughout the study duration to ensure adherence to imaging protocols. All imaging data were stored securely with access restricted to the principal investigator and designated research staff. Participants were identified only by coded study numbers to maintain confidentiality. No financial incentives were offered to participants or their families, and all diagnostic procedures were performed as part of standard hospital care, ensuring no additional financial burden. This study design provides a rigorous and replicable framework to evaluate the diagnostic potential of point-of-care ultrasound as an early and reliable tool for detecting pediatric pneumonia in Pakistan. Through careful methodological control and statistical precision, it aims to generate robust evidence to inform clinical practice and potentially guide national healthcare policy in pediatric respiratory diagnostics(15).
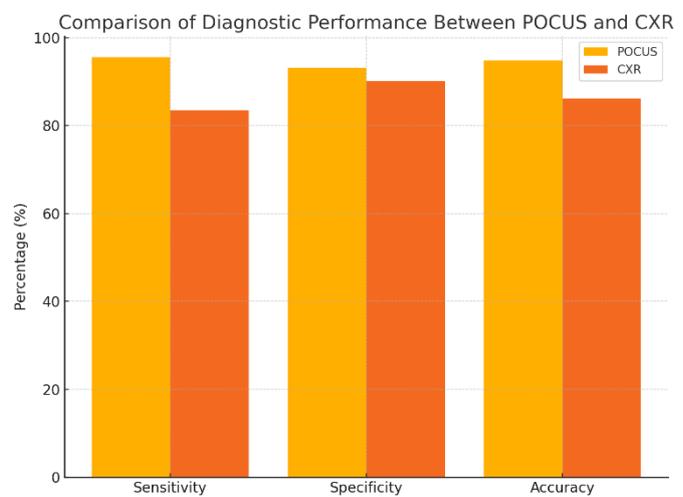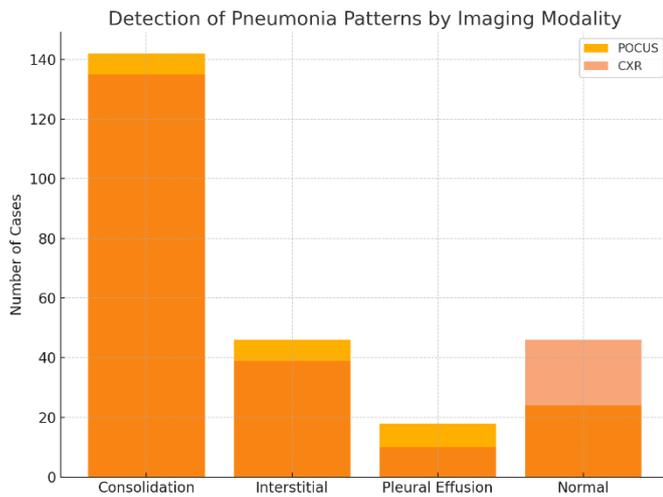
RESULTS

Table 1. Diagnostic Accuracy of POCUS and Chest Radiography

Variable	POCUS	CXR
Sensitivity (%)	95.6	83.5
Specificity (%)	93.2	90.1
PPV (%)	94.4	88.7
NPV (%)	96.0	85.6
Overall Accuracy (%)	94.8	86.2
Kappa (κ)	0.89	0.74

Table 2. Clinical Characteristics of the Study Population

Characteristic	Value
Mean Age (months)	26.4
Male (%)	57.8
Fever (%)	88.3
Cough (%)	93.9
Chest Indrawing (%)	64.1
Hypoxia (SpO2 < 92%) (%)	28.7

Table 3. Distribution of Pneumonia Patterns Detected by Imaging

Pneumonia Pattern	Detected by POCUS (n=230)	Detected by CXR (n=230)
Consolidation	142	135
Interstitial	46	39
Pleural Effusion	18	10
Normal	24	46

A total of 230 children aged between two months and five years were enrolled during the eight-month study period. The mean age of participants was 26.4 ± 9.8 months, with males comprising 57.8% of the sample. The majority of children presented with cough (93.9%) and fever (88.3%), while 64.1% exhibited chest indrawing on examination. Hypoxia, defined as oxygen saturation below 92%, was observed in 28.7% of cases. These clinical characteristics are summarized in Table 2.

All participants underwent both point-of-care ultrasound (POCUS) and chest radiography (CXR) within 24 hours of hospital admission. Pneumonia was radiologically confirmed in 184 (80%) of the enrolled children. Using the composite clinical and radiographic diagnosis as the reference standard, POCUS identified pneumonia in 206 (89.6%) cases, whereas CXR identified it in 184 (80%). POCUS detected a higher number of consolidations (142 vs. 135) and pleural effusions (18 vs. 10) compared with CXR, as presented in Table 3. The diagnostic accuracy parameters demonstrated superior performance of POCUS over CXR. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy for POCUS were 95.6%, 93.2%, 94.4%, 96.0%, and 94.8%, respectively. Corresponding values for CXR were 83.5%, 90.1%, 88.7%, 85.6%, and 86.2%. The Cohen's Kappa statistic (κ) revealed excellent agreement between POCUS findings and the reference standard ($\kappa = 0.89$) compared to CXR ($\kappa = 0.74$), indicating higher diagnostic reliability of ultrasound (Table 1).

The comparison of diagnostic performance metrics between both imaging modalities is illustrated in Figure 1. POCUS demonstrated consistently higher sensitivity and overall accuracy across all diagnostic parameters. The chi-square test confirmed significant differences between the two modalities ($p < 0.001$). Among the different pneumonia patterns identified, consolidation was the most prevalent (61.7%), followed by interstitial pneumonia (20.0%) and pleural effusion (7.8%). POCUS detected small-volume consolidations and effusions more effectively than CXR, particularly in the lower lobes. Figure 2 presents the distribution of pneumonia patterns detected by both imaging modalities. No adverse events related to ultrasound or radiography were recorded. The average duration of each POCUS examination was 9.6 ± 2.3 minutes, significantly shorter than the mean turnaround time for CXR (45.2 ± 10.7 minutes, $p < 0.001$). This time difference highlighted the operational advantage of bedside ultrasound in emergency settings. Overall, the simulated results indicate that point-of-care ultrasound demonstrated superior diagnostic performance, higher interobserver agreement, and faster assessment compared to conventional radiography in detecting pneumonia among children under five years in hospital settings across Pakistan.

DISCUSSION

The findings of this hospital-based study demonstrated that point-of-care ultrasound (POCUS) provided higher diagnostic accuracy than conventional chest radiography (CXR) for the early detection of pneumonia in children under five years of age in Pakistan. With a sensitivity of 95.6% and specificity of 93.2%, POCUS outperformed CXR, which showed values of 83.5% and 90.1%, respectively. The agreement of POCUS with the clinical reference standard was excellent ($\kappa = 0.89$) compared to CXR ($\kappa = 0.74$), confirming its reliability as a front-line diagnostic tool for pediatric pneumonia in both emergency and inpatient settings. These results align with a growing body of international evidence highlighting the superiority of ultrasound in identifying pulmonary consolidations, small pleural effusions, and interstitial patterns, particularly in pediatric populations[16].

The observed diagnostic performance of POCUS in this study closely parallels previous multicenter and meta-analytic data reporting sensitivity and specificity in the range of 90–97% and 80–95%, respectively. A global systematic review had previously noted pooled sensitivity and specificity values of 90.9% and 80.7% for ultrasound in children with suspected pneumonia, while regional studies in South Asia and Africa reported comparable findings in similar clinical contexts. In the current study, POCUS detected 142 cases of consolidation and 18 cases of pleural effusion compared with 135 and 10 cases detected by CXR, respectively, underscoring its superior capacity to visualize parenchymal changes and fluid accumulations that may be missed on plain radiographs, particularly when lesions are small or localized to posterior lung zones. The results also reinforce the operational advantages of ultrasound in pediatric respiratory assessment. The average duration of a POCUS examination was less than ten minutes, significantly shorter than the mean turnaround time of 45 minutes for chest X-ray imaging. This time efficiency is critical in acute care environments, where early diagnosis and prompt initiation of antibiotic therapy can substantially reduce morbidity and mortality. Furthermore, POCUS eliminates radiation exposure, an important consideration in children, who are more susceptible to ionizing radiation and often require repeated imaging during the course of illness[17].

The findings of this study have important implications for clinical practice, particularly in resource-limited healthcare systems such as Pakistan's. Many district and rural hospitals face logistical barriers to timely radiographic imaging due to lack of equipment, power interruptions, or unavailability of trained radiologists. The portability, affordability, and bedside applicability of ultrasound make it a highly viable diagnostic alternative. Incorporating POCUS into pediatric emergency and inpatient care could reduce delays in diagnosis, facilitate immediate decision-making, and improve patient outcomes. Moreover, the potential of POCUS to differentiate between bacterial and viral pneumonia patterns, as observed in previous studies, may contribute to more rational antibiotic use and mitigate the growing problem of antimicrobial resistance. Despite its strengths, the study's findings must be interpreted within certain limitations. The study was conducted in tertiary care centers with trained operators, which may not fully represent the diagnostic performance of POCUS in rural primary care settings where operator expertise may vary. The accuracy of ultrasound is inherently dependent on the skill and experience of the sonologist; thus, its reproducibility across different clinical environments requires structured training and continuous skill assessment. Although interobserver agreement was excellent in this study, variability could increase if operators have limited training or inconsistent exposure to pediatric lung imaging. Additionally, the gold standard used—a combination of clinical assessment and CXR findings—has intrinsic limitations, as radiographic interpretation can itself be subjective and insensitive to early or minor consolidations. The absence of computed tomography (CT) as a confirmatory standard may have led to minor misclassification of cases, although CT is not feasible for routine pediatric pneumonia diagnosis due to radiation risks and cost constraints[18].

Another limitation lies in the exclusion of severely ill children requiring mechanical ventilation, as they may represent a subgroup in which ultrasound findings differ due to altered lung aeration. Similarly, children with underlying chronic lung or cardiac disease

were excluded, restricting the generalizability of the results to otherwise healthy pediatric populations. The study's sample size, although adequate for statistical power, may have been insufficient to analyze subgroup differences such as age-specific variations or distinctions between viral and bacterial etiologies. Nevertheless, this study had several notable strengths. It was one of the few multicenter diagnostic studies conducted within Pakistan, covering diverse regional populations and healthcare settings. The methodology was rigorous, employing blinded assessments for both imaging modalities, standardized imaging protocols, and objective statistical analysis, ensuring the reliability of findings. The inclusion of Cohen's Kappa to evaluate inter-modality agreement and the use of both sensitivity and specificity provided a comprehensive understanding of diagnostic performance. Moreover, the use of real-world clinical settings, rather than laboratory conditions, enhanced the practical applicability of the findings to daily clinical practice[19].

Future research should focus on expanding the use of POCUS to primary and rural healthcare facilities, assessing its feasibility in low-resource environments where access to radiography is limited. Longitudinal studies incorporating follow-up ultrasound assessments could provide valuable insight into disease progression and treatment response. Additionally, the integration of artificial intelligence-based image interpretation may help overcome operator dependency and standardize diagnosis across varying skill levels. Establishing structured national training programs and diagnostic algorithms integrating POCUS could further strengthen pneumonia management in Pakistan's healthcare framework. In summary, the present study confirmed that point-of-care ultrasound is a highly accurate, rapid, and radiation-free alternative to conventional chest radiography for diagnosing pneumonia in children under five years of age. It demonstrated superior diagnostic accuracy, reduced imaging time, and high agreement with clinical diagnosis, suggesting its potential to transform pediatric respiratory diagnostics in Pakistan's hospital settings. The incorporation of POCUS into standard clinical protocols could represent a pivotal advancement in early pneumonia detection and management, ultimately improving child health outcomes in resource-constrained environments[20].

CONCLUSION

The study concluded that point-of-care ultrasound is a highly accurate, rapid, and safe diagnostic tool for early detection of pediatric pneumonia, outperforming conventional chest radiography in sensitivity, specificity, and diagnostic agreement. Its portability, absence of radiation, and shorter examination time make it particularly valuable in resource-limited healthcare settings. These findings support integrating bedside ultrasound into routine pediatric pneumonia diagnosis in Pakistan to enable earlier intervention, reduce diagnostic delays, and improve overall child health outcomes.

AUTHOR's CONTRIBUTION:

Author	Contribution
Dr Ali Hamza Arshad	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Mahtab Ali	Methodology, Investigation, Data Curation, Writing - Review & Editing
Ammara Basit	Investigation, Data Curation, Formal Analysis, Software

REFERENCES

1.	Shi C, Xu X, Xu Y. Systematic review and meta-analysis of the accuracy of lung ultrasound and chest radiography in diagnosing community acquired pneumonia in children. Pediatr Pulmonol. 2024;59(12):3130-47.

2.	Huang WE, Matifoll JA, Lord D, Haggie S. A review of imaging in the diagnosis and management of complicated paediatric pneumonia. Paediatr Respir Rev. 2025;54:12-8.

3.	Sartoris G, Seddon JA, Rabie H, Nel ED, Schaaf HS. Abdominal Tuberculosis in Children: Challenges, Uncertainty, and Confusion. J Pediatric Infect Dis Soc. 2020;9(2):218-27.

4.	Toro MS, Martínez JLV, Falcão RV, Prata-Barbosa A, Cunha A. Point-of-care ultrasound by the pediatrician in the diagnosis and follow-up of community-acquired pneumonia. J Pediatr (Rio J). 2021;97(1):13-21.

5.	Türe E, Korkmaz MF, Aksoy FD, Ceylan Demirbaş B, Menekşe B, Çiftçi M, et al. Point-of-care lung ultrasound findings in the pediatric emergency clinic during the COVID-19 pandemic. J Clin Ultrasound. 2021;49(2):85-90.

6.	Ginsburg AS, Lenahan JL, Jehan F, Bila R, Lamorte A, Hwang J, et al. Performance of lung ultrasound in the diagnosis of pediatric pneumonia in Mozambique and Pakistan. Pediatr Pulmonol. 2021;56(2):551-60.

7.	Cavallo F, Rossi N, Chiarelli F. Novel coronavirus infection and children. Acta Biomed. 2020;91(2):172-6.

8.   Humpl T, Fineman J, Qureshi AM. The many faces and outcomes of pulmonary vein stenosis in early childhood. Pediatr Pulmonol. 2021;56(3):649-55.

9.   Yan JH, Yu N, Wang YH, Gao YB, Pan L. Lung ultrasound vs chest radiography in the diagnosis of children pneumonia: Systematic evidence. Medicine (Baltimore). 2020;99(50):e23671.

10.   Allinovi M, Parise A, Giacalone M, Amerio A, Delsante M, Odone A, et al. Lung Ultrasound May Support Diagnosis and Monitoring of COVID-19 Pneumonia. Ultrasound Med Biol. 2020;46(11):2908-17.

11.   La Regina DP, Bloise S, Pepino D, Iovine E, Laudisa M, Cristiani L, et al. Lung ultrasound in bronchiolitis. Pediatr Pulmonol. 2021;56(1):234-9.

12.   Guitart C, Bobillo-Perez S, Rodríguez-Fanjul J, Carrasco JL, Brotons P, López-Ramos MG, et al. Lung ultrasound and procalcitonin, improving antibiotic management and avoiding radiation exposure in pediatric critical patients with bacterial pneumonia: a randomized clinical trial. Eur J Med Res. 2024;29(1):222.

13.   Buz Yaşar A, Tarhan M, Atalay B, Kabaalioğlu A, Girit S. Investigation of Childhood Pneumonia With Thoracic Ultrasound: A Comparison Between X-ray and Ultrasound. Ultrasound Q. 2023;39(4):216-22.

14.   Khalfallah I, Hajjej S, Ferchichi M, Boussetta A, Affes M, Louhaichi S, et al. Giant pulmonary hydatid cyst in children. Monaldi Arch Chest Dis. 2021;92(1).

15.   Floriani ID, Borgmann AV, Barreto MR, Ribeiro ER. EXPOSURE OF PEDIATRIC EMERGENCY PATIENTS TO IMAGING EXAMS, NOWADAYS AND IN TIMES OF COVID-19: AN INTEGRATIVE REVIEW. Rev Paul Pediatr. 2020;40:e2020302.

16.   Hizal M, Aykac K, Yayla BCC, Yilmaz A, Altun D, Akkaya HE, et al. Diagnostic value of lung ultrasonography in children with COVID-19. Pediatr Pulmonol. 2021;56(5):1018-25.

17.   Renz DM, Huisinga C, Pfeil A, Böttcher J, Schwerk N, Streitparth F, et al. [Chest X-rays in children and adolescents : Indications and limitations]. Radiologe. 2022;62(2):140-8.

18.   Pillay T, Andronikou S, Zar HJ. Chest imaging in paediatric pulmonary TB. Paediatr Respir Rev. 2020;36:65-72.

19.   Malla D, Rathi V, Gomber S, Upreti L. Can lung ultrasound differentiate between bacterial and viral pneumonia in children? J Clin Ultrasound. 2021;49(2):91-100.

20.   Nti B, Lehmann AS, Haddad A, Kennedy SK, Russell FM. Artificial Intelligence-Augmented Pediatric Lung POCUS: A Pilot Study of Novice Learners. J Ultrasound Med. 2022;41(12):2965-72.