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Role of chest X-ray and Lung Ultrasound in diagnosis and treatment of Children and Infants with Pneumonia

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ABSTRACT

Background: When accessible, chest x-rays (CXRs) are frequently utilized to aid in clinical care decisions regarding pneumonia in children and serve as a benchmark for diagnosis in research investigations. Its technical and diagnostic limits are acknowledged, nevertheless, for both uses. According to recent data, lung ultrasonography (LUS) may be useful in the diagnosis of pneumonia.

Objective: To identify knowledge gaps and provide practical guidance for countries having low or middle-income (LMICs) regarding the usage of Chest X-ray and Ultra sound of lung for handling of severe pneumonia in children.

Methodology: Peer-reviewed papers including babies and children with severe pneumonia, ages one month to nine years, and published between 2015 and 2020 were included in our analysis. LUS research and CXR reports were restricted to only from LMICs. The mapping of LUS and CXR papers was done using the themes of role in management, role in diagnosis, indications, effect on findings, and practical considerations for LMIC situations.

Results: Total of 22 papers, comprising 13 CXR investigations and 09 LUS studies, satisfied all inclusion requirements. Studies on CXR were mostly observational and looked at correlations between radiographic anomalies and the causes or effects of pneumonia. The correlation between CXR consolidation and mortality risk was the most consistent finding. The inability to get high-quality CXR pictures and the variation in interpretation among readers were often mentioned difficulties.

Conclusion: The current body of research refutes the notion that CXR and LUS are necessary diagnostic or treatment instruments for severe pneumonia. To ascertain the clinical relevance and viability of these imaging modalities in less resourced locations, more research is necessary.

Keywords: Chest X-Ray; Ultrasound; Lung Ultrasonography

Introduction

When it comes to under-five children living in environments with few resources, pneumonia is a major cause of mortality.[1] Reducing pneumonia-related mortality requires early and accurate diagnosis. The diagnosis of pneumonia cannot be made with a single test that has a high specificity or sensitivity since the clinical symptoms are non-specific, especially in young children. Although chest computed tomography (CT) is thought to be the gold standard in radiologic diagnosis of pneumonia, its routine usage is not realistic due to cost, accessibility, and radiation exposure.[2]

Currently, CXR is the prime method of imaging for pneumonia and is often utilized as a reference point for diagnostic purposes.[3] Around 50% of the global population have no link to imaging resources,[4] and there are a number of recognized technical and diagnostic limitations with CXR.[3,4] In addition, maintaining radiography equipment can be expensive. To get and interpret pictures, skilled workers and a reliable power source are required. Pneumonia in children ages 2 to 59 months is defined by the World Health Organization Integrated Child Handbook as cough, tachypnea, or chest in drawing; severe pneumonia also involves risk indications.[5] Currently, imaging not being considered to be a required part of the initial care of pneumonia; nevertheless, if a child is not responding as predicted to medicinal management, a CXR is recommended. While recommendations for severe pneumonia vary greatly, global guidelines generally recommend against routine usage of Chest X-ray for pneumonia which is not severe.[6–9]

Lung ultrasonography (LUS) is being assessed more and more as an imaging modality for the diagnosis and treatment of pediatric pneumonia,[11-12] having been employed to identify pleural effusion and other pneumonia-related problems.[10] A qualified practitioner can use ultrasound at the patient's bedside since it is a portable, low-cost, radiation-free method with instantaneous results. It is a desirable tool in situations with limited resources because of these qualities. This comprehensive review aimed to give relevant recommendations for resource-constrained settings by methodically mapping and analyzing the available research on the effectiveness of LUS and CXR in pediatric patients with severe pneumonia.

Objective

To identify knowledge gaps and provide practical guidance for countries having low or middle-income (LMICs) regarding the usage of Chest X-ray and Ultra sound of lung for handling of severe pneumonia in children.

Methodology

The search of studies was done by using (MeSH) phrases and keywords; it was then refined. We searched “Embase”, “PubMed” and “MEDLINE” for research published between January 1, 2015, and July 31, 2020. We searched the lists of reference that included research for any other publications that could have been overlooked. The only participants of the analysis of studies assessing the function of either ultra sound of lungs or Chest X-ray in connection to of our pre-suggested themes were children 0-9 years with acute severe pneumonia were the sole subjects of the analysis of studies assessing the function of both CXR or LUS in connection with one or more of our pre-established themes: LMIC practical considerations, signs for imaging, the nature of imaging in diagnosis and management, the effect of imaging on patient outcomes, and practicality. Even though CXR studies were limited to LMICs, we included LUS data from all over the world since LUS therapy for pneumonia is still novel and untested globally.

Results

1200 distinct studies were found by our search; two more studies were found in the references of other publications (Figure 1). In the end, 22 papers satisfied our inclusion criteria assessing CXR, and LUS.

Of the 13 CXR studies that possessed the original data, 8 (61%) of them included children whose pneumonia was classified as severe or very severe by the WHO criteria 2005; the other studies used a more inclusive criterion for pneumonia and severity. No research used the WHO 2014 criteria of severe pneumonia to assess pediatric patients. The majority of CXR studies (n = 8, 61%) included observational information about correlations between abnormalities in the CXR and the clinical course, whereas one systematic review focused on factors associated with pneumonia severity.

Use of chest x-rays for patients with severe pneumonia

The objectives and strategies of the 13 initial CXR research varied widely (Table 1). In LMICs, the majority of studies (100%) were carried out. The majority of CXR studies (92%) were conducted in inpatient or emergency department (ED) settings. A study was also carried out in 04 urban health centers of Pakistan.[24]

Chest x-ray's diagnostic role

According to a research,[13] pneumococcal isolation in blood or pleural culture was linked to alveolar opacities and pleural effusion (P<.001). According to a research

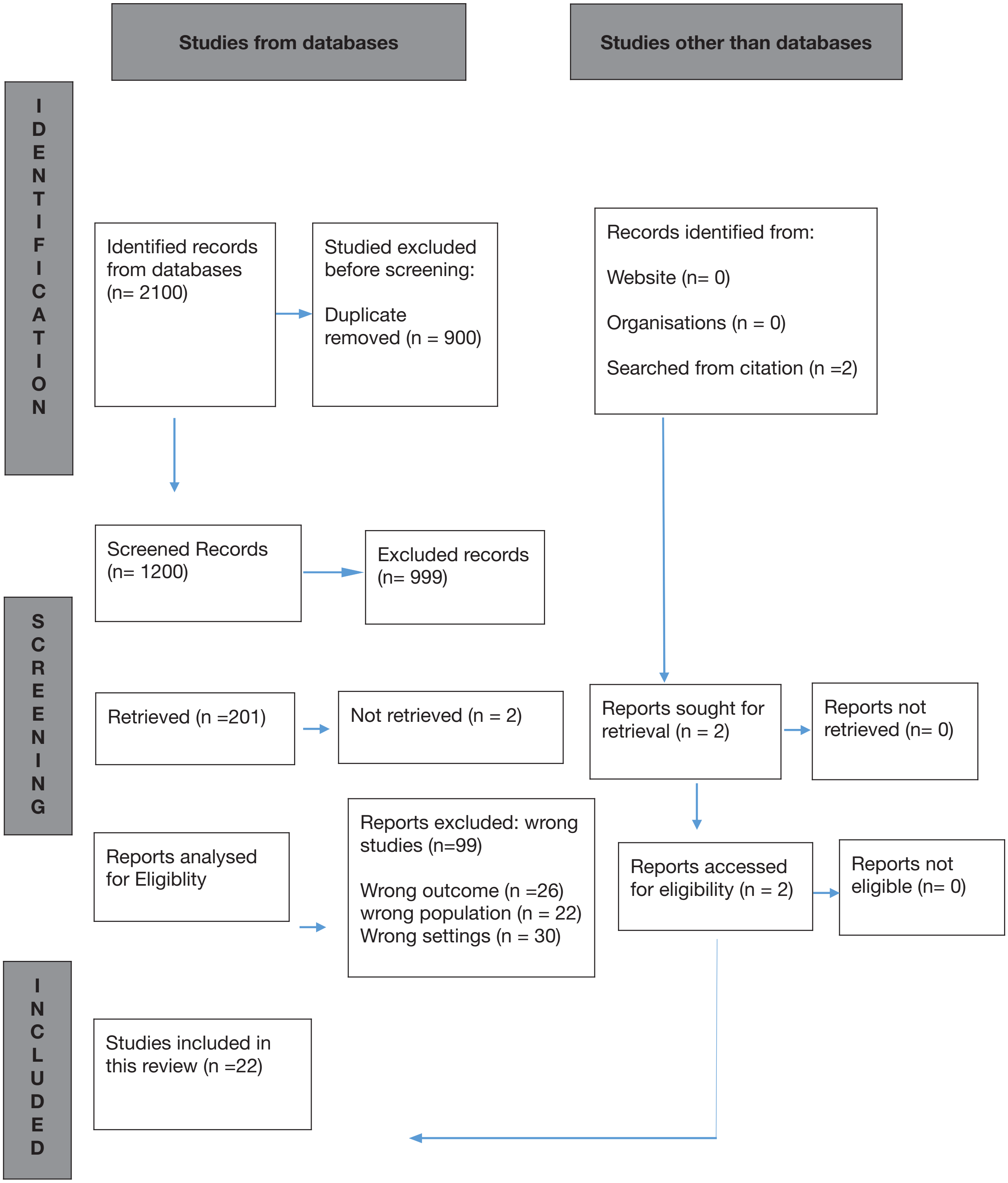

Figure 1. Flow diagram of literature Review

Table 1. Features of studies performed based on CXR

Study	Region of Study	Inclusion criteria	Study design	Aim(s)
Diagnostic Role of CXR				
Nascimento-Carvalho (2015)[13]	Brazil	symptoms related to the respiratory system, fever, breathing difficulties, pulmonary infiltration etc	Cross-sectional Age 0-5 years n = 209	To "Assess if there is an association between a specific etiology and radiologically confirmed pneumonia"
CXR and Observations				
Araya (2016)[14]	Paraguay	respiratory symptoms and indications, a history of fever, and consolidation on the chest x-ray upon admission	Retrospective cohort	To study "the use of a modification of PIRO scale (used in adult pneumonia) and the association between modified PIRO score and mortality, stratified by risk"
Awasthi (2020)[15]	India	World Health Organization 2014[5]	prospective studies Age = two to 59 months. n = 3214	To "Assess the radiological abnormalities in CXRs and identify demographic and clinical correlates of specific radiological abnormalities in children with pneumonia aged 2-59 month"
Basnet (2015)[16]	Nepal	World Health Organization 2005[15]	Randomized control trail Age 2-35 month n = 598	To "Assess cohort of Nepalese children given standard pneumonia treatment, and the correlation between clinical and radiological and other variables"
Dean (2018)[17]	Multiple	Studies observing childs with pneumonia that exclude those without a high wheezing rate or those who don't require focalization during a CXR	56 study (Systematic review)	"Systematic review of evidence for predictors of pneumonia severity in children and risk stratification of children with pneumonia"

Dembele (2019)[18]	Philippines	World Health Organization 2005[15]	Case studies (Prospective) multiple center age = 0-5 y n = 5054	To “Define aetiological, demographic, and environmental factors, and clinical findings associated with mortality due to childhood pneumonia among hospitalised children in the Philippines”
Fancourt (2017)[19]	Gambia, Mali, Kenya, Bangladesh, South Africa, Zambia, Thailand	World Health Organization 2005	Case control studies Multiple countries Age 1-59 months n = 4242	To “Describe CXR findings of clinically diagnosed pneumonia cases and determine if there were differences by geography, epidemiological setting, particular clinical signs, or pneumonia risk factors”
Jakhar (2018)[20]	India	World Health Organization 2005	Prospective cohort Age=2-5 years n = 120	To “Determine the aetiology of severe pneumonia in under-five children and study the risk factors of poor outcomes (persistence of features of severe pneumonia after 72 h or worsening of clinical condition, need for change of antibiotics, need for mechanical ventilation, prolonged hospitalization >5 d and death)”.
Kelly 2016[21]	Botswana	World Health Organization 2005	Prospective study Age=one to-23 months n=249	To “Assess if findings on CXR associated with treatment failure, need for respiratory support, length of stay, and in hospital mortality for children with pneumonia”.
Nguyen (2020)[22]	Vietnam	World Health Organization 2014	Prospective observational Age=2-59 months n = 3817	To “identify predictors of an adverse pneumonia outcome and combine this with predictive models an existing guidance to suggest a potential pragmatic algorithm to reduce unnecessary antibiotic use and hospitalization”

Seear (2016)[23]	India	World Health Organization 2005	Prospective study Age = 0-59 months n=134	To "Test the predictive accuracy and reporting reproducibility of digital chest radiographs under low resource conditions"
Waris (2016)[24]	Pakistan	Pneumonia opn the basis of clinical scoring system	Cross sectional Age = 2-36 months n=581	To "Assess the association of haematological and radiological findings with clinical outcome in hospitalized children with severe pneumonia"
Practical Considerations				
Hassen (2019)[25]	Ethiopia	World Health Organization 2005	Prospective study Age= 3-14 months n=22	To "Assess role of CXR for diagnosis of pneumonia and association of clinical characteristics with radiologic findings, and predictors of hospitalization. Regression model done for predictors"

conducted on 209 children in Brazil, there is a correlation between a normal chest X-ray and suspected viral pneumonia, and between an abnormal chest X-ray and suspected bacterial pneumonia. Nevertheless, based solely on CXR, it is inaccurate to attribute 30%-50% of cases to viral or bacterial pneumonia.[13]

Practical and feasible aspects for LMICs

Interobserver reliability in the interpretation of CXR for pneumonia was found in three investigations. The radiography result in question and observer experience had an influence on reliability[30,35,39] (n = 925, kappa value ( ) range=0.15-0.7). Using the WHO's standardized criteria for interpretation, agreement was highest when reporting lobar consolidation or main endpoint pneumonia; reliability declined with more esoteric results, such as "other infiltrates".[21,25]

Lung ultrasonography's diagnostic role

Table 2 lists the features, objectives, and conclusions of the 05 studies assessing LUS as diagnostic tool for severe pneumonia. LMICs were the setting for three of the five trials that evaluated LUS in the diagnosis of severe pneumonia.[27–29] When children appear with nonspecific respiratory symptoms, three countries—Egypt, Peru, and Turkey—evaluated the diagnostic value of LUS. They found that a final physician diagnosis and the diagnosis based on LUS for pleural effusion, pneumonia, and pneumothorax agreed rather well. Another Turkish research on ED physician diagnosis demonstrated accuracy comparable to LUS.[30] The larger sample included children with respiratory symptoms. There was little association between LUS pneumonia and the WHO criteria of pneumonia.[26,27] The number of patients with consolidation on Lung ultrasound was comparable for children with pneumonia as defined by the WHO and children with respiratory symptoms not matching the criteria (23 vs. 21%, P=0.68) in a study of 378 children with respiratory symptoms carried out in Peru and Nepal.[26]

Results of lung ultrasonography

There hasn't been research that specifically evaluated how using LUS affected patient outcomes. One study from an LMIC (Turkey) examined the relationship between LUS anomalies and outcomes. Among the 380 infants with bronchiolitis in all 04 observational studies (03 from Europe and one from Turkey) revealed no discernible advantage over clinical evaluation alone in correlations between LUS anomalies and the requirement for respiratory assistance or hospital admission.[30]

Table 2. Lung ultrasound studies

Study	Region of Study	Aim of the study	Findings
Diagnostic Role of CXR			
Pervaiz (2018)[27]	Peru	To "Evaluate prediction models for clinical pneumonia with lobar consolidation +/– effusion, and included LUS in diagnostic algorithm"	Of the 832 kids who were enlisted, 191 satisfied the radiological and clinical requirements for pneumonia as specified by the WHO in 2014. A mode of clinical prediction l for radiographically established clinical pneumonia benefited by consolidation on LUS, either by itself (AUC=0.82, 95% CI=0.78-0.85) or in conjunction with lung auscultation and pulse oximetry.
Ozkaya (2019)[28]	Turkey	Prospective study To "evaluating concordance of ED diagnosis, final diagnosis, and Point-Of-Care (POC) LUS diagnosis performed by a single experienced sonographer, in a subset of children presenting with undifferentiated respiratory distress"	Utilizing the ultimate clinical diagnosis as the benchmark, LUS was able to diagnose pneumonia with 81.4% and 100% sensitivity and specificity for the etiology of respiratory distress. The ED physician and LUS had a good level of agreement (kappa value of 0.8). Similar agreements were noted for the diagnosis of asthma, cough, and acute bronchiolitis; though, it was unclear how these conditions were diagnosed using LUS.
Hegazy (2020)[29]	Egypt	Cross-sectional study To "evaluating bedside ultrasound performed by experienced operator in the emergency department to diagnose undifferentiated acute respiratory distress, using clinical diagnosis as reference standard"	31 children had clinical diagnosis of Pneumonia was clinically diagnosed in 31 children. When compared to CXR, LUS demonstrated a greater sensitivity and specificity for the diagnosis of pneumonia (LUS=97% specificity 93.5% sensitivity,). Pleural effusion and pneumothorax were detected by LUS with ninety eight and 100% NPV.
Chavez (2015)[26]	Peru & Nepal	Case control study To "evaluating feasibility of portable LUS performed by GPs as well as agreement between WHO defined pneumonia and consolidation on LUS. GPs underwent 7 d of training (including 3 d theoretical and 4 d ward-based)"	The "WHO defined pneumonia and lung US consolidation gave different diagnoses in 39% of youngsters. 35% of the children (n = 169) who were diagnosed with WHO pneumonia had normal US and 23% showed lung consolidation. Thirty-three percent of children (n=12/169) with WHO severe pneumonia had lung consolidation on LUS". When LUS results of any abnormality were added to the diagnosis of pneumonia, misclassification rates remained high (28%). Lung consolidation in children with respiratory symptoms who did not have WHO pneumonia was as common in the US.

Relation between outcomes and LUS abnormalities			
Ozkaya (2020)[30]	Turkey	Infants presenting to ED with bronchiolitis (n=76) Prospective study evaluating LUS predictive value for hospital admission	It is unclear if LUS added value to the bronchiolitis severity score in terms of predicting hospital admission, however LUS corresponded for bronchiolitis in 41/44 hospitalized individuals and 74/76 babies appearing to the ED with bronchiolitis.
LUS Practical considerations "feasibility, inter-operator reliability"			
Pervaiz (2019)[31]	Peru	To "Evaluate training of General Practitioners in LUS as part of broader vaccine impact study. fivemonth training program with significant financial support involved seven days practical and didactic training (12 zone technique), expert review of LUS images, local expert supervision followed by refresher training to achieve >85% accuracy in diagnosis of primary endpoint pneumonia"	PEP diagnosis had persistently high levels of agreement (κ>0.78); children exhibiting danger signals had greater levels of agreement. Due to the training's high cost and resource requirements, its use in environments with low resources may be restricted. The PEP on LUS criteria provided by this study need more diagnostic confirmation before they can be widely used.
Nadimpalli (2019)[32]	Brazil	To "Assessed LUS inter-operator reliability between a resident who received 14 h of practical training in point of care LUS (six zone) and an expert sonologist, they also compared LUS to CXR"	Consolidation showed significant convergence as a result of this training (κ=0.635, 95% CI=0.532- 0.738). Regarding lung consolidation, LUS showed a high sensitivity when compared to CXR in this small sample, but a low specificity when comparing to CXR imaging (secondary result).
Correa (2018)[34]	Peru	Research was conducted using a computerized program that could automatically identify pulmonary infiltrates from LUS pictures taken by technicians who are not experts but have been trained to acquire linear LUS images (12 zone; the specifics of the training are not disclosed).	Attained 100% specificity and 90.09% sensitivity, when contrasted with expert analyst visual recognition.

Chavez (2015)[26]	Peru & Nepal	Two general practitioners received training in LUS through a standardized seven-day program that comprised four days of practical training in a pediatric unit and three days of theoretical instruction from an experienced radiologist.	An average of 6.4 +/- 2.2 minutes was spent on setup and video recording (no oblique or transverse views were used). There was strong agreement amongst the observers: κ=0.79, 95% CI=0.73-0.81. Only in the supine position (no oblique or transverse views), six portions were assessed using a laptop-sized portable equipment. There have been no reported installation concerns.

Practical and feasible aspects for environments in low- and middle-income countries

Nine studies, six of which were carried out in LMICs, evaluated the viability of LUS using interoperate reliability as a main or secondary outcome.[26,31–34] The usefulness of teaching inexperienced doctors' point-of-care ultrasonography for suspected pneumonia in low- and middle-income countries (LMICs) was evaluated in four trials, one of which included a sizable vaccination effect study with 9051 participants. The duration of the training ranged from 12 hours to 7 days, with additional supervision and refresher courses. For consolidation, all training produced strong inter-rater reliability amongst seasoned and inexperienced LUS operators (kappa values ranged from 0.635 to 0.78). Despite being resource-consuming and expensive, the lengthier and more intense training program produced maintained levels of agreement for LUS outcomes throughout the follow-up for almost two years.[31]

Discussion

Despite the fact that CXR is often used to treat pediatric pneumonia, there is insufficient data to determine the best or most practical use of CXR for kids who appear to have pneumonia. The majority of previous studies examined CXR as a stand-alone diagnostic tool for pneumonia or assessed the correlation between CXR results and patient outcomes; nevertheless, important limitations were noted. The primary emphasis of research assessing LUS has been diagnostic accuracy; usefulness and feasibility have not yet been shown. Determining the exact accuracy of diagnosis by LUS and CXR for pneumonia rests tricky due to the problem of lacking a "gold standard" for pneumonia diagnosis.

Various studies from Low- and middle-income countries evaluated LUS in the diagnosis of severe pneumonia.[27–29] When children appear with nonspecific respiratory symptoms, three countries—Egypt, Peru, and Turkey—evaluated the diagnostic value of LUS. They found that a final physician diagnosis and the diagnosis based on LUS for pleural effusion, pneumonia, and pneumothorax agreed rather well. Another Turkish research on ED physician diagnosis demonstrated accuracy comparable to LUS.[30] The larger sample included children with respiratory symptoms. There was little association between LUS pneumonia and the WHO criteria of pneumonia.[26,27] The number of patients with consolidation on Lung ultrasound was comparable for children with pneumonia as defined by the WHO and children with respiratory symptoms not matching the criteria (23 vs. 21%, P=0.68) in a study of 378 children with respiratory symptoms carried out in Peru and Nepal.[26]

Although CXR did not perform as well as it could have as an self-determining modality in cases of severity in pneumonia, the indications were insufficient to either backing or contradict the conventional interpretation of CXR, which takes into account clinical and contextual factors like age, comorbidities, length of illness, and history of antibiotic use. CXR is frequently utilized to look into treatment failure and or alternative diagnoses in addition to helping with diagnostic clarity. Nevertheless, no research has been done to assess these uses for CXR. The significant difference in international and national guidelines for the use of radiography in cases of severity in pneumonia in LMIC settings is indicative of the absence of conclusive data.[6]

The literature had a few recurring themes in spite of numerous gaps in the data. Mortality was linked to radiographic consolidation that was "dense." These investigations were conducted in contexts where resources were scarce. While CXR did not perform as well as it could have in cases of severity in pneumonia, there was not enough eminence evidence to upkeep or contest the conventional interpretation of CXR, which considers clinical and related factors such as comorbidities, age, period of disease, and history of antibiotic use. CXR is frequently utilized to probe treatment failure and find sequelae, comorbidities, or alternative diagnosis in addition to aiding in diagnostic clarity; however, no research has evaluated these applications of CXR. The notable discrepancy between national and international guidelines for the use of radiography in cases of severe pneumonia in high income countries and LMIC settings [6] is indicative of the lack of conclusive data.

Furthermore, CXR was unable to accurately identify the cause of pneumonia—bacterial or viral. The adoption of a structured framework for interpretation improves concordance, as there is significant inter-observer heterogeneity in the interpretation of CXR abnormalities, especially with less experienced physicians and more cryptic results.

There hasn't been research that specifically evaluated how using LUS affected patient outcomes. One study from an LMIC (Turkey) examined the relationship between LUS anomalies and outcomes. Among the 380 infants with bronchiolitis in all 04 observational studies (03 from Europe and one from Turkey) revealed no discernible advantage over clinical evaluation alone in correlations between LUS anomalies and the requirement for respiratory assistance or hospital admission.[30]

When it comes to identifying lung consolidation and pleural effusion, LUS is more effective than CXR. Multiple meta-analyses have consistently shown that LUS has a high sensitivity. Additionally, specificity was excellent, but it depended on the pneumonia reference standard, so it could have been lower in kids with coexisting conditions. Currently, there is no agreement on the best scanning methodology or sonographic criteria for pneumonia. LUS may be able to diagnose children with undifferentiated respiratory distress, according to small trials. Although operator experience has an impact on LUS's inter-operator reliability, early research on the technology's viability in LMICs suggests that new operators may be trained to reach high diagnostic performance. The use of LUS as a first line examination for pneumonia is not common, even though point-of-care ultrasound machines are readily available in HIC settings.[32] This is especially true in situations when physicians lack previous familiarity with the instrument. Clinicians list difficulty retaining competence over time and confidence lack in one's abilities as barriers.[33] Although LUS is less expensive to execute than CXR [34], there may be substantial long-term monetary and personnel expenses associated with training and continuing assistance to preserve competence.

Limitations

We purposefully conducted a thorough scoping study to fully grasp the breadth of pertinent literature. As a result, we were able to pinpoint important knowledge gaps and get a comprehensive picture of the advantages and disadvantages of the research that was already accessible. The absence of an ideal reference regarding pneumonia poses a significant assessment challenge for LUS and CXR investigations. Furthermore, the absence of a standardized epidemiological definition of pneumonia in clinical settings in both modalities makes it more difficult for us to reach reliable findings. We realize that data relevant to resource-constrained settings may have been missed by eliminating. Because there were no relevant trials for some outcomes and there was a lack of high-quality evidence, the conclusions made on the practical value of LUS and CXR are on the basis of restricted data.

Practical applicability

The low diagnostic accuracy, difficulties in producing high-quality pictures, and requirement for expert interpretation preclude the widespread programmatic use of CXR for pneumonia in healthcare institutions, nor do they support particular guidelines for usage in resource-constrained settings. It is improbable that CXR will change how children with severe pneumonia are first managed. Research on the use of CXR in particular situations, such as examining other diagnoses and looking into abrupt worsening or a poor response to therapy, is few. In these situations, a chest X-ray can detect problems like lung abscess, pleural effusion, pneumothorax, pneumatoceles, or typical signs of a particular aetiology like TB. For the time being, there is not enough data to provide recommendations on the application of LUS in the case management of pediatric pneumonia patients. It is currently known that LUS can help treat complex pneumonia and may even help improve the clinical diagnosis of pneumonia; however, further research is required to determine whether or not LUS is practical and useful in low-resource environments.

Conclusions

The clinical course of pneumonia is dependent on several factors such as the host, the clinical setting, and the availability of prompt and suitable therapy. Pneumonia is a heterogeneous entity with a range of aetiologies. The data supporting the effectiveness of CXR and its continuous and widespread usage for pneumonia are significantly at odds. To comprehend its function and the advantages that are thought to be associated with it, high-quality, practical research is required. This includes determining alternative diagnoses or comorbidities in children who arrive with severe pneumonia, looking into treatment failure, or identifying problems.

With the added advantage of having higher sensitivity for pneumonia than CXR, LUS has the potential to enhance diagnostic capacities in environments with limited resources. Nonetheless, there are still a lot of unanswered questions. In areas with limited resources, high-quality, prospective studies are necessary to investigate the potential advantages and dangers of LUS as an imaging tool and to improve the accuracy of clinical diagnosis, anticipate and manage pneumonia complications, and so on. While LUS observations in pneumonia are widely documented, agreement is needed on scanning procedures and diagnostic standards. Subsequent feasibility studies ought to assess the obstacles to the execution and adoption of LUS by physicians, along with a long-term follow-up to comprehend the equipment and technical skill upkeep requirements over time. Research on imaging methods should include children with co-morbidities (such as HIV, congenital heart disease, and malnourishment) that enhance vulnerability to pneumonia-related death in order to encourage early and accurate identification in this high-risk group.

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