Volume 3, Issue 3, 2025

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

ACCURACY OF LUNGS ULTRASOUND IN THE DIAGNOSIS OF PNEUMONIA: A SYSTEMATIC REVIEW

Sara Kamal[1], Muhammad Zubair[*2], Syeda Faiza Hussaini[3], Syed Zaigham Ali Shah[4]

[1,3,4]*Department of Radiological Sciences and Medical Imaging Technology, Ibadat International University Islamabad, Pakistan.*

[*2]*Lecturer, Department of Radiological Sciences and Medical Imaging Technology, Ibadat International University Islamabad, Pakistan.*

[*2]zubairm955@gmail.com

[*2]orcid.org/0000-0001-5142-9606

DOI: https://doi.org/10.5281/zenodo.15412226

Keywords
Pneumonia, Diagnosis of pneumonia, Lungs ultrasound, Accuracy of lungs ultrasound, chest ultrasound.

Article History
Received on 05 April 2025
Accepted on 05 May 2025
Published on 14 May 2025

Corresponding Author: *
Muhammad Zubair

Abstract

Background: *Pneumonia is one of the leading cause of death. Chest ultrasound is reliable, quick, bedside invasive, non-ionizing, more accurate, and easily educated for early detection of chest diseases and their follow up.*

Objectives: *To assess diagnostic accuracy of LUS in the diagnosis of pneumonia by analyzing its sensitivity, specificity, positive predicative value (PPV) and negative predicative value (NPV) across various studies.*

Materials & Methods: *An electronic database search was performed (PubMed, Google scholar) with the data ranges from 2011 to 2025. All the studies included in the search was in English language. The study included randomized control trials (RCTs) studies, cohort studies, cross sectional studies performed in the patient of any age (neonates, Childrens, adults, elderly) with suspected or confirmed pneumonia performed by lungs ultrasound.*

Results: *The majority of research (seven out of ten) concentrated on the pediatric population, demonstrating that LUS is especially helpful in this demographic. Lung ultrasonography's sensitivity (ST) varied between 87.5% and 100%. A further metric, specificity (SP), which ranged from 87.5% to 100%, indicates that LUS is also reasonably effective at ruling out pneumonia. The positive predictive value (PPV) varied according to the study population and methodology, ranging from 50% to 98.5%.*

Conclusion: *Lung ultrasonography (LUS) is a very accurate and first-line imaging method for diagnosing pneumonia in a wide range of disease populations. LUS demonstrated outstanding results in both pediatric and adult populations, providing radiation-free, bedside-accessible alternatives that are noninvasive and have high sensitivity and specificity.*

INTRODUCTION

Pneumonia is a frequent illness that causes lung inflammatory consolidations due to an infection that affects the interstitium, distal airways, and alveoli[1]. Worldwide, acute pneumonia, also known as an acute respiratory tract infection, is thought to be the leading cause of death for children. The prevalence of community-acquired pneumonia has stayed consistent over the past few decades, primarily

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ISSN: (e) 3007-1607 (p) 3007-1593

affecting the young and old, with 3–5 cases per 1000 person-years[2]. Only ischemic heart disease and cerebrovascular disorders are more common causes of death globally than pneumonia. One of the most frequent causes of hospitalizations and ER visits, it is the primary infectious cause of death[3]. Pneumonia is linked to numerous bacteria, but recent research has focused on the significance of viruses as pathogens. Pneumococcal and Haemophilus influenza type B conjugate vaccines have been widely incorporated into immunization programs, raising concerns about the increasing prevalence of viruses as causes of pediatric pneumonia. The importance of respiratory viruses as causes of severe pneumonia has been again highlighted by the appearance of the 2009 pandemic influenza A (H1N1) virus, avian influenza A (H5N1) virus, and severe acute respiratory syndrome (SARS). Over the last ten years, new respiratory viruses have been identified, including human metapneumovirus, coronaviruses NL63 and HKU1, and human Boca virus. Significantly, our capacity to identify and describe the epidemiology of respiratory viral infections has significantly improved with the advent of molecular diagnostic techniques[4]. In underdeveloped nations, pneumonia is thought to be mostly caused by bacteria. Staphylococcus aureus and Klebsiella pneumonia are the most frequent causes, with Haemophilus influenza type b (Hib) coming in second[5]. The clinical burden of ventilator-associated pneumonia (VAP), hospital-acquired pneumonia (HAP), and community-acquired pneumonia (CAP) remains high despite the quick advancements in treatment approaches. The prognosis outcome for patients with pneumonia is improved when antibiotics are administered promptly, as has been well shown. When combined with radiographic pulmonary infiltration, laboratory changes (leukocytosis and elevated C-reactive protein/ procalcitonin) and respiratory system symptoms (often referred to as dyspnea, cough, and fever) suggest a strong case of pneumonia[6].

Epidemiology of pneumonia

Pneumonia kills around 4 million people year, or 7% of the 57 million people who die from the disease, according to WHO estimates of 450 million cases. Children under five years old and seniors over 75 years old have the highest incidences. According to estimates, there are 150–156 million cases of pneumonia among children aged 5 and under worldwide each year. Of these, approximately 11–20 million require hospitalization, and 1.1 million result in death. More children under the age of five die from pneumonia than from TB, AIDS, and malaria combined, accounting for 18% of all pediatric deaths globally[7].

Diagnosis of pneumonia

Three mainstays have historically been used to diagnose pneumonia: imaging methods, microbiological investigations, and clinical and laboratory data. Currently, the first line of treatment for suspected pneumonia is a chest X-ray (CXR), where the typical radiographic result is the presence of a new infiltrate. Nevertheless, a number of studies indicate that CXR has a low sensitivity for diagnosing pneumonia. Additionally, patients in the decubitus position and those utilizing portable equipment had lower picture quality, which suggests patient movement, radiation exposure, and substantial interobserver variability. For the diagnosis of pneumonia, chest computed tomography (CT) is more sensitive than chest radiography (CXR); nonetheless, it is only used in more complicated cases and when treatment is ineffective. Its primary disadvantages are the necessity of moving the patient to the X- ray unit, the elevated radiation dose, and the expense. Bedside lung ultrasonography for pleuropulmonary diseases has garnered attention recently due to its portability, speed, lack of radiation, ease of reproducibility, and real-time scanning capabilities, while not being covered by current clinical practice standards. Additionally, available data points to excellent diagnostic performance. For the diagnosis of adult pneumonia, lung ultrasonography seems to be a useful adjunct to chest radiography due to its high sensitivity and specificity[3,8].

Role of Ultrasound:

Lung ultrasonography has been used to diagnose community-acquired pneumonia in both adults and children and has been characterized as a flexible diagnostic tool for a variety of pulmonary disorders[9]. Because of the air barrier, the lung was traditionally thought to be difficult to penetrate by

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

ultrasonography. When it comes to accurately diagnosing pneumonia, lung ultrasonography can be quite helpful[10], due to having a better safety record and being less expensive than computed tomography (CT) and chest X-rays (CXR). For patients who are immobile, pregnant, or in environments with limited resources where CXR devices are not yet available, LUS offers several distinct advantages over CXR[2].

Ultrasonic appearance of pneumonia:

The following were gathered as the most frequent ultrasound findings linked to pneumonia: hypoechoic regions of different sizes and shapes, air and fluid bronchogram, comet-tail artifacts (B-lines), a vascular pattern inside the consolidation and pleural effusion. The impression of pneumonia based on LUS was made by any of the characteristics of air bronchogram, fluid bronchogram, vascular pattern within the consolidation, or pleural effusion[11].

METHOD AND MATERIAL

This systematic review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta- Analyses) guidelines. The systematic review aim to compare LUS finding with standard diagnostic modalities such as chest X-rays and CT scan assessing its reliability in different population including pediatrics, adults and critically ill patients. A comprehensive search of major electronic databases, including PubMed, Google scholar, will be conducted using relevant keywords as pneumonia, lungs ultrasound accuracy, diagnosis of pneumonia, from last 15 years. The search will be limited to studies published in English.

Inclusion criteria & Exclusion Criteria:

The study included randomized control trials (RCTs) studies, cohort studies, cross sectional studies, case control studies performed in the patient of any age (neonates, childrens, adults, elderly)with suspected or confirmed pneumonia performed in the last 10-15 years (2011-2025). Studies comparing lungs ultrasound with other gold standard diagnostic tests (e.g. X-rays, CT scan).This study excluded case report studies, expert opinions, and letters to editors, non-systematic review and the studies focusing on the others conditions than pneumonia.

Study selection and data Extraction:

All identified articles were screened for relevancy based on the titles and abstract. Duplicates was removed before proceeding with the full text review. On the basis of predefined criteria full text articles were then assessed for eligibility. Data extraction focuses on author details, publication year, sample size, target population, specificity, sensitivity, Positive predicative value (PPV). Negative Predicative value (NPV) and accuracy of lungs ultrasound.

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ISSN: (e) 3007-1607 (p) 3007-1593

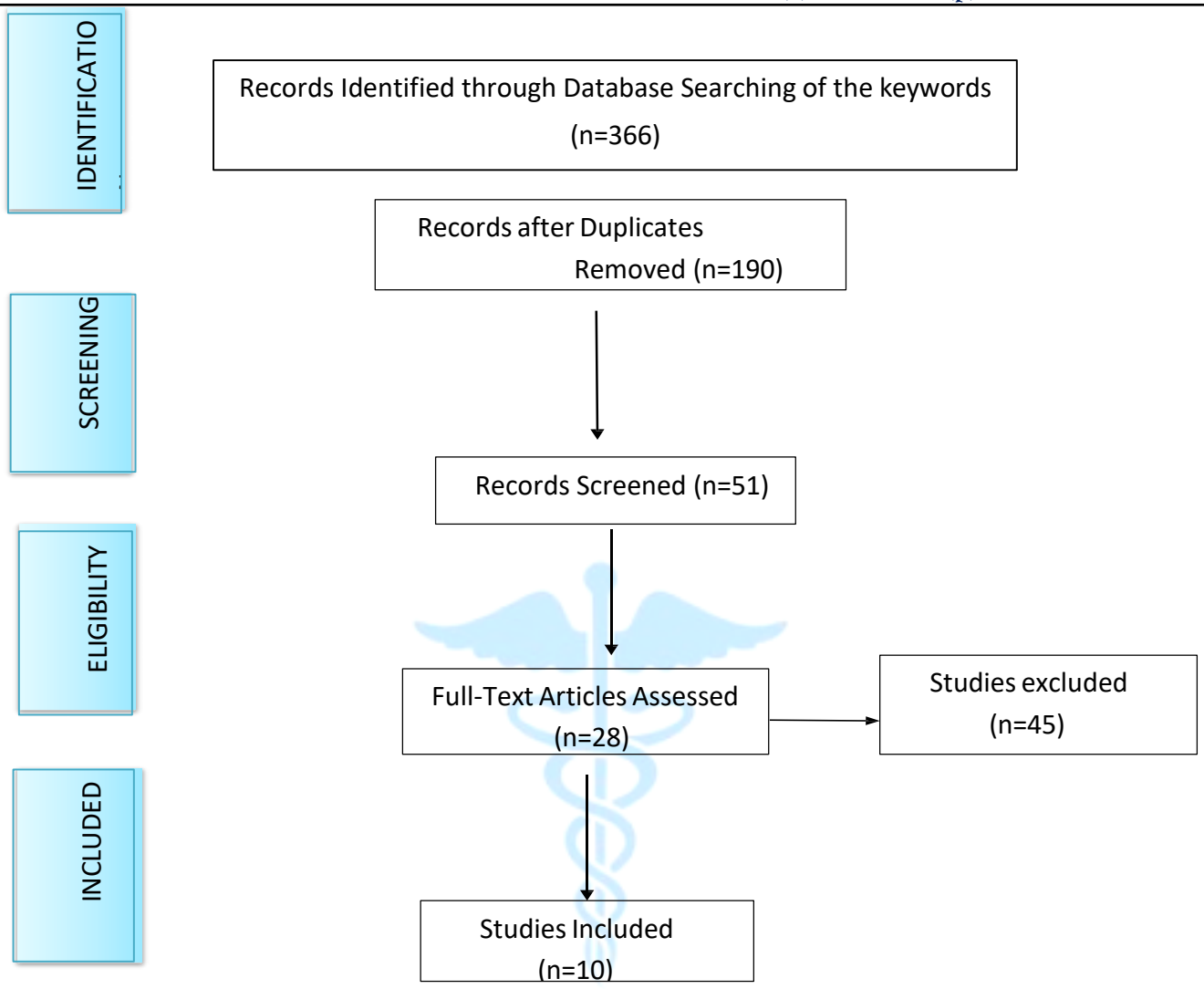

Figure 1: PRISMA flow diagram

RESULTS

Electronic database like PubMed Google scholar identified 366 records. After removal of duplication, screening on the basis of inclusion criteria 10 studies are included. These studies was published between 2011-2025 focusing on author details, publication year, sample size, target population, specificity, sensitivity, Positive predicative value (PPV). Negative Predicative value (NPV) and accuracy of lungs ultrasound for the diagnosis of pneumonia. The study had a sample size of 52–262 participants and assessed both adults and children. The majority of research (seven out of ten) concentrated on the pediatric population, demonstrating that LUS is especially helpful in this demographic. Research including adults also demonstrates good diagnostic performance. Lung ultrasonography's sensitivity (ST) varied between 87.5% and 100%. Research has repeatedly demonstrated good sensitivity, suggesting that LUS is a useful diagnostic tool for pneumonia cases. A further metric, specificity (SP), which ranged from 87.5% to 100%, indicates that LUS is also reasonably effective at ruling out pneumonia. The positive predictive value (PPV) varied according to the study population and methodology, ranging from 50% to 98.5%. Some studies had lower negative predictive values (NPVs), which could be because of variations in research design or disease prevalence. The range of NPVs was 36.84% to 100%. In the studies that were chosen, the diagnostic accuracy of lungs ultrasound varied from

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ISSN: (e) 3007-1607 (p) 3007-1593

89% to 100%; the maximum accuracy recorded was 100%, while the lowest was 89%.

Table 1: Summary of accuracy of ultrasound in different populations across the studies.

Authors	Publication Year	Sample size	Target population	ST	SP	PPV	NPV	AUC
Ahmadreza Lameh et al[12]	2019	130	Children (Less than 14 years)	95.83	97.56	95.83	97.56	96.92
Youssef Ibrahim Haggag et al[13]	2019	100	Adults(40 - 63 years)	__	100	85.7	92.9	100
Nermeen M. Ali et al[14]	2019	124	Adults (more than 18 years)	87.5	97.7	98	93	93
Emilia Urbankowska et al[15]	2015	76	Children's	93.4	100	100	85.7	95.3
Nosheen Sadiq et al[16]	2023	261	Children (6 months-12 years)	95.28	87.5	99.59	36.84	95.04
Marwa Essayed et al[17]	2022	120	Adults	94.1	97.1	98.8	87.2	95.0
Carlotta Biagi et al[18]	2018	87	Childrens	100	83.9	95.2	92.4	89
Susanna Esposito et al[19]	2014	103	Childrens	97.9	94.5	90.4	98.1	NA
Contantinia Boursiani et al[20]	2017	69	Childrens	92.42	100	100	50	NA
Giulio Iorio et al[21]	20	52	Childrens	96.5	95.6	96.5	95.6	NA

ST= Sensitivity, SP=Specificity, PPV= Positive predicative value, NPV=Negative predicative value, AUC=Accuracy

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ISSN: (e) 3007-1607 (p) 3007-1593

DISCUSSION

Pneumonia is a frequent cause of emergency department visits and has been concluded to be responsible for one million hospital admission per year22. Chest ultrasound can be a good alternative to radiological methods for pneumonia diagnosis23. The finding of systematic review evaluates the accuracy of lungs ultrasound in the diagnosis of pneumonia. The evidence gathered from multiple studies confirms that lungs ultrasound is one of best option for diagnosis pneumonia. Ahmadreza Lameh et al.'s study offers compelling evidence for the usefulness of lung ultrasonography in identifying the reasons behind pediatric patients' chest X-ray opacity. According to the study, ultrasound is a dependable and accurate modality for identifying pulmonary diseases, with high sensitivity (95.83%) and specificity (97.56%). Its therapeutic relevance as a diagnostic tool, especially in situations involving radiation exposure, is reinforced by its accuracy of 96.92 percent12. Haggag et al. assessed the diagnostic utility of lungs ultrasonography vs chest X-rays for identifying lung consolidation in adults aged 40–63. The study showed perfect sensitivity (100%) and specificity (100%) with a sample size of 100, suggesting that lung ultrasonography could accurately detect all true positive and negative cases. The diagnostic accuracy was 100% since the positive predictive value was 87.5% and the negative predictive value was 92.9%. The aforementioned findings highlight the dependability of ultrasound in adult patients and its potential as an independent diagnostic tool, particularly in clinical settings where quick bedside imaging is crucial13 .

In a 2019 study, Namreen Muhammad Ali assessed the diagnostic accuracy of lung ultrasonography in detecting pneumonia in persons over the age of 18, comparing the results with those from chest X-rays. The results showed that lung ultrasonography is very good at accurately identifying patients without pneumonia, with high sensitivity (87.5%) and even greater specificity (97.7%). Furthermore, the feasibility of lung ultrasonography as a diagnostic tool was supported by the high positive predictive value (98%) and negative predictive value (93%). Excellent overall diagnostic performance was indicated by the area under the curve (AUC), which was 97.5%. This study emphasizes how well lung ultrasonography works as a noninvasive, bedside substitute for chest X-rays in the adult population14. The study by Emilia Urbankowska et al., which involves a smaller cohort of 26 patients, focuses on the utility of lung ultrasonography in the diagnosis and follow-up of community-acquired pneumonia in children. These results showed perfect specificity (100%) and high sensitivity (93.4%), with PPV and NPV of 100% and 85.7%, respectively. With an overall accuracy of 93.5%, ultrasonography appears to be useful for follow-up in pediatric cases but ineffective for initial diagnosis. It is especially appropriate for usage in youngsters because to its non-invasive nature and lack of radiation exposure15. Nosheen Sadiq et al.'s 2023 study used chest X-rays as the gold standard to assess the diagnostic accuracy of lung ultrasonography in identifying pneumonia in children aged 6 months to 12 years. In addition to reporting high sensitivity (95.28%) and accuracy (95.04%), the study included a strong sample size of 261 participants, demonstrating the usefulness of lung ultrasonography in detecting true positive cases. The remarkably high positive predictive value (99.59%) indicates remarkable reliability in confirming the presence of pneumonia when ultrasonography results are positive. The very low negative predictive value (36.84%), however, suggests that the negative ultrasound result should be interpreted cautiously because a sizable percentage of cases may still go unnoticed. These results demonstrate that although lung ultrasonography is a useful diagnostic tool for verifying pediatric pneumonia, it might not be enough to diagnose the illness on its own, and in the event of negative results, additional imaging modalities would be needed16. Marwa Essayed et al. conducted a study that examined the similar diagnostic accuracy in persons who had community-acquired pneumonia. This observational trial, which involved 120 adults and was conducted at a single center, demonstrated high diagnostic performance with a 95% overall accuracy, 94.1% sensitivity, 97.1% specificity, 98.8% PPV, and 87.2% NPV. Based on these findings, lungs ultrasonography is a viable and non- invasive imaging method for diagnosing pneumonia in adult patients17. In 2018, Carlotta Biagi et al. evaluated pediatric patients' use of lung ultrasonography to diagnose pneumonia in children with bronchiolitis. The study, which involved 160

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ISSN: (e) 3007-1607 (p) 3007-1593

youngsters, reported 83.6% sensitivity, 95.2% specificity, 92.4% PPV, and 89% accuracy. Despite having a lower sensitivity than other studies, the high specificity and PPV indicate that lung ultrasonography is a valuable diagnostic tool in pediatric settings, especially for confirming pneumonia when there is a high level of clinical suspicion18.

The study conducted by Esposito et al. in 2014 on 103 children with community-acquired pneumonia revealed a sensitivity of 97% and specificity of 94.5%, as well as a negative predictive value (NPV) of 98.1% and a positive predictive value (PPV) of 90.4%. LUS is a highly reliable method for both diagnosing and ruling out pneumonia in pediatric patients, according to these findings19. Similarly, Boursiani et al. (2017) examined the use of LUS as a first-line diagnostic tool in 69 children and discovered that it had a perfect specificity, PPV, and sensitivity of 92%. Although LUS is quite good at detecting actual pneumonia patients, it may overlook certain negative instances, as indicated by the lower NPV of 50%, highlighting the necessity of clinical correlation in ambiguous situations. In their investigation of fifty-two children, Lorio et al. provided additional support for these findings by reporting a sensitivity of 96% and specificity of 95.6%, with both PPV and NPV above 95%. This study supported the procedures as a potential reliable non-invasive diagnostic tool in clinical practice and suggested a more standardized method for using LUS in pediatric pneumonia diagnosis20. A similar study that involved 52 children and a pediatric population was carried out by Giulio Lorio et al. The purpose of the study was to evaluate the effectiveness of lung ultrasonography in the diagnosis of pediatric pneumonia. According to this study, lungs ultrasonography is quite accurate in detecting both true positive and true negative instances in pediatric pneumonia cases, with a sensitivity of 96.5% and a specificity of 95.6%. These findings, which have a negative predictive value of 96% and a positive predictive value of 96.5%, significantly support the use of lung ultrasonography as a viable diagnostic technique in children. Further confirming the exceptional diagnostic capabilities is the 96.4% accuracy rate. According to these findings, pulmonary ultrasound has the potential to replace radiation-based imaging as the main diagnostic method in pediatric settings21.

CONCLUSION

Lung ultrasonography (LUS) is a very accurate and first-line imaging method for diagnosing pneumonia in a wide range of disease populations. LUS demonstrated outstanding results in both pediatric and adult populations, providing radiation-free, bedside-accessible alternatives that are noninvasive and have high sensitivity and specificity.

AUTHOR CONTRIBUTION

Author	Contribution
Sara Kamal	Manuscript writing, Conceptualization, and methodology
Muhammad Zubair	Supervision, review of methodology, and editing of the final draft.
Syeda Faiza Hussaini	Data extraction, risk of bias assessment, data synthesis, and critical revision of the manuscript.
Syed Zaigham Ali Shah	Quality assessment, formatting, reference management, and proofreading

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