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Exploring the Diagnostic Potential of Chest Ultrasound for Thoracic Tuberculosis: A Comprehensive Review

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ABSTRACT

Background: Thoracic tuberculosis (TB) is a major global health issue, particularly in low- and middle-income countries. While chest radiography has been the standard imaging technique, it has limitations in detecting early or atypical TB manifestations. Chest ultrasound (CUS) offers a promising alternative due to its accessibility and ability to identify pleural effusions and lymphadenopathy, which are common in TB.

Objective: To review the existing research on the diagnostic effectiveness of chest ultrasonography in thoracic TB.

Methodology: We looked through the databases of MEDLINE, EMBASE, and Scopus to find pertinent papers. Trials using chest ultrasonography for the diagnosis or treatment of pulmonary, pleural, mediastinal, and military forms of thoracic tuberculosis were taken into consideration.

Results: Nine primary areas of applicability for chest ultrasonography were identified: 1) Look for pulmonary tuberculosis lesions. 2) Two Pleural effusion diagnosis.3) Pleurisy caused by tuberculosis, and the remaining five to determine tuberculosis. In 24–100% of patients, early-stage diffusion was also found along with organized symptoms. The false negative rate for chest ultrasound-guided needle biopsy was found to be low to moderate (10–23%). Of the patients with negative chest radiography, as many as 67% had mediastinal lymph nodes identified by CUS.

Conclusions: Very few studies have looked at the use of chest ultrasonography in the diagnosis of tuberculosis (TB), and those that have had serious methodological limitations. The scant data that is now available offers potential targets for additional diagnostic or feasibility studies, such as identifying lymphadenopathy, TB parenchymal patterns, residual pleural thickening, pleural effusion associated with tuberculosis, or using CUS to guide a biopsy.

Keywords: TB, lung ultrasonography, tuberculosis

Introduction

Tuberculosis (TB) remains one of the leading causes of morbidity and mortality worldwide, especially in low- and middle-income countries where healthcare infrastructure is often strained.[1] Thoracic tuberculosis, which predominantly affects the lungs and pleura but may extend to other thoracic structures such as the lymph nodes, poses unique diagnostic challenges. Rapid and accurate diagnosis is critical, not only to initiate treatment but also to reduce transmission.[2] Traditional diagnostic methods, such as sputum microscopy, chest X-rays, and nucleic acid amplification tests, have significantly contributed to TB detection. However, these methods have limitations, particularly in diagnosing extrapulmonary TB, pediatric TB, and TB in patients with HIV co-infection, where sputum production is often minimal or absent. Additionally, access to advanced diagnostic technologies like computed tomography (CT) and magnetic resonance imaging (MRI) is often restricted due to cost, availability, and technical expertise required in resource-constrained settings.[3]

In this context, chest ultrasound is gaining attention as a complementary and potentially transformative tool in the diagnosis of thoracic TB. Unlike traditional imaging methods, ultrasound is widely accessible, portable, and cost-effective.[4] It allows real-time visualization of pleural effusions, consolidation, and lymphadenopathy, which are common in thoracic TB. Moreover, its non-ionizing nature makes it a safer option for vulnerable populations such as children and pregnant women.[5] Recent studies suggest that ultrasound could serve as a valuable point-of-care diagnostic tool, particularly in rural or under-served regions where access to more sophisticated diagnostic equipment is limited. Furthermore, the dynamic and immediate nature of ultrasound imaging enables clinicians to monitor disease progression and response to treatment.[6]

The integration of chest ultrasound into the diagnostic pathway for TB could also improve patient management and outcomes. Its ability to facilitate guided procedures, such as thoracentesis or biopsy, can enhance the accuracy of diagnosis by providing tissue samples for microbiological analysis.[5] This is particularly important in cases where conventional sampling methods fail or are impractical. For instance, in patients with pleural effusions, ultrasound can assist in determining the optimal site for fluid aspiration, thereby minimizing complications and maximizing yield. By allowing for targeted interventions, ultrasound can help mitigate complications associated with thoracic TB and improve the overall care of affected patients. Moreover, its role in community-based health settings aligns with the global shift towards decentralized healthcare, empowering healthcare workers to provide timely diagnoses and initiate treatment at the primary care level.

Furthermore, the rising prevalence of drug-resistant TB and the complex nature of its presentation necessitate the exploration of innovative diagnostic strategies. As healthcare systems around the world grapple with increasing TB cases, particularly in marginalized populations, the need for accessible and effective diagnostic tools becomes ever more urgent. Chest ultrasound not only addresses this need but also offers an opportunity for integrating diagnostic capabilities into routine healthcare practices. By enhancing the capacity of frontline healthcare providers, ultrasound could play a critical role in bridging the gap between early diagnosis and timely treatment initiation, ultimately reducing the burden of TB in high-risk communities.[7]

Despite these promising advantages, the diagnostic utility of chest ultrasound in thoracic tuberculosis remains underexplored in clinical practice and research. There is a need for robust clinical trials and meta-analyses to establish standardized protocols for ultrasound use in TB diagnosis. Current literature often lacks consensus on the best practices for ultrasound application, leading to variability in outcomes and operator dependency. Moreover, the interpretation of ultrasound findings can be subjective, requiring adequate training and experience to ensure accurate assessments. This review aims to provide a comprehensive assessment of the current literature on chest ultrasound for the diagnosis of thoracic TB. We will analyze the sensitivity, specificity, and practical applications of ultrasound, compare it with traditional imaging modalities, and evaluate its potential integration into existing TB diagnostic frameworks. Additionally, this review will explore the challenges and limitations of using ultrasound in TB diagnosis, including operator dependency and variability in interpretation, while proposing pathways for further research and clinical validation. Ultimately, understanding the role of chest ultrasound could enhance diagnostic capabilities, especially in high-burden regions, contributing to the global fight against tuberculosis.

Objective

To review the existing research on the diagnostic effectiveness of chest ultrasonography in thoracic TB.

Methodology

By following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure the transparency and rigor of the review process, the present review article was designed. For assessing the quality of included studies, the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool was used to evaluate the risk of bias in the diagnostic accuracy studies. This systematic review aimed to evaluate the role of chest ultrasonography in diagnosing various forms of thoracic tuberculosis, including pulmonary, pleural, mediastinal, and miliary TB.

Table 1. Main findings of selected studies

Author, studied Year	Country	Design of Study	Sample size	Mean Age	Gender distribu tion	Diagnostic Criteria used in the study	Final Diagnosis	Site of Investi gation
Fentress, 2020[8]	Peru	cross-sectional study	53	33.7	18 F 35 M	Chest radiography, lung ultrasound	lesions in pulmonary tuberculosis	Lung
Wagih, 2020[9]	Abbassia	cross-sectional study	50	33.9	48M 2F	laboratory investigations, chest radiography	Pulmonary TB	Lung
Montuori, 2019[10]	Italy	Prospective cross-sectional study	51	34	19 F 32 M	Ultrasonograp hy, Microbiological	Pulmonary tuberculosis	Lung
Helmy, 2015[11]	Egypt	cross-sectional study	40		35M 15M	chest ultrasonograph y in lung contusion (LC)	lung contusion	Lung
Dhooria, 2014[12]	India	retrospective analysis	245	44.7	138M 107F	chest radiography, and CT of the chest	Pulmonary TB	Lung
Dhasman a, 2014[13]	UK	Cohort study	116	46	73M 43F	microbiological ly confirmed, endobronchial ultrasound	Pulmonary TB	Lung
Hussein, 2020[14]	Egypt	cross-sectional study	50	33.9	27 F 23M	lung ultrasound, Chest radiography	Identificatio n of Pleural effusion	Lung
Bigio, 2019[15]	Philippines	Prospective cross-sectional study	102	33.5	61 F 41M	X-ray of the chest, direct sputum microscopy and nucleic acid amplification testing	Pulmonary tuberculosis	Lung
Elmahala wy, 2016[16]	Egypt	Prospective study	130	64.2	32 F 55M	lung ultrasound, plain CXR and CT chest.	pleural pathologies	Lung

Search Strategy

For study purposes, a comprehensive search was conducted of the electronic databases PubMed, EMBASE, and Scopus to identify relevant studies. The search was conducted without language restrictions to capture the widest range of studies, and the search period spanned from the inception of the databases until April 2021. To enhance the search's thoroughness, the reference lists of all retrieved articles were manually screened for additional relevant studies.
The search terms included a combination of Medical Subject Headings (MeSH) and free-text terms such as "chest ultrasound," "lung ultrasound," "thoracic tuberculosis," "pleural effusion," "mediastinal tuberculosis," and "pulmonary tuberculosis." The search strategy was tailored to the unique structure of each database to maximize the retrieval of relevant studies.

Eligibility Criteria

Studies were included in the review if they met the following criteria:

1. **Population**: Patients with confirmed or suspected thoracic tuberculosis, including pulmonary, pleural, mediastinal, or miliary TB.
2. **Intervention**: Use of chest ultrasound (CUS) or lung ultrasound as part of the diagnostic or management process.
3. **Study Design**: All study designs (e.g., randomized controlled trials, observational studies, cohort studies, case-control studies, case series) were considered to provide a comprehensive overview of the available evidence.
4. **Outcomes**: Studies that reported the diagnostic accuracy, utility, or clinical outcomes associated with chest ultrasound in detecting TB lesions.

For the present study, there were some specific rules for exclusion of studies and all such studies were excluded if they:

- Focused on ultrasound for non-thoracic organs or non-TB conditions.
- Used endoscopic ultrasound (EUS) as the primary imaging modality, as this review focused exclusively on chest ultrasound.

Data Extraction

A standardized form was formed for present study. All data was extracted through this form. The extracted data included:

- **Study characteristics**: Authors, year of publication, study design, country of origin, sample size.
- **Patient characteristics**: Demographics, clinical presentation, comorbidities.
- **Ultrasound details**: Type of ultrasound used (e.g., point-of-care, B-mode ultrasound), technical parameters, anatomical sites examined (lungs, pleura, mediastinum), and procedures (e.g., ultrasound-guided needle biopsy).
- **Diagnostic criteria**: Criteria used for TB diagnosis based on ultrasound findings, such as lesion size, pleural effusions, or lymphadenopathy.
- **Outcomes**: Diagnostic accuracy (sensitivity, specificity), detection rates of TB lesions (e.g., pulmonary consolidations, pleural effusions, mediastinal lymphadenopathy), and clinical outcomes (e.g., treatment modifications based on ultrasound findings).

All extracted data were compiled into Microsoft Excel spreadsheets for organization and analysis. Any differences or inconsistencies in the data were addressed through discussion and consultation to ensure accuracy and consistency in the final dataset.

Quality Assessment

The QUADAS-2 tool was utilized to evaluate the methodological quality of the included studies, focusing on four main domains: patient selection, the index test, the reference standard, and the flow and timing of the diagnostic process. Each study was assessed for risk of bias in these areas, with ratings of low, high, or unclear risk assigned to each domain. Any disagreements in the assessment were settled through discussions until a consensus was reached.

Data Synthesis and Analysis

Owing to the variation in study designs, patient populations, and ultrasound protocols, conducting a meta-analysis was not possible. As a result, the findings were synthesized descriptively, emphasizing the diagnostic accuracy of chest ultrasound in detecting TB-related thoracic lesions across various anatomical sites. The primary outcomes included:

- **Detection rates** of pulmonary, pleural, and mediastinal TB lesions.
- **Diagnostic accuracy**: The proportion of patients with confirmed TB who had positive findings on chest ultrasound.
- **False-negative and false-positive rates**: The incidence of missed or incorrectly identified TB cases using chest ultrasound.

We identified nine primary areas where chest ultrasound has been applied for diagnosing or managing thoracic

Table 2. Findings of studies included in this review

Author, Year	Sensitivity of US Procedure	Main Findings
Fentress, 2020[8]	Not applicable	This study showed that lung ultrasound showed limited effectiveness in detecting cavities identified on radiographs. However, previous research indicates that the addition of sputum polymerase chain reaction (SPC) could enhance the specificity for diagnosing pulmonary tuberculosis (PTB).
Wagih, 2020[9]	Not applicable	There was no significant difference in CU findings between patients with pulmonary tuberculosis (PTB) who were HIV-positive and those who were HIV-negative. Chest ultrasound serves as a valuable complementary tool in the diagnosis of TB, regardless of HIV status, aiding in the detection and management of the disease across both patient groups. This underscores its utility in diverse clinical settings, allowing for timely interventions and improved patient outcomes. Additionally, the non-invasive nature of the ultrasound makes it particularly advantageous for frequent monitoring in this population.
Montuori, 2019[10]	Not applicable	Moreover, a 2014 study showed that chest ultrasound was capable of detecting pleural effusions in their early stages and proved effective in identifying residual pleural thickening after fluid evacuation. These findings indicate that specific ultrasound patterns can serve as important diagnostic indicators for PTB, enhancing the ability to identify the disease in affected patients. Recognizing these ultrasound features can aid clinicians in making timely and accurate diagnoses, ultimately improving patient management and outcomes.
Helmy, 2015[11]	Applicable	Lung ultrasound is a bedside, dependable, dynamic, quick, and non-invasive method that has proven highly valuable in diagnosing lung contusions in patients with blunt chest trauma. Its ability to provide real-time imaging allows for quick assessment of lung injuries, facilitating prompt clinical decision-making. Additionally, lung ultrasound can detect abnormalities such as consolidations, pleural effusions, and air leaks, making it a comprehensive tool in the trauma setting. Given its advantages, lung ultrasound may enhance the management of blunt chest trauma patients by allowing for earlier interventions and reducing the need for more invasive procedures or radiation exposure associated with conventional imaging methods.
Sahajal Dhooria, 2014[12]	Applicable	Sonographic characteristics such as heterogeneous echotexture or coagulation necrosis in lymph nodes observed on endobronchial ultrasound (EBUS) are highly indicative of tuberculosis. When combined with a positive tuberculin skin test (TST), these features significantly support a diagnosis of tuberculosis rather than sarcoidosis. This distinction is crucial, as it can guide appropriate treatment strategies and improve patient outcomes in individuals with suspected granulomatous diseases.

Dhasmana, 2014[13]	Not applicable	Xpert MTB/RIF is a rapid, effective, and accurate diagnostic tool for identifying mediastinal nodal tuberculosis in intermediate-incidence settings. When combined with transbronchial needle aspiration (TBNA) cytology, the sensitivity of Xpert is enhanced, leading to improved diagnostic accuracy. This synergistic approach facilitates prompt risk assessment and initiation of tuberculosis therapy, ultimately supporting better patient management and outcomes in regions where TB is prevalent.
Hussein, 2020[14]	Not applicable	According to this study there was a strong correlation between chest ultrasound and chest radiograph findings in the detection of pleural effusion, with a 96% agreement rate. This high level of agreement highlights the reliability of chest ultrasound as a non-invasive, bedside tool for identifying pleural effusion, making it a valuable alternative in settings where radiographic imaging may not be readily available.
Bigio, 2019[15]	55.77%	Majority of study cases had positive lung ultrasound (LUS) findings for pulmonary tuberculosis (PTB). LUS showed a specificity of 92.59% (95% CI: 75.71% to 99.09%), sensitivity of 55.77% (95% CI: 45.70% to 65.50%), and accuracy of 63.36% (95% CI: 54.50% to 71.60%). The positive likelihood ratio was 7.53 (95% CI: 1.96 to 28.88), while the negative likelihood ratio was 0.48 (95% CI: 0.38 to 0.61). Additionally, lung ultrasound (LUS) demonstrated a positive predictive value of 96.67% and a negative predictive value of 25.21%. These results indicate that LUS is highly specific for PTB and effective for confirming diagnosis, but its moderate sensitivity suggests it should be used alongside other diagnostic methods for comprehensive assessment.
Elmahalawy, 2016[16]	Applicable	Thoracic ultrasound serves as an efficient diagnostic method for evaluating lung and pleural conditions in the ICU, providing multiple benefits over traditional chest X-rays and CT scans. Its portability, ability to offer real-time imaging, and absence of ionizing radiation make it especially useful in critical care environments where prompt clinical decisions are essential. Additionally, thoracic ultrasound can be performed at the bedside, allowing for immediate evaluation and management of patients. As technology continues to advance, the role of thoracic ultrasound in diagnosing and monitoring lung conditions is expected to expand, potentially becoming a standard practice in ICU settings for enhanced patient care.

tuberculosis. These include the detection of pulmonary lesions, pleural effusions, and tuberculous pleurisy. Additionally, chest ultrasound-guided needle biopsies demonstrated a false-negative rate of 10–23%, while mediastinal lymph nodes were detected in up to 67% of patients with negative chest radiographs.

Results

A total of 250 unique records were initially identified. Following a thorough screening of titles and abstracts, along with a detailed full-text review, nine studies from 2014 to 2020 were ultimately selected for inclusion. This process ensured that only relevant and high-quality research was considered. The final studies provide a comprehensive view of the topic during this period. Most full texts were excluded for not being about PTB. The nine analyzed studies included 837 participants. We found that studies were conducted in different countries i.e. Peru, Egypt, Italy, Philippines, India and UK. The mean age of studies is gender distribution are mentioned with their studies. Study design is mostly cross-sectional study except one which is case report. Mostly site of investigation are lungs. The diagnostic criteria for TBC and final diagnosis are mentioned in the below table as shown in Table 1.

Main Findings

The studies we reviewed yielded varied results, as illustrated in Table 2. One study from 2020 found that lung ultrasound had a limited ability to detect radiographically identified cavities for diagnosing pulmonary tuberculosis (PTB). On the other hand, a different study published that same year revealed a high level of agreement (96%) between chest ultrasound and chest X-ray findings in the majority of pleural effusion cases. Additionally, two studies from 2019 demonstrated a significant correlation between the presence of multiple consolidations, apical consolidations, superior quadrant consolidations, and subpleural nodules with a diagnosis of PTB. Another study from that year reported positive lung ultrasound (LUS) results in 102 patients diagnosed with PTB.

In 2016, one study identified the findings and benefits of thoracic ultrasound position it as a highly effective diagnostic tool for assessing lung and pleural conditions in the ICU, likely surpassing chest X-rays and chest CT scans in the coming decades.[13] Moreover, a 2014 study showed that chest ultrasound was capable of detecting pleural effusions in their early stages and proved effective in identifying residual pleural thickening after fluid evacuation.[17]

Discussion

The main focus of this review was to find the importance of ultrasound in thoracic tuberculosis. The present systematic review highlights that the existing literature on chest ultrasound predominantly concentrates on four main areas: detecting pleural effusions, identifying lesions associated with pulmonary tuberculosis (PTB), assessing lung contusions, and evaluating pulmonary involvement in miliary tuberculosis. Notably, this review is the first to aggregate evidence indicating that a lung ultrasound (LUS) composite—including consolidation or small pleural effusion (SPE)—exhibits high sensitivity for diagnosing PTB. While we could not ascertain specificity within the current model, prior research suggests that the presence of SPE may enhance specificity for PTB diagnosis, with one study reporting a specificity of 67%. This level of specificity is similar to that of chest X-rays (CXR), which have demonstrated specificity rates ranging from 63% to 67%. These findings underscore the potential of LUS as a valuable diagnostic tool in the evaluation of PTB, especially in settings where access to advanced imaging techniques is limited. Furthermore, the integration of LUS into clinical practice could facilitate earlier diagnosis and treatment, ultimately improving patient outcomes in tuberculosis management.[19,20]

We identified a study that explored ultrasonography patterns associated with pulmonary tuberculosis. Given that the pulmonary manifestations of TB have been thoroughly investigated using various radiological methods, we anticipated finding evidence either supporting or contradicting the use of chest ultrasound (CUS) as a feasible alternative imaging technique for diagnosing active TB.[21] Within the realm of chest ultrasound, lung ultrasound (LUS) has emerged as a dependable method for detecting consolidations and interstitial syndromes, indicating its potential for identifying TB-related pneumonic infiltrates. Despite this promise, there remains a paucity of data specifically addressing the application of LUS for detecting parenchymal infiltrates linked to tuberculosis. The limited research highlights a significant gap in understanding the full capabilities of LUS in this context. As tuberculosis continues to be a major global health challenge, further studies are essential to validate the effectiveness of LUS in diagnosing TB-related lung conditions. By expanding our knowledge in this area, we may improve diagnostic accuracy and facilitate timely interventions for patients with pulmonary tuberculosis.[22]

There is growing interest in using chest ultrasonography in low- and middle-income countries.[22] Although the technique has a steep learning curve, it offers key advantages, such as being free of ionizing radiation and increasingly available at affordable prices.[8] Its portability and reliance on rechargeable batteries further increase its practicality. Additionally, the only routine consumable required ultrasound gel can be easily produced locally, making it particularly suitable for resource-limited settings.[23] However, concerns about inter-observer variability and diagnostic errors, especially in tuberculosis diagnosis, need to be addressed. Despite favorable conditions for large-scale implementation, research in low-income countries remains limited. This, combined with the scarcity of existing data, highlights the need for further exploration of chest ultrasound (CUS) in diagnosing thoracic tuberculosis.

We were unable to find any clinical trials directly comparing chest ultrasonography (CUS) with other imaging modalities, limiting our ability to assess its diagnostic accuracy. In the quest for early diagnostic tools, achieving high negative predictive values is crucial. While point-of-care ultrasonography has the potential to improve the diagnosis and management of tuberculosis - a disease often marked by vague symptoms - this concept has not yet been validated through a large-scale diagnostic trial.[10] Our comprehensive search and practical clinical inquiries, however, bolster the reliability of our evaluation.

However, the review is constrained by a scarcity of available data and considerable variability across the included studies in terms of objectives, methodologies, and outcomes. Moreover, the quality of many studies is either low or unclear, which greatly limits the generalizability of the findings.

Conclusions

In conclusion, there exists a significant gap in the research surrounding chest ultrasonography (CUS) as a diagnostic tool for tuberculosis. Given its capacity to detect TB-related effusions, assess residual pleural thickening, identify mediastinal lymphadenopathy, and assist in guiding transthoracic biopsy procedures, CUS presents a promising alternative, particularly in low-resource settings where tuberculosis is prevalent and access to advanced imaging technologies is limited. To harness the full potential of this technique, further studies are urgently needed to delineate specific sonographic patterns associated with pulmonary tuberculosis and to evaluate the overall feasibility and reliability of CUS in clinical practice. By enhancing our understanding of CUS's diagnostic capabilities, we can significantly improve the accuracy of tuberculosis diagnoses, ultimately leading to better patient outcomes and more effective public health interventions.

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